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CONSERVATION BIODIVERSITY IN SILVER FIR (*ABIES ALBA* MILL.) FORESTS: A BIBLIOMETRIC REVIEW

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Abstract

Biodiversity conservation is a long-standing scientific and practical concern, extensively studied across various contexts. Within this domain, the conservation of silver fir (Abies alba) holds a significant place due to the species' widespread distribution and its ecological and silvicultural value. A bibliometric analysis of this topic was conducted using the Web of Science Core Collection database, with data processed through the VOSviewer software. The results reveal that between 1996 and 2023, numerous publications, particularly articles, were produced in scientific fields such as Forestry, Ecology, Environmental Sciences, and Biodiversity Conservation. These studies were published in 131 journals, with the majority appearing in Forest Ecology and Management, Biological Conservation, and Biodiversity and Conservation. The most frequently used keywords were biodiversity, conservation, diversity, dead wood, and management, with recent years seeing increased usage of terms like climate change, species richness, and forest management. The authors contributing to this research predominantly hail from regions where silver fir is more prevalent, especially Central and Eastern Europe. An interesting observation is the significant representation of Scandinavian authors, likely due to the low species diversity in the forests of this region and the large number of articles they have contributed on both resinous species and biodiversity conservation. This analysis is considered important and is likely to be referenced by scientists in the future.

Keywords*: VOSviewer; Silver fir; Multiple experimental; Forest ecosystems; Dendrochronological studies; Bibliometric analysis.*

Introduction

Conservation science has emerged as a dynamic and developing field. The processes within ecosystems influence the survival of numerous species, but many theoretical models of ecosystems have resulted in increasingly imaginative portrayals of nature. Conservation efforts are inherently local and will only succeed if we discover methods to harmonize human activities

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with nature. Yet, observational and experimental research on small wild populations can offer practical insights for managing biodiversity on a broader geographical scale [1].

Preserving biodiversity is argued to be one of the most effective indicators for establishing boundaries that may help to define sustainability more accurately [2].

Although there have been some successful conservation initiatives, especially at local levels, and a growing public and governmental interest in sustainable living, biodiversity continues to face decline. More transformative changes are necessary, which recognize biodiversity as a global public good, integrate its conservation into policies and decision-making frameworks for resource use, and emphasize broader institutional and societal shifts to implement policies more effectively [3].

In response to the urgent need for accelerated global actions aimed at restoring damaged ecosystems [4], the United Nations launched the Decade on Ecosystem Restoration (2021-2030) to prevent, halt, and reverse global ecosystem degradation [5].

The 1992 United Nations Conference on Environment and Development (UNCED) acknowledged forest biodiversity within the non-legally binding Forest Principles. Since then, the Conferences of Parties of the Convention on Biological Diversity (CBD) have underscored the importance of maintaining forest ecosystems for biodiversity conservation [6]. In 2000, the term "forest landscape restoration" (FLR) was introduced, aimed at restoring forests on a landscape scale to address both human needs and ecological priorities. This concept was developed to merge biodiversity conservation with productive uses, addressing ecological and economic needs not fully covered by ecological restoration alone [7, 8].

Fir trees are essential for sustaining high biodiversity in forest ecosystems due to their shade tolerance, adaptability to various environmental conditions, and capacity to coexist with numerous tree species [9, 10].

Multiple experimental and dendrochronological studies have highlighted fir trees' vulnerability, initially to atmospheric and soil drought [11, 12], and subsequently to sudden frost, as well as extremely low winter and spring temperatures [13]. Silver fir is known for its stringent environmental requirements, particularly regarding soil and air humidity [14-16].

Climate change has likely negatively affected the growth of native fir populations in Europe over recent decades [17, 18].

Several studies have shown that silver fir is notably sensitive to climatic variables, especially in late spring and summer [19-21]. Under ongoing global climate change, fir is expected to move to higher elevations with adequate precipitation, whereas in the southern parts of its natural range or at lower elevations outside moisture-rich habitats, it is predicted to decline [10].

