Biodiversity accounting: a bibliometric analysis for comprehensive literature mapping

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Abstract

Purpose – The paper aims to carry out a comprehensive literature mapping to synthesise and descriptively analyse the research trends of biodiversity accounting, providing implications for managers and policymakers, whilst also outlining a future agenda for scholars.

Design/methodology/approach – A bibliometric analysis is carried out by adopting the Preferred Reporting Items for Systematic Review and Meta-Analyses protocol for searching and selecting the scientific contributions to be analysed. Citation analysis is used to map a current research front and a bibliographic coupling is conducted to detect the connection networks in current literature.

Findings – Biodiversity accounting is articulated in five thematic clusters (sub-areas), such as "Natural resource management", "Biodiversity economic evaluation", "Natural capital accounting", "Biodiversity accountability" and "Biodiversity disclosure and reporting". Critical insights emerge from the content analysis of these sub-areas.

Practical implications – The analysis of the thematic evolution of the biodiversity accounting literature provides useful insights to inform both practice and research and infer implications for managers, policymakers and scholars by outlining three main areas of intervention, i.e. adjusting evaluation tools, integrating ecological knowledge and establishing corporate social legitimacy.

Social implications – Currently, the level of biodiversity reporting is pitifully low. Therefore, organisations should properly manage biodiversity by integrating diverse and sometimes competing forms of knowledge for the stable and resilient flow of ecosystem services for future generations.

Originality/value – This paper not only updates and enriches the current state of the art but also identifies five thematic areas of the biodiversity accounting literature for theoretical and practical considerations.

Keywords Bibliometric analysis, Biodiversity accountability, Biodiversity accounting, Biodiversity disclosure and reporting, Natural capital accounting, Natural resource management

Paper type Literature review

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1. Introduction

Biodiversity accounting is an important extension of corporate social responsibility reporting (Roberts *et al.*, 2020). It deals with the account of the variety of life on earth, including the vast array of genetically distinct populations within species, as well as the full variety of species and communities, and ecosystems of which they are parts (Adler *et al.*, 2021). Biodiversity is crucial for both current and future generations, as its deterioration is widely known as one of the most genuine existing threats to human life and economic development (Mahyuddin *et al.*, 2022). This awareness is internationally recognised as one of the most serious issues of the ongoing environmental crisis in both academic and policy literature (Ferreira, 2017). Concrete solutions are needed to counteract the decline in nature (Smith *et al.*, 2020; Gray, 2010; Boiral, 2016) that the World Economic Forum has declared as one of the top five global risks to society (Hassan *et al.*, 2022, 2020) since 2015.

Since its inception, biodiversity accounting literature has evolved significantly and, to date, it refers to a vast and ever-expanding research area that cannot be potted in a single scope. It includes several sub-areas of the accounting scientific domain, such as species extinction (Atkins and Maroun, 2018), ecological crisis (Maunders and Burritt, 1991), ecosystems (Edens and Hein, 2013), climate change (Milne and Grubnic, 2011), environmental disasters (Sargiacomo, 2015), natural capital (Obst, 2015). Over the years, continuing a centuries-old tradition, extensive research has offered a valuable contribution by feeding the literature on biodiversity accounting through significant theoretical insights (Jones, 2014; Atkins and Maroun, 2020) and empirical evidence (Skouloudis *et al.*, 2019; Syarifuddin and Damayanti, 2019; Siddiqui, 2013; de Boer and van Bergen, 2012). However, despite biodiversity having catalysed several accounting authors' attention, there is still relatively scarce recognition of the critical role of accounting for biodiversity issues (Jones and Solomon, 2013). There is a paucity of scientific works that focus on what accounting scholars and practitioners do or should do to effectively minimise the risks of biodiversity loss. In addition, if, on one hand, only a few authors have drawn on any systematic research in biodiversity accounting (Roberts *et al.*, 2021; Wang *et al.*, 2021; Gamarra *et al.*, 2018; Zhong *et al.*, 2016), on the other, since the beginning of the new millennium, there is no previous review that uses bibliometrics to investigate biodiversity accounting along with the main features and evolution of its thematic sub-areas.

The paper fills this gap by carrying out a comprehensive literature mapping on biodiversity accounting research trends through bibliometric methods (Lardo *et al.*, 2022; Baker *et al.*, 2022). Our analysis updates and enriches the current state of the art of biodiversity accounting literature, whilst also identifying the main features and conceptual evolution of its thematic sub-areas. It also provides both practical and theoretical implications for managers, policymakers and scholars by outlining three main areas of intervention, i.e. adjusting evaluation tools, integrating ecological knowledge and establishing corporate social legitimacy. Our findings not only confirm an increasing interest in biodiversity from accounting researchers but also reveal how most organisations publish environmental reports as a generic rhetoric exercise to hide any information about negative issues (Boiral and Heras-Saizarbitoria, 2017). This evidence leads to assuming that conventional accounting is unsuitable to address the current biodiversity challenge, whilst also stressing the urgency of genuine biodiversity accountability (Jones and Solomon, 2013). Highlighting the main gaps and prejudices that emerge in current literature, this bibliometric analysis uncovers the serious risk of underestimating the importance of natural capital preservation (Mace, 2019). Biodiversity accounting is still an immature political tool (Barker, 2019) because it has a bureaucratic style (Grilli *et al.*, 2021) and is not integrated into broader government actions (Guerry *et al.*, 2015). Thus, we advocate the need to institutionalise the procedures for

evaluating natural resources (Adler *et al.*, 2017). Our research also attempts to prevent further biodiversity loss by providing accounting scholars with some research hints. We claim the synergistic integration of interdisciplinary economic and environmental skills and experience (O'Dwyer and Unerman, 2020; Atkinson and Obst, 2017; Mouysset *et al.*, 2011), the conception of new frameworks to enhance biodiversity, the development and promotion of a global standard to ensure uniformity and reliability in sustainability reporting (Aggarwal and Singh, 2019). Finally, we emphasise the accounting function as an emancipatory mechanism, capable of raising stakeholders' awareness of organisations' impact on natural capital and resources (Jones and Solomon, 2013).