Broadus, [22], describes bibliometric as “the quantitative study of published physical units, bibliographic units, or their surrogates.” Sen Gupta, [23], defines bibliometric as the classification, organization, and quantitative analysis of publication patterns in macro and micro communication, including authorships, using mathematical and statistical methods. Bibliometric serves as a tool to examine how disciplines progress, focusing on intellectual and social structures.

Bibliometry, or bibliometric analysis, is increasingly utilized to map the structure and development of scientific fields, assessing the progression of specific disciplines [24, 25]. It involves evaluating and tracking the progress of disciplines by sorting data, such as citations, author affiliations, keywords, and research themes, using both basic and advanced statistical techniques [26, 27]. Many studies have employed bibliometric methods to shed light on methods, prolific scholars or institutions, intellectual structures, knowledge domains over time, geographic regions of different fields, specific research themes, and the maturity levels of topics [28].

A large number of bibliometric review articles have been published (a search of WOS on 14.07.2024 shows 6,450 articles since 1985, with a significant increase between 2020 and 2023, where 1,000 to 3,000 articles were published annually).

Many of these articles are from domains such as environment [29-31], remote sensing [32, 33], and transport [28, 34, 35].

In the field of ecology, bibliometric method has been used to investigate advance in various topics, such as biodiversity [36, 37], landscape restoration [38-40], waste management [41].

The goal of this article is to conduct a bibliometric review of publications related to biodiversity conservation in silver fir forests. The analysis includes the distribution of publication types, the main scientific fields, publication years, authors, their countries of origin, journals where the articles appeared, and the primary keywords used.

Experimental part

Materials

A bibliometric analysis was conducted to assess the global scientific output on conservation biodiversity within silver fir forests from 1996 to 2023. This analysis utilized the online Science Citation Index Expanded – Web of Science database, resulting in the retrieval of 613 publications. The online SCI-Expanded database was searched using the terms "conservation biodiversity in silver fir forests," "conservation biodiversity in fir forests," and "conservation biodiversity in Abies alba forests" to compile a bibliography of relevant research papers from 1996 to the present. The analysis focused on nine key areas: (1) types of publications, (2) Web of Science categories, (3) publication years, (4) countries, (5) institutions, (6) journals, (7) publishers, (8) authors, and (9) keywords.

Methods

The data were processed using the tools provided by Web of Science Core Collection [42], Excel [43] as well as with the help of VOSviewer version 1.6.20 [44]. This software offers features such as visualization maps and cluster analysis.

Visualization maps featuring links and nodes representing analytical elements like authors, countries, journals, references, and keywords were created. A link between two nodes indicates a relationship, such as collaboration between authors, institutions, or countries [45]. The node size and linkage numbers reflected the total frequency of co-occurrences of an item, while the node thickness and color ring indicated the time periods of these co-occurrences.

Cluster analysis is used to identify significant patterns and relationships from large, complex data sets. This statistical method groups publications based on the similarity of their authors, keywords, or topics [46].

Results and discussion

A total of 613 publications were identified and analyzed. Of these, 291 are articles (90% of the total publications), 23 are review articles (7%), 8 are proceedings papers (2%), and 3 are book chapters (1%) (Fig. 1).

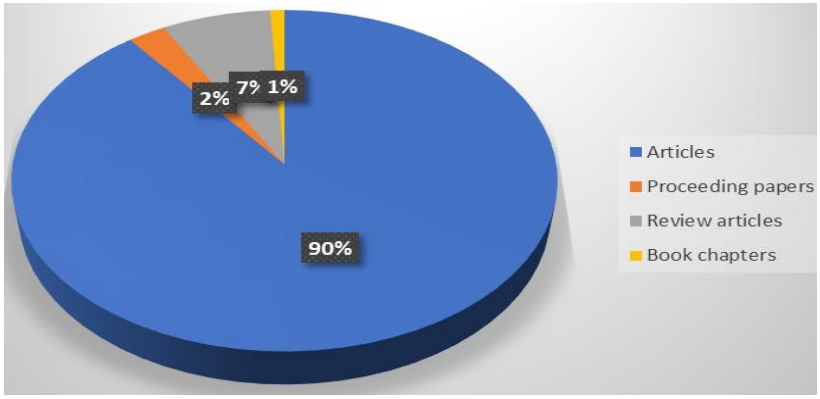

Fig. 1. Distribution of the main types of publications used in the bibliometric analysis

Regarding the scientific fields of the published articles, the most representative are Forestry (137), Ecology (105), Environmental Sciences (62) and Biodiversity Conservation (63) (Fig. 2).

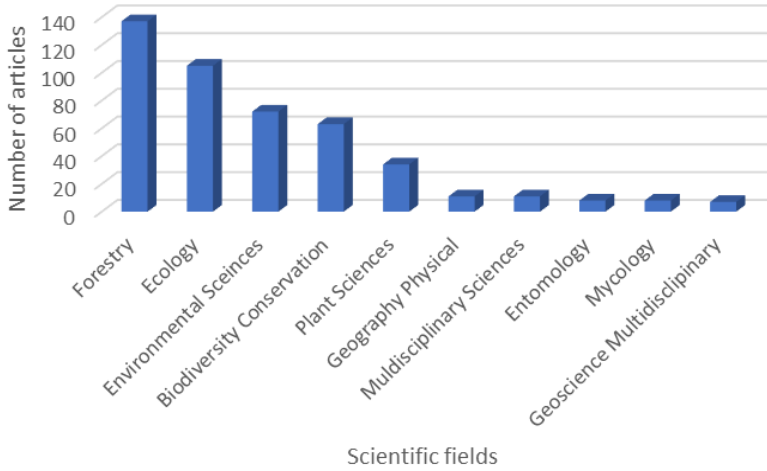

Fig. 2. Distribution of the main 25 scientific fields of publications used in the bibliometric analysis

In terms of the years of publication, there has been a significant number of articles published annually, with a marked increase in the last three years (Fig. 3). The first article on this topic was published in a reputable scientific journal in 1996.

A total of 201 authors have published on this topic. The most prolific authors are Matts Lindbladh (11 articles), Miroslav Svoboda (10), and Bengt Gunnar Jonsson (9), all of whom are European.

Authors from 53 countries have contributed to this topic. The most represented countries are Sweden, Germany, Finland, the USA, and the Czech Republic. However, authors from Italy, Norway, Canada, France, India, Romania, Slovakia, and others were also identified (Fig. 4).