The remainder of this paper is organised as follows. Section 2 provides a historical overview of the biodiversity accounting literature. Section 3 describes the workflow for the literature mapping, providing information on the study design, data collection and analysis. Section 4 presents the findings. Section 5 discusses the results and unfolds the implications of the work. Section 6 concludes the paper by highlighting the research originality and limitations.

2. Historical overview of biodiversity accounting

The debate surrounding biodiversity accounting can be conventionally traced back to the 18th century when Gilbert White's "Naturalist's Journals" presented an early version of biodiversity accounting focused on flora and fauna reporting (White, 1774).

In the early 19th century, due to the high demand for wood from shipbuilders, Israel Adolf Ström commissioned the first forest management plan in Sweden, which aimed to produce an oak population report within the Stockholm National Urban Park (Slottsarkivet, 1807). Later, Ström (1822) wrote a textbook entitled *Proposal for an improved forest management in Sweden*, which remained the only Swedish book on the subject for over 100 years. More detailed testimonies on biodiversity were published in the late 1800s (Allen, 1876), with a focus on the impact of human activity on natural balance and resource consumption (Marsh, 1864). Estimates of national wealth produced during this period only considered the economic perspective (Bollfras, 1878). After 1930, new estimates emerged on the variation of living species in nature (Volterra, 1931), and the problem of regulating natural resource consumption (Hotelling, 1931) started to gain interest, with more research being carried out in the following years.

During the second half of the 20th century, concern over the impact of human activities on biodiversity grew (Carson, 1962). The role of production was identified as destabilising natural systems (Krutilla, 1967). The exponential growth of the world population led to the need to quantify and conserve natural resources (Pigou, 1952), leading to a renewed interest in biodiversity accounting (Ehrlich, 1968). Legitimacy theory also emerged during this period, emphasising the importance of aligning an organisation's activities with the social values and norms of its surrounding community (Parsons, 1960). Legitimacy was defined as the process through which an organization justifies its right to exist in its superordinate system, including the right to import, process and export resources (Maurer, 1971).

In the 1970s, technological progress began to be considered a possible cause of environmental degradation and a threat to humanity (Ruttan, 1971). Deep ecology philosophy also emerged at this time, attributing a crucial role to biodiversity in the ecosystem, whilst also urging for the abandonment of human centrality in favour of a harmonic balance with nature (Næss, 1973).

The scarcity of resources continued to be a central theme in the following decade (Freeman and Boeker, 1984), with the research of the 1980s supporting the protection of ecosystems and encouraging companies to conserve resources in their operations

(Hall, 1984). Organisations recognised the importance of considering not only those who held direct power over their processes and profits but all those stakeholders who were affected by their activities. This led to the emergence of stakeholder theory, which became one of the primary modes of thought in organisational ethics (Freeman and Reed, 1983). The theory emphasised that all organisations, regardless of their objectives, must aim to increase the general welfare of their stakeholders.

The concern for environmental deterioration continued to be a significant issue in the 1990s when the requests for political, economic and ethical foundations of modern society became pressing (Jones, 1996). Whilst the stakeholder concept originally included only employees, customers, suppliers, institutions, authorities and competitors, in this decade even the non-human natural environment gained the status of stakeholder, as it was considered as affecting organisational conduct and, in turn, affected by it (Starik, 1995). Many organisations started to adopt impression management tactics to demonstrate their commitment to the natural environment, inflate their environmental performances, neutralise unethical behaviours and raise environmental legitimacy towards stakeholders (Elsbach and Sutton, 1992; Elsbach, 1994; Suchman, 1995; Brown, 1997).

3. Study design

3.1 Research questions

The first highly important step in any bibliometric work is to design the study through the specification of the research questions (RQs) (Zupic and Čater, 2015). To perform a comprehensive literature mapping on biodiversity accounting research trends since 2000, the paper answers the following *RQs*:

RQ1. Which countries, journals and authors are mostly affecting the current biodiversity accounting research stream?

RQ2. What are and how have the main thematic areas in the biodiversity accounting literature evolved?

RQ3. What implications can a bibliometric analysis of biodiversity accounting literature offer to managers, policymakers and scholars?

3.2 Methods

Bibliometrics is a set of rigorous methods for exploring and analysing large volumes of scientific data (Donthu *et al.*, 2021). It helps to represent the history and general state of the art of a research field or topic (Aria and Cuccurullo, 2017), considering any written production as the main formal channel of communication among scientists (Bellardo, 1980). Several recent accounting studies use these methods (Lardo *et al.*, 2022; Baker *et al.*, 2022; Bruns *et al.*, 2020; Buonocore *et al.*, 2018; Chiu *et al.*, 2019). In this paper, bibliometrics has been carried out by using the bibliometrix R-package (Aria and Cuccurullo, 2017). Unlike many other tools for science mapping, it allows to address the entire literature workflow, whilst also providing a set of useful tools for quantitative research in bibliometry, based on the open-source R language. The presence of substantial, effective statistical algorithms, access to high-quality numerical routines and integrated data visualization tools are perhaps the strongest qualities to prefer R to other languages for scientific computation (Aria and Cuccurullo, 2017). Operationally, bibliometric analysis has been carried out through *Biblioshiny*, an online application with an intuitive and well-organised interface (Secundo *et al.*, 2020). It offers multiple analysis options

in a menu that incorporates analytics and graphs for three-level metrics (i.e. sources, authors and documents).

3.3 Data search

3.3.1 Protocol. The protocol used for searching and selecting the scientific contributions is Preferred Reporting Items for Systematic Review and Meta-Analyses (Moher *et al.*, 2009). Its checklist allows to identify, synthesise and evaluate previous studies (Tranfield *et al.*, 2003), facilitating the reader's understanding and usability (Moher *et al.*, 2015). The search for the articles was carried out on 4 February 2021 on the Web of Science (WoS) database. WoS allows to explore the literature of different scientific domains. It includes a large number of citations relating to several specific fields and covers more than 20,000 sources (Aria and Cuccurullo, 2017). The debate on its adequacy in relation to the main alternative database, namely, Scopus, is lively (Harzing and Alakangas, 2016; de Winter *et al.*, 2014). However, WoS performs significantly better than Scopus in terms of the accuracy of its journal classification system (Wang and Waltman, 2016), providing information of the highest quality over a much longer period than any other competing alternative databases (Aria and Cuccurullo, 2017).