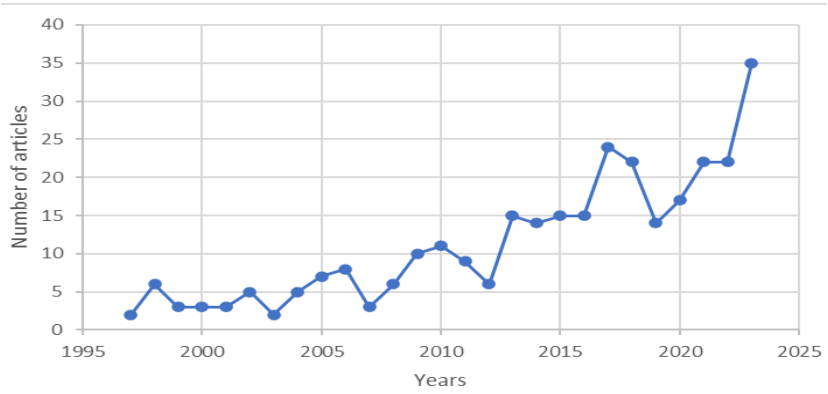

Fig. 3. Distribution of articles on years

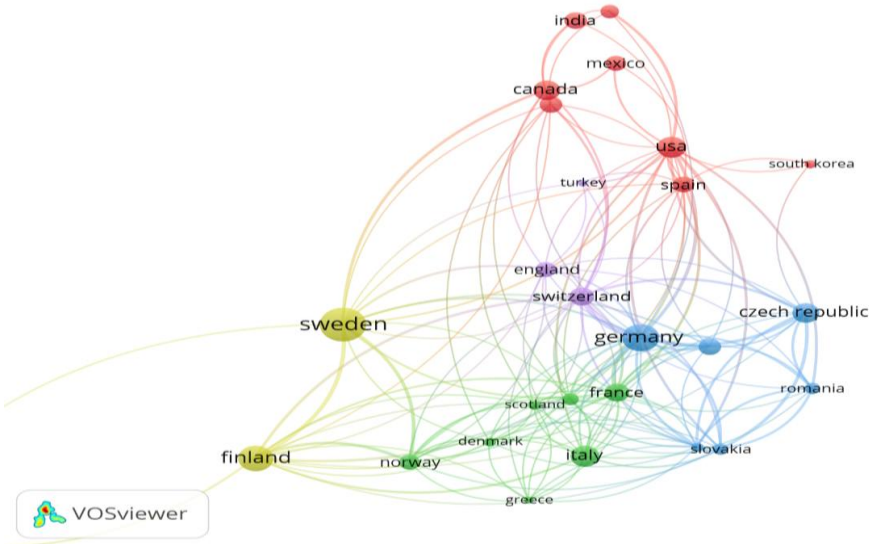

Fig. 4. Countries with authors who have published articles on biodiversity conservation in silver fir forests. The node size and the thickness of the connecting lines are proportional to the number of documents assigned to each country. The connections represent the collaboration network among research institutions

The institutional representation of authors mirrors the geographic distribution, with the most numerous institutions located in Sweden, Finland, and the Czech Republic: Swedish University of Agricultural Sciences = 56; University of Helsinki = 19; Czech University of Life Sciences Prague = 15.

Articles on this topic are found in 131 journals, with most being published in Forest Ecology and Management (57 articles), Biological Conservation (17 articles), and Biodiversity and Conservation (57 articles). However, considering Total Link Strength, the top three journals are Forest Ecology and Management, Biological Conservation, and Ecological Applications (Table 1).

The clustering of journals reveals four main clusters: Cluster 1 includes Forest Ecology and Management, Journal of Forest Research, Journal of Environmental Management, Journal of Applied Ecology, European Journal of Forest Research, and Journal of Nature Conservation; Cluster 2 includes Biodiversity and Conservation, Canadian Journal of Forest Research, Scandinavian Journal of Forest Research, Ecological Indicators; Cluster 3 includes Biological Conservation, Silva Fennica, Landscape Ecology, and Baltic Forestry; Cluster 4 includes PLOS

ONE, Forests, Frontiers in Forests and Global Change, and Applied Ecology and Environment (Fig. 5).

The most representative publishers are Elsevier (108 articles), Springer Nature (46 articles), and Wiley (42 articles).

The most frequently used keywords are biodiversity, conservation, diversity, dead wood, and management (Fig. 6 and Table 2).

Table 1. The most representative journals for publications on biodiversity conservation in silver fir forests

Crt. no.	Review	Documents	Citations	Total link strength
1	Forest Ecology and Management	57	1936	92
2	Biological conservation	17	1101	45
3	Ecological applications	6	443	20
4	Scandinavian Journal of Forest Research	5	312	19
5	Silva Fennica	5	348	18
6	Biodiversity and Conservation	15	361	17
7	Canadian Journal of Forest Research	9	323	14
8	Plos One	6	195	12
9	Journal of vegetation science	3	162	11
10	European Journal of Forest Research	7	143	10
11	Journal of Environmental Management	4	82	10
12	Conservation Biology	3	258	9
13	Ecological indicators	5	71	8
14	Frontiers in forest and global change	4	17	7

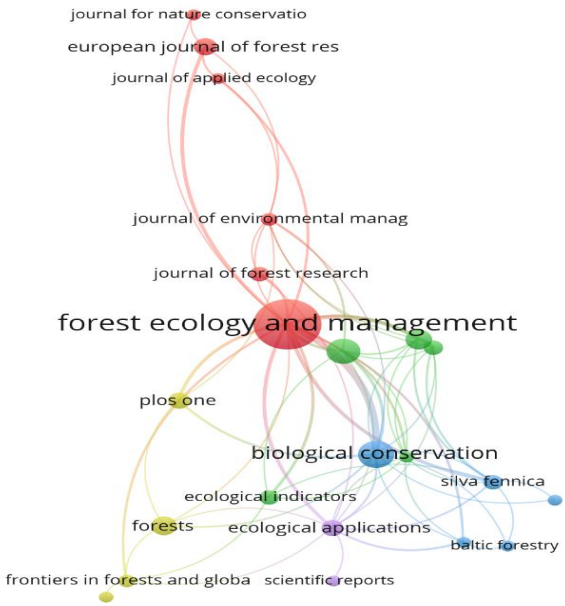

Fig. 5. Main journals where articles on biodiversity conservation in silver fir forests have been published

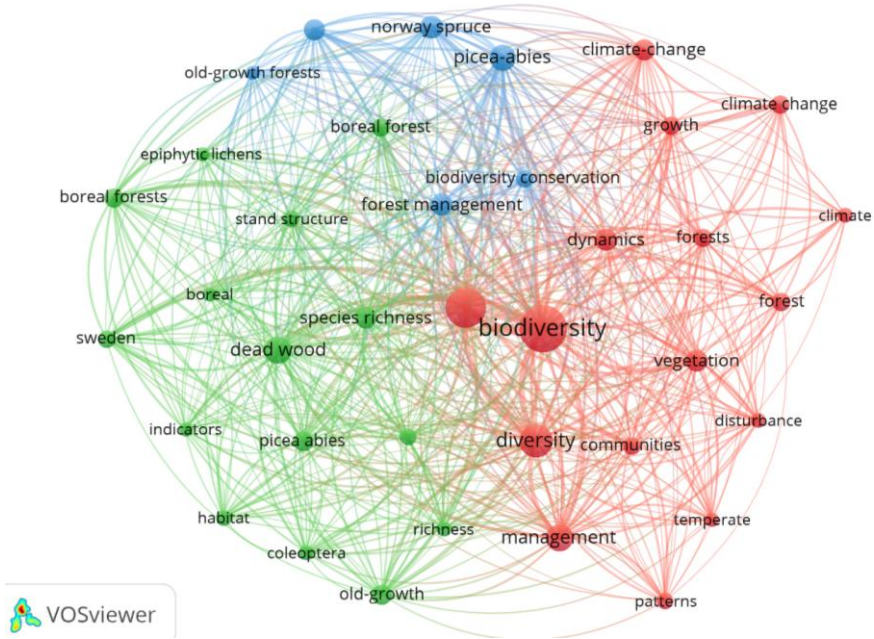

Fig. 6. Authors' keywords regarding the conservation biodiversity in silver fir forests. The node size and thickness of the connecting lines are proportional to the number of documents in which the keyword appears. The colors indicate the cluster the item belongs to, and the connection line between nodes represents co-occurrence; the shorter the distance between the different nodes, the stronger the relationship between the keywords

Table 2. The most frequently used keywords in articles on biodiversity conservation in silver fir forests

Crt. no.	Keyword	Occurrences	Total link strength
1	biodiversity	156	536
2	conservation	112	413
3	diversity	77	273
4	dead wood	50	252
5	management	50	210
6	species richness	33	161
7	dynamics	34	131
8	forest management	33	129
9	boreal forests	27	126
10	old-growth	28	119
11	coarse woody debris	31	118
12	vegetation	34	113
13	climate change	32	101
14	growth	24	93
15	boreal forest	23	92
16	biodiversity conservation	21	87
17	stand structure	20	86
18	forests	24	83

The keywords used in these articles are grouped into three clusters: the first includes keywords such as biodiversity, vegetation, management, forest, climate change, dynamics, and disturbance; the second includes dead wood, species richness, boreal forest, stand structure, old-growth, and indicators; and the third includes management, biodiversity conservation, and coarse woody debris.