3.3.2 Query. To minimise the risk of omitting studies potentially relevant to the research, the search query was developed by including some terms and expressions with a meaning considered strictly related to biodiversity accounting. To this end, the concept of "extinction accounting" was included, which Atkins and Maroun (2020, 2018) consider an extension of accounting for biodiversity. Likewise, the concept of "natural asset" was included as a conceptual umbrella of which, as Jones (1996) stated, biodiversity forms a sub-category. Based on what the author discussed in the same work, even "natural capital", understood as the first level of biodiversity, was used to outline the search string. Since Mace (2019) asserted that natural capital accounting provides a consistent means of reporting on stocks and flows of natural resources, "natural resource" was also included. On the subject, Cuckston (2018) pointed out that, in corporate disclosure, biodiversity should be seen in terms of natural resources that are economically valuable. Thus, the word "disclosure" was also used in the query. A further term considered was "accountability" as recent studies (Adler *et al.*, 2021; Skouloudis *et al.*, 2019) jointly deal with the concepts of biodiversity accounting and biodiversity accountability. For the same reason, the word "reporting" was added to the search string (Skouloudis *et al.*, 2019; Weir, 2018). The search query is as follows:

> *(biodiversity OR extinction OR "natural asset" OR "natural capital" OR "natural resource") AND (accounting OR disclosure OR report OR accountability).*

3.3.3 Collection. Entering the query on the WoS search engine originally returned 45,063 items. Subsequently, different inclusion/exclusion criteria were applied (Tommasetti *et al.*, 2020). Both in verifying compliance with these criteria and in data collection, we worked independently, following a mixed procedure (Figure 1): initially semi-automated and subsequently manual.

The first operation of the semi-automated procedure began with the use of the time filter, limiting the analysis only to scientific contributions published after 2000, considering that from that particular year onwards, there was a significant change in publication trends on biodiversity accounting (Lardo *et al.*, 2022). In addition, articles published in 2022 were excluded since the year was still ongoing at the time of drafting this paper. The use of the time filter reduced the number of publications to 41,515. Subsequently, the type of document to be included was chosen (Aria and Cuccurullo, 2017). By selecting exclusively journal

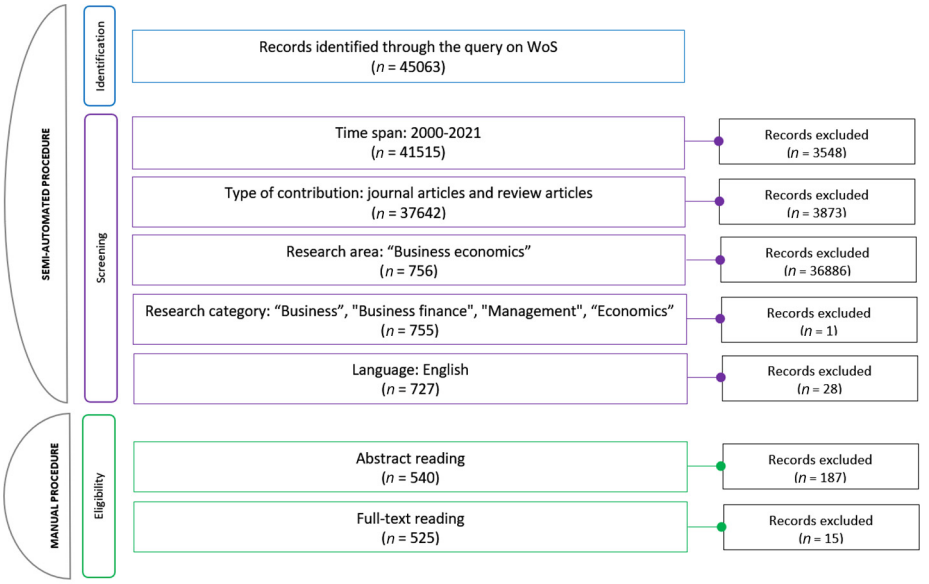


Figure 1.
Search flowchart

Source: Authors' elaboration

articles and review articles, 37,642 items remained. Then, the research area was defined (Lardo *et al.*, 2022), excluding any articles extraneous to "Business economics". This filter was necessary to develop new knowledge on the specific impact and relevance of biodiversity accounting in current business, management and accounting scientific literature. This filtering significantly reduced the size of the data set to 756 contributions. Subsequently, the research categories (Aria and Cuccurullo, 2017) were selected: "Business"; "Business finance"; "Management"; and "Economics". This operation excluded another article. Afterwards, to allow for the replicability of the review and ensure that all the records included in the analysis had an international audience, all non-English publications were excluded (Polese *et al.*, 2017), resulting in 727 records.

Once having completed the semi-automated procedure, we proceeded to read all the abstracts (Adams and Larrinaga, 2019), working independently in assessing the relevance and risk of bias of the previously semi-automatically selected scientific contributions. At the end of the abstract reading, only the contributions unanimously considered adequate for the purpose of the work were included. This operation reduced the data set to 540 items. The same way of operating was adopted for the last screening phase, consisting of a full-text reading of the remaining articles based on the predefined inclusion/exclusion criteria to minimise the risk of any errors in the WoS indexing (Manetti *et al.*, 2021). Among the reasons for exclusion after the reading of the articles, we considered the lack of a clear relationship with the aim and scope of this study (i.e. limited focus on biodiversity), the marginal contribution to the advancement of scientific knowledge (i.e. descriptive reports of biodiversity tools) and the paucity of theoretical and practical implications (i.e. articles unable to provide useful insights for scholars and/or practitioners) (Palumbo *et al.*, 2021). This operation excluded 15 contributions. The final data set is made up of 525 articles. Having defined the data set, the records were exported to a plain text file and then imported to *Biblioshiny* to be analysed.

3.4 Data analysis

Data analysis entails a descriptive analysis and network extraction. Among the different alternative approaches for data analysis, such as co-word analysis, co-author analysis and citation analysis, this paper used the latter, as it is the most recommended analysis in bibliometrics to map a current research front (Aria and Cuccurullo, 2017). It uses citation counts as a measure of similarity between documents, journals and authors. Within the citation analysis scope, bibliographic coupling was applied to both authors and journals to detect the connection networks in literature (Gao and Guan, 2009). Any two articles are said to be bibliographically coupled whether at least one of them cites a source indicated in the bibliography or reference list of both articles (Kessler, 1963). Starting from a bibliographic data frame, the *biblioNetwork* function calculates the most frequently used bibliographic coupling networks, such as documents, sources, authors, keywords and countries. Bibliographically coupled studies are likely to share the same underlying research theme. Once having built the networks, a normalization process was performed on the relations between its nodes through Pearson's correlation. Finally, data reduction helped identify the main thematic sub-areas of the biodiversity accounting literature through principal component analysis.

4. Findings

4.1 Data visualization

The data collection returned a sample of 525 scientific contributions published from 2000 to 2021 in 144 journals. Of these contributions, 511 were published as journal papers and 14 as review articles. Overall, 1,309 scholars are involved in these publications, with 107 having published as a single author. Table 1 presents the main information on the data set features.

The authors writing on the theme of biodiversity accounting come from 71 countries.

Table 1. Main information about the collection

Data set features		
General information	Timespan	2000:2021
	Journals	144
	Documents	525
	Average years from publication	8.02
	Average citations per documents	29.91
	Average citations per year per doc	2.991
	References	25064
Document types	Article	511
	Review	14
Document contents	Keywords plus	1250
	Author's keywords	1756
Authors	Authors	1309
	Author appearances	1483
	Authors of single-authored documents	107
	Authors of multi-authored documents	1202
Authors' collaboration	Single-authored documents	119
	Documents per author	0.401
	Authors per document	2.49
	Co-authors per documents	2.82
	Collaboration index	2.96

Source: Authors' adaptation from *Biblioshiny*

Table 2 indicates the twenty countries with the largest number of authors involved in scientific publications on biodiversity accounting, highlighting the prevalence of papers written by English-speaking scholars (i.e. scholars whose first language is English). The USA, UK, Australia and Canada are among the six most contributing countries by the number of authors interested in biodiversity accounting, with 539 out of a total of 1,180 (45.7%). There are also several European Union (EU) countries on the list, such as Germany (72, 6.1%), France (65, 5.5%), Spain (46, 3.9) and The Netherlands (36, 3.1%).

Regarding the countries' scientific collaboration networks (Figure 2), the bibliometric analysis shows that, whilst the anglophone authors frequently collaborate with their foreign colleagues, the European Union scholars tend to write with other Europeans. There seems to be a dense network of collaborations in Europe that includes Germany, Sweden, The Netherlands and Switzerland. There are some exceptions, such as Italy (involved in the USA network), France and Spain (involved in the UK network). Many countries seem to be isolated. This means that the authors tend to write alone or predominantly collaborate with their compatriots.

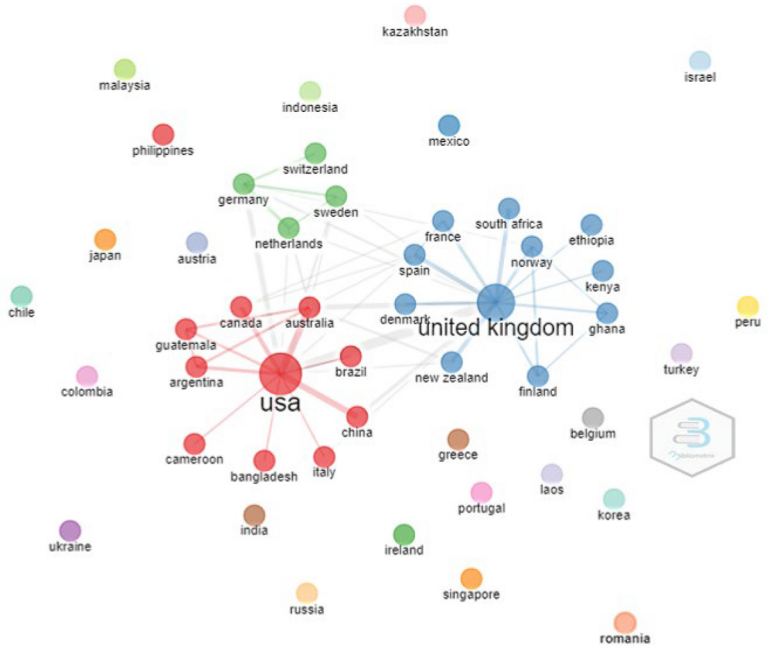
Regarding the source relevance (Figure 3), what is striking is the clear predominance of the journal *Ecological Economics*, with 191 contributions (36.4% out of the total). Accounting, Auditing and Accountability Journal follows in the second position with 30 contributions (5.7% out of the total). The presence of only one accounting journal (according to Scimago Journal and Country Rank [1]) in this ranking underlines the high multidisciplinary nature of the topic.

Examining the source impact (Figure 4), expressed by the number of local citations (that is the number of citations from the data set), the first two positions remain unchanged but the distance between those journals is considerably reduced. *Ecological Economics* records 1,138 local citations, whilst *Accounting, Auditing and Accountability Journal* records 695 local citations. In the ranking of the most local cited sources, there is another accounting journal, *Accounting, Organizations and Society*, with 331 local citations.

Table 2.
Countries' scientific production by the number of publications

Rank	Country	No. of authors
1	USA	233
2	UK	180
3	Australia	74
4	Germany	72
5	France	65
6	Canada	52
7	Spain	46
8	The Netherlands	36
9	China	33
10	Sweden	33
11	Ukraine	33
12	Italy	31
13	New Zealand	24
14	South Africa	22
15	Norway	21
16	Japan	16
17	Finland	13
18	India	13
19	Portugal	11
20	Belgium	10

Source: Authors' adaptation from Biblioshiny



Source: Biblioshiny

Figure 2.
Countries' scientific collaboration network

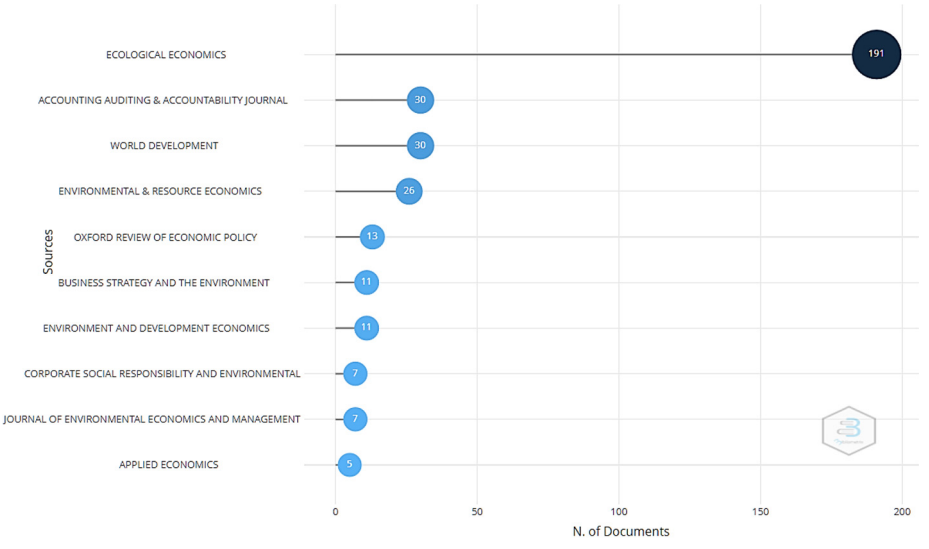


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Figure 3.
Sources relevance by the number of publications

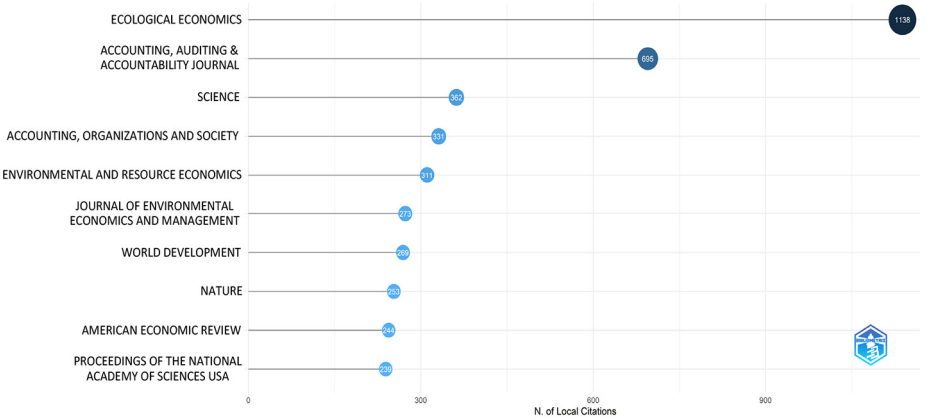


Figure 4.
Most local cited sources

Source: Authors' adaptation from Biblioshiny

Figure 5 shows the ten most local cited documents, which means the papers recording the greatest number of citations from the data set. In this case, 8 of the 10 most cited articles were published in *Accounting, Auditing and Accountability Journal*.

As for the authors' impact (Figure 6), measured by the number of local citations (that is the number of citations from the data set), Thomas Cuckston leads the rank with 36 citations, followed by Gunnar Rimmel with 31 citations. In third place, there are 30 citations for both Jill Atkins and Kristina Jonäll, the only two women in this top ten.

4.2 Clustering by coupling

The clustering by coupling was carried out over two time windows: 2000–2015 and 2016–2021. This choice came from a twofold consideration. First, the number of publications in the

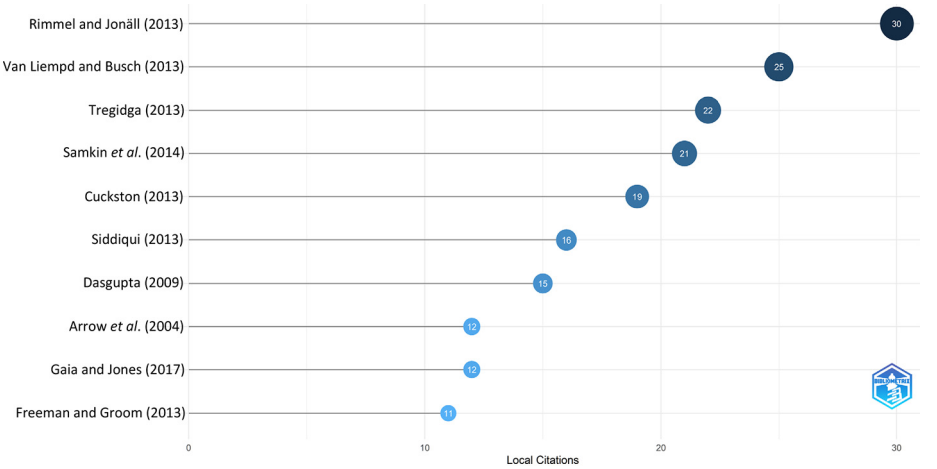
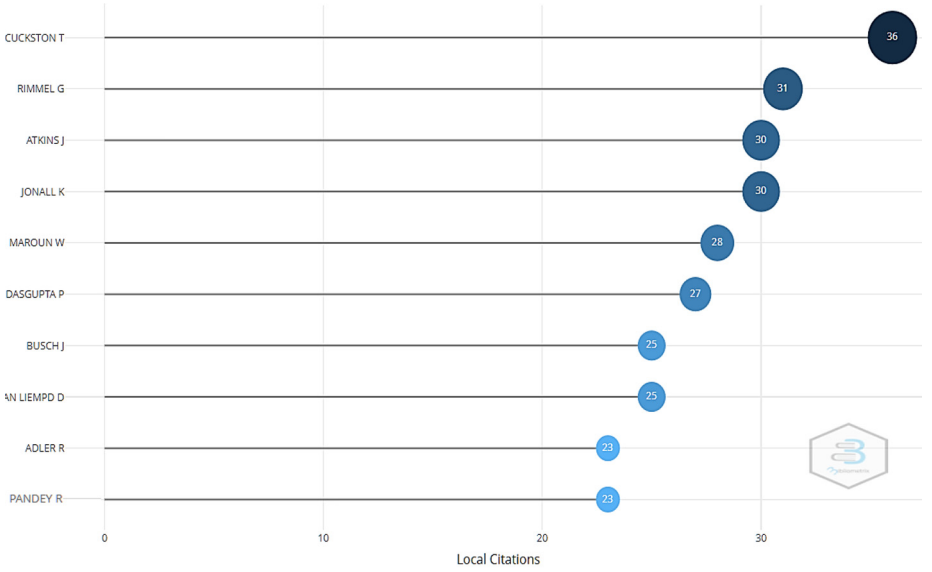


Figure 5.
Most local cited documents

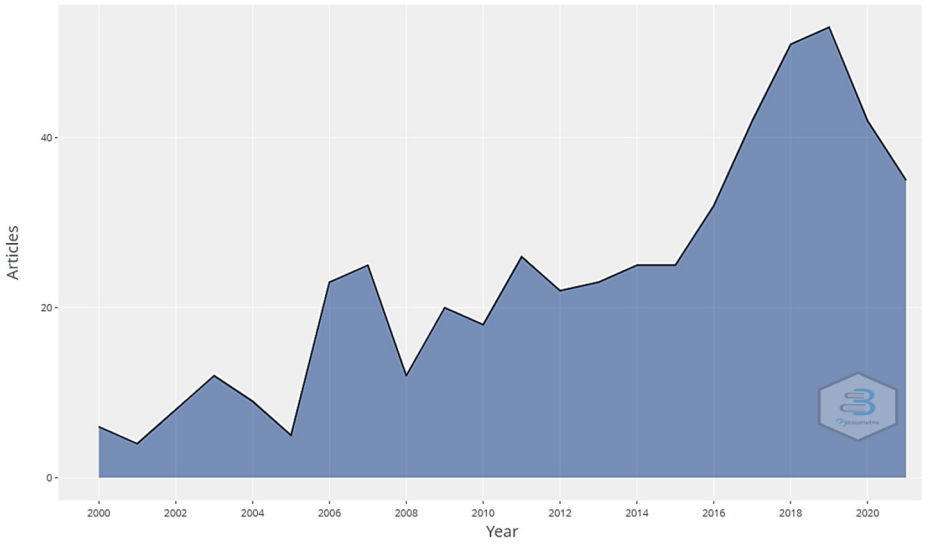
Source: Authors' adaptation from Biblioshiny



Source: Biblioshiny

Figure 6.
Most local cited authors

data set showed a marked increase starting from 2016 (Figure 7). The number of publications in the past 6 years (262) was almost equivalent to that of the publications in the first 15 years (263). Second, the high growth in the number of publications over time suggested that the researchers' interest in the subject progressively increased. This evidence



Source: Biblioshiny

Figure 7.
Annual scientific production

led to the belief that a specific analysis of the literature on biodiversity accounting in the 2016–2021 period was appropriate to verify possible analogies and differences compared to the time window 2000–2016.

Regarding the time window 2000–2015 (Figure 8), the clustering by coupling reveals the presence of four clusters: "Natural resource management"; "Biodiversity economic evaluation"; "Natural capital accounting"; and "Biodiversity accountability".

Whilst recording significant shifts between the quadrants, the cluster analysis performed by considering the period 2016–2021 (Figure 9) confirms the presence of three of the four thematic areas identified within the previous time window. The cluster "Biodiversity economic evaluation" disappears whilst a new cluster takes shape: "Biodiversity disclosure and reporting".

4.2.1 Natural resource management. Cluster 1, labelled as "Natural resource management", places in Quadrant 3 (lower-right) during the period 2000–2015. This result suggests that, at least in a first phase, the cluster synthesises a basic, general and transversal theme, characterised by high centrality and density but low impact. However, since 2016, it records a shift to the left, straddling Quadrant 4. This means that, recently, its centrality is progressively decreasing by causing a reduction in its relevance within the biodiversity scientific domain. Overall, the content analysis of the articles in Cluster 1 underscores that, for several years, biodiversity has been being widely recognised as a valuable natural asset to be conserved (Gerber, 2011). This recognition is also due to the increases in economic activities, which put pressure on natural resource stocks and causes environmental degradation (Polasky *et al.*, 2015). A proactive approach to anticipate ecosystem changes and prevent disruptive impacts on natural resource conservation is

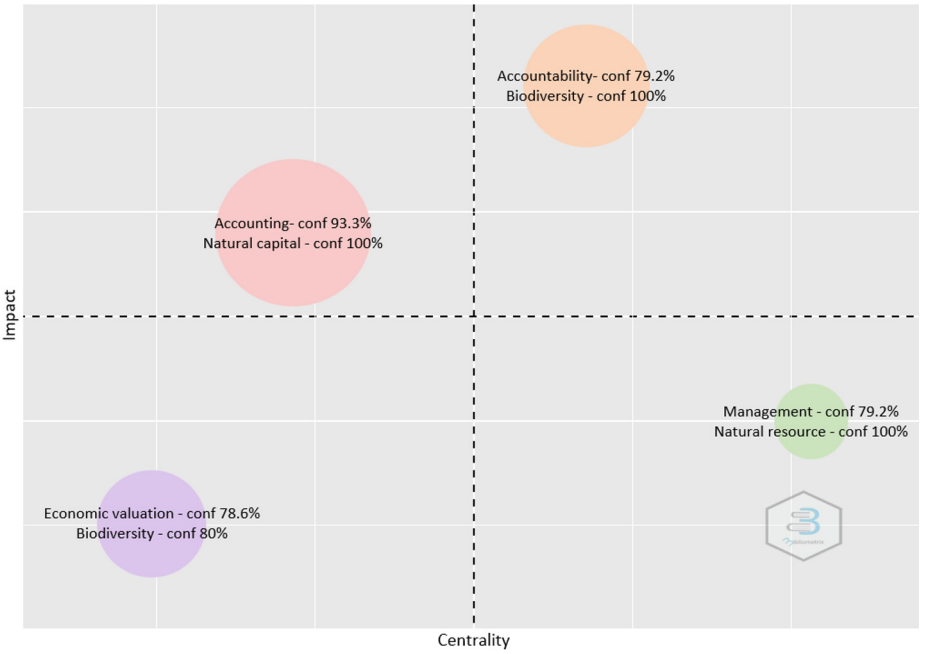
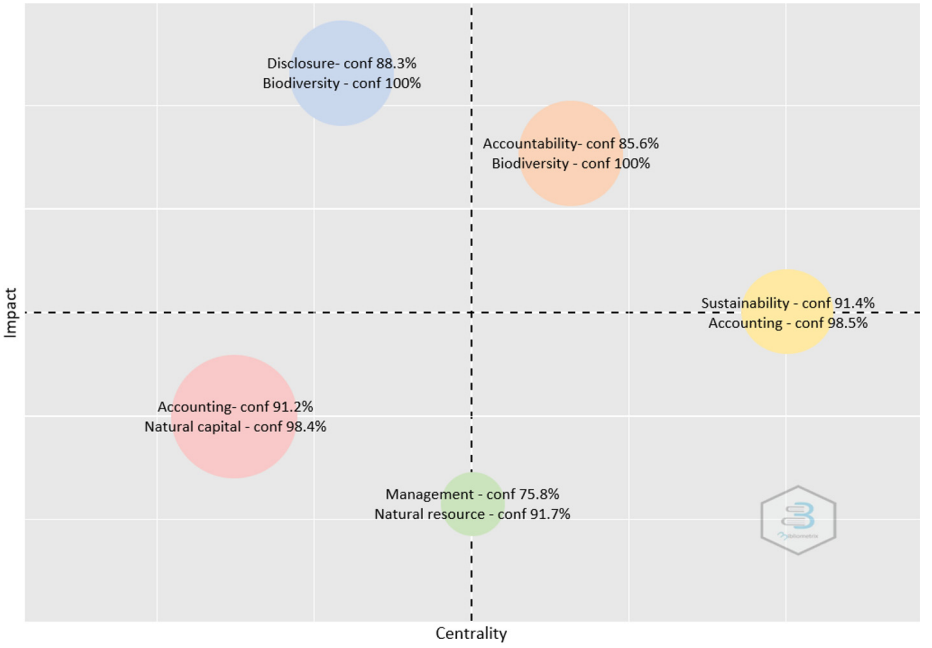


Figure 8.
Thematic clusters by documents coupling from 2000 to 2015

Source: Biblioshiny



Source: Biblioshiny

Figure 9.
Thematic clusters by documents coupling from 2016 to 2021

needed (Stein *et al.*, 2013). This approach is necessary because natural resource management affects the ecosystem and, in turn, human interventions influence resources (Kvamsdal *et al.*, 2020). This statement is similar to Polasky *et al.*'s idea (2015), according to which sustainability management strategies must consider the interactive effects of any possible ecosystem mutation whilst maintaining the capacity for future natural resource needs (Hsiao *et al.*, 2022). To this aim, Vegera *et al.* (2018a) state that natural resource management strategies have to be implemented at different interlinked layers. As Monge and McDonald (2020) assert, a long-term management of natural resources is essential for the stable and resilient flow of ecosystem services for future generations facing evolving socio-economic and climatic uncertainty. In this respect, Adler *et al.* (2017) underline and appreciate the attempts of the United Nations decade on biodiversity 2011–2020 to promote biodiversity awareness globally and communicate the serious challenges that the world is facing in terms of natural resource management. However, the objective of managing impacts and dependencies on natural resources can be overly complex (Smith *et al.*, 2020). To gain social legitimacy, some companies – especially the most polluting ones – often resort to impression management techniques as the easiest way to please their stakeholders (Adler *et al.*, 2018) by hiding or omitting any information on the exploitation of natural resources that could affect their image and reputation (Boiral, 2016). However, the unwary employment of impression management techniques risks undermining companies' credibility and generating stakeholders' scepticism (Adler *et al.*, 2017). Companies' failure to understand stakeholders' perspectives when proposing initiatives aimed at responsibly managing natural resources is a potential cause of resistance and erosion of social legitimacy (Lafreniere *et al.*, 2013). Within the biodiversity field, legitimacy depends on the companies' ability to meet

stakeholders' expectations by ensuring transparency for natural resource management initiatives. However, stakeholder participation does not ensure compliance with these kinds of initiatives (Berkes, 2009). Efficient and effective natural resource management strategies and policies call for an adequate knowledge integration for safeguarding biodiversity and convincing stakeholders in this regard (Van Noordwijk, 2019). The poor integration of knowledge related to the several disciplinary sectors of the biodiversity accounting research area could be the cause of the progressive decrease in the centrality of the cluster natural resource management in current literature.

4.2.2 Biodiversity economic evaluation. Considering the period 2000–2015, Cluster 2, labelled as "Biodiversity economic evaluation", stands in Quadrant 4 (lower-left), highlighting its low centrality, poor density and weak impact. This means that it could comprise an emerging or declining theme. However, looking at the analysis of the period 2016–2021, the cluster disappears, confirming an increasing researchers' disinterest in further studying it over the past few years. The cluster includes articles focused on the assessment of biodiversity in the context of coevolution among economic systems and natural ecosystems. Ferreira (2017) points out that the relationship between nature and economics has an ontology that sees nature as a set of externalities to be managed for economic value. For this very reason, Mäler *et al.* (2008) underline that, since the 1970s, the development of evaluation techniques for natural resources and ecosystem dynamics has been phenomenal and rising steadily. The cluster analysis also sheds light on the presence of a fervid debate on the monetary evaluation of biodiversity and natural capital (De Groot *et al.*, 2003), as not all the benefits experienced by humans from the natural world are amenable to monetary valuation (Bateman *et al.*, 2011). Thus, the economic evaluation of environmental resources emerges as the best way to confirm the importance of ecosystem services to human welfare and environmental sustainability (Taye *et al.*, 2021). Natural resources valuation stands as worthwhile to decision-making, being able to affect stakeholders to invest in natural capital stocks (Mace, 2019). Assessing biodiversity in economic terms is a complex issue, as natural capital is an asset and its many contributions to the economy and society, often called ecosystem services, are both malleable and adaptable. Its value changes with time and context, as it becomes more or less important and relevant for particular purposes (Mace, 2019). Accordingly, Brandon *et al.* (2021) assert that the extent and complexity of data requirements, valuation methodologies, institutional capacity and coordination hinder the uptake of natural capital application and evaluation. Recalling Repetto's (1988) statement, Harris and Fraser (2002) recognise the presence of a dangerous asymmetry in the way to measure the value of natural resources. The paradox is that a country could exhaust its mineral assets, cut down its forests, erode its soils, pollute its aquifers and hunt its wildlife to extinction, whilst increasing its income. This can occur because the traditional measures of economic activity, such as gross and net domestic product, are not able to accurately measure the contribution and impact of economic activities on the environment. The main problem lies in the inadequacy of most indicators, which often fail to consider the specificities of the interconnection among human beings, natural resources, territories and nature (Sobkowiak *et al.*, 2020). All these difficulties and uncertainties might potentially represent the factors that, over the past few years, have caused Cluster 2 to lose centrality and density in the biodiversity accounting literature. To overcome these difficulties, the adoption of a broader perspective, based on a sort of metaphysical shift (Battistoni, 2017), is needed. To this end, for example, embracing the deep ecology philosophy could facilitate the acquisition and dissemination of a new ecological consciousness that recognises the unity of humans and nonhuman nature (Ikeke, 2020).

4.2.3 Natural capital accounting. Labelled as "Natural capital accounting", Cluster 3 stands in Quadrant 2 (upper-left) in the 2000–2015 period, showing a high centrality but low impact and poor density. Therefore, at first glance, it could be considered alternatively as either a theme investigated within a network of research questions likely to become a future motor theme or a point of transfer between different but connected networks, with a centrality destined to diminish over time. However, the cluster analysis performed by selecting the period 2016–2021 provides the answer to this apparent uncertainty, displaying a shift towards Quadrant 4 (low centrality, poor density and weak impact). This sort of involution highlights that, over the past few years, the theme is becoming increasingly marginalised and risks disappearing before long, unless it is reinvigorated by new and valuable studies. However, the research strand dealing with natural capital accounting is not arid. On contrary, Turner *et al.* (2019) assert that recent debates surrounding the application of natural capital accounting have produced several approaches to further develop this sub-area of biodiversity accounting, as well as highlighted a number of conceptual and methodological issues. Even Grilli *et al.* (2021) acknowledge the current relevance of the theme, stating that expanding the set of tools available for natural capital accounting can enhance the management of ecosystem services and policy decision-making. In this perspective, natural capital accounting may be identified as a vehicle to systematically accelerate the mainstreaming of biodiversity into decision-making and development policies (Vardon *et al.*, 2016). According to Atkinson and Ovando (2022), natural capital accounting describes a body of statistical work that seeks to construct better metrics of nature for policy. It provides important information to support public policy and land-use management decisions (Helm, 2014). Barker (2019) recognises accounting as prominent to the conservation of natural capital, whilst Vegera *et al.* (2018b) affirm that the natural capital involvement in the management decision-making process of business entities reduces the negative impact on the environment. Hence, in light of what has been described so far, despite the involution previously indicated as a result of the cluster analysis, the prevailing orientation in the literature recognises and valorises the importance of natural capital accounting, contributing to stimulating optimism about its future possibilities for further study and development (Barbier, 2019). For now, this recognition is confirmed only on a theoretical level. Natural capital accounting is rarely used as a tool in corporate strategies and governmental policies to foster stakeholders' satisfaction and citizens' legitimacy for ecological economics in the economic discourse of sustainability (Khan, 2021; Amoako-Tuffour, 2016). In many cases, natural capital information appears disconnected from the practices that organisations undertook, leaving room for justifications instead of actions regarding the environment (Vola *et al.*, 2021). This approach sets the scene for the use of impression management tools (Boiral and Heras-Saizarbitoria, 2017) to gain and keep legitimacy over time. Even if the management of impressions through neutralization techniques is easier than the release of substantial and transparent information on natural capital (Boiral, 2016), this approach prevents companies from building strong stakeholder relationships (Bansal and Clelland, 2004). In the long term, the inappropriate use of impression management tactics risks exasperating the stakeholders' scepticism and eroding legitimacy (Bansal and Kistruck, 2006).

4.2.4 Biodiversity accountability. Titled "Biodiversity Accountability," Cluster 4 is situated in Quadrant 1 (upper-right) since 2000, albeit with a slight and marginal decline between 2016 and 2021. This positioning denotes biodiversity accountability as a driving theme in the literature, characterised by a high centrality, density and impact. This evidence suggests that accountability is an important topic in the research domain and an evolving argument within biodiversity literature, with an escalating interest among researchers over

the past two decades. However, accounting studies indicate that corporate biodiversity accountability remains nascent (Addison *et al.*, 2019). Raar *et al.* (2020) assert that organisations require novel tools to facilitate the planning, controlling and assigning of responsibility and accountability for reporting. Cuckston (2013), Tregidga (2013), Carnegie and West (2005) contend that accountability necessitates more than mere financial representation. Consistently, Boiral (2016) underscores the insufficiency of comprehensive information disclosed by organisations and the subsequent demand for more detailed reports. Gray (2010, 2006) posits that, whilst the emergence of non-economic reports may suggest increased corporate accountability for biodiversity, social and environmental concerns frequently become secondary to economic matters. Several scholars have attempted to resolve the technical challenge of how companies can concretely account for biodiversity and develop accountability mechanisms to fulfil their responsibility and commitment to stakeholders concerning their impact on biodiversity (Russell *et al.*, 2017; Freeman and Groom, 2013). Adler *et al.* (2021) emphasise the significance of accountability in safeguarding, preserving and augmenting biodiversity for present and future generations. However, accounting for biodiversity can constitute an effective accountability