Initially, keywords specific to the analyzed domain (e.g., biodiversity, conservation) were predominantly used. However, in the last three years, there has been a greater emphasis on the influence of climate change on species and corresponding management measures, with keywords like climate change, species richness, and forest management being more frequently utilized (Fig. 7).

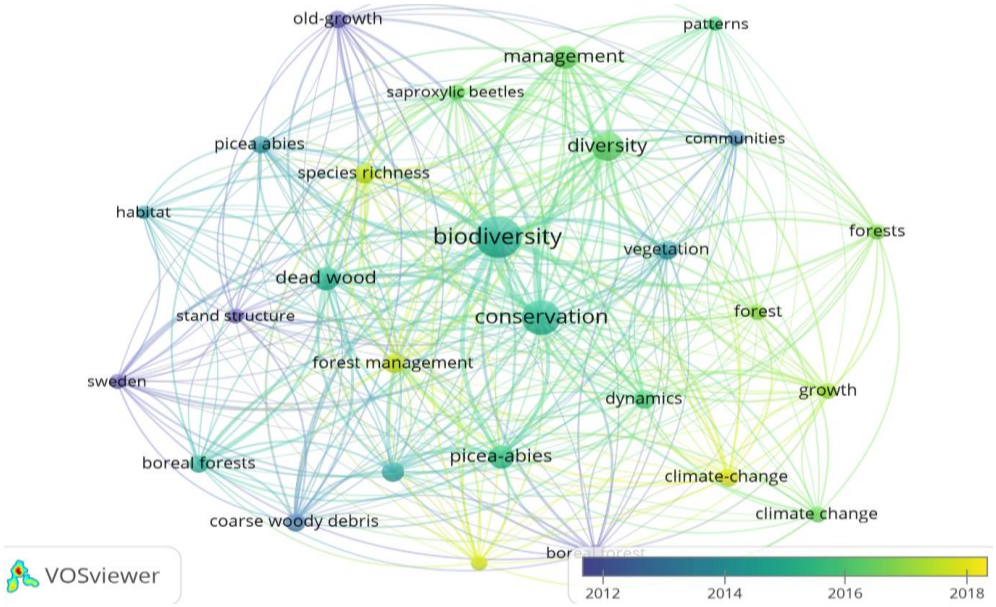

Fig. 7. Distribution of keywords regarding the conservation biodiversity in silver fir forests. The node size and thickness of the connecting lines are proportional to the number of documents in which the keyword appears. The colors indicate the cluster the item belongs to, and the connection line between nodes represents co-occurrence; the shorter the distance between the different nodes, the stronger the relationship between the keywords

While the majority of publications on this topic are articles, the significant number of published reviews is also noteworthy. Many of these reviews focus on the species' ecology [9, 47], genetics [48, 49], or forest management of the species [10, 50].

The title of this article (conservation biodiversity) is one of the scientific fields established by Web of Science. However, it does not hold the top position in the quantification of scientific fields, being surpassed by Forestry, Ecology, and Environmental Sciences. This reflects the increasing priority given to environmental fields and the classification within forestry due to the tree species under analysis.

In the case of conservation biodiversity of silver fir, the number of published articles has grown exponentially over the last decade, similar to other bibliometric analyses [51-54]. This phenomenon can be explained by the sharp increase in the number of high-impact scientific journals and the researchers publishing in them, along with the growing interest in this subject.

Silver fir is predominantly distributed in Central Europe and in some areas of Southern and Eastern Europe [55]. Thus, the presence of authors from these regions is logical. In Germany, the decline of Abies alba forests has been ongoing for a long time; the term "fir dying" was introduced as early as 1908 by Neger [56]. Other reports of damage were noted in the early 1970s, confined to a single species—silver fir, Abies alba, which accounted for 2% of the forest area [57]. Given this history, it is not surprising that German authors rank second on this topic.

In Italy silver fir is widespread across the Alps and more scattered along the Apennines, due to post-glacial climate dynamics and anthropogenic pressure [58]; Italian authors rank fourth on this topic, with 24 published articles.

In the Czech Republic, silver fir was well-represented in the past, covering approximately 16% of the forest area [59-61]. However, over time, this proportion has significantly decreased, now representing less than 1% of the Czech forests [62]. Authors from this country are well-represented on this topic, with 22 authors.

In the Southern Carpathians of Romania, out of a total area of 806,771 ha, 17,038 ha (5.4%) are occupied by silver fir [63, 64]; 7 articles by authors from this country have been published on this topic.

In Slovenia, however, silver fir is the third most widely distributed tree species, occurring in approximately 40% of the total forest area [65]; 5 articles by authors from Slovenia have been published on this topic.

More interesting is the significant presence of Scandinavian authors: Sweden with 64 authors, Finland with 37 authors, and Norway with 13 authors. The species' distribution here is sporadic, and these countries do not even appear on maps of silver fir distribution. A possible explanation is that the forests in these regions do not have a high species diversity [66, 67], and in this context, silver fir is considered a noteworthy species [68-70]. Additionally, Scandinavian literature on resinous species is very strong [71-76]. It is also logical that Scandinavian authors, who are among the world's leaders in publications related to biodiversity conservation [77-80], would focus on an important tree species in Europe within the broader context of this topic.

Regarding the journals where articles on this topic have been published, they fall into two major categories: general ecology or environmental journals (Biological Conservation, Ecological Applications, Ecological Indicators, Biodiversity and Conservation, Journal of Environmental Management) and forestry journals (Forest Ecology and Management, Frontiers in Forests and Global Change, Forests). Among forestry journals, those from Northern Europe or North America are prominent (Scandinavian Journal of Forest Research, Silva Fennica, Canadian Journal of Forest Research, Baltic Forestry), aligning with the distribution of authors by country.

In bibliometrics, information retrieval, and knowledge organization, keywords are widely used [37, 81, 82]. Given the significant increase in text documents on the Internet and in digital libraries, manual analysis is no longer practical. Efficient keyword extraction methods to identify the ‘key’ elements of these documents are now essential. This extraction has been a vibrant research area for many years, encompassing various applications [83]. Therefore, identifying the most relevant terms related to the document's content and utilizing these keywords as features can be highly beneficial [84]. Automatic keyword extraction involves finding key terms, phrases, segments, or words from a document that accurately represent its subject matter [85]. The Web is an abundant source of information and continues to expand.

The dominance of keywords used in this topic starts with two keywords found in the title: biodiversity and conservation, followed by dead wood and management. The presence of dead wood in this top list might seem surprising at first, as it appears to have little direct connection to the analyzed subject. However, deadwood is a key component for biodiversity and ecosystem services in boreal forests [86], and there are hundreds of scientific papers dealing with the issues of biodiversity and extinction debt in temperate forests, both of which are partly related to the absence of deadwood [87]. Dead wood plays an important role in the regeneration of silver fir [88], carbon sequestration [89, 90], and nutrient dynamics [91].

Conclusions

Biodiversity conservation in silver fir forests is a topic that has been studied for a long time, but with a particularly high prevalence in the last 10 years. A total of 613 publications were identified, most of which (90%) were articles, along with review articles (7%), proceeding papers (2%), and book chapters (1%). Regarding the published articles on this topic, it can be noted that they predominantly belong to the scientific fields of Forestry, Ecology, Environmental Sciences, and Biodiversity Conservation; they were written by 201 authors from 53 countries, with the highest representation from Sweden, Germany, Finland, the USA, and the Czech Republic; they were published in 131 journals, with most articles appearing in Forest Ecology and Management, Biological Conservation, and Biodiversity and Conservation; the most frequently used keywords were biodiversity, conservation, diversity, dead wood, and management. An analysis of the temporal use of keywords indicates that in recent years, there has been a greater emphasis on the impact of climate change on species and corresponding management measures.

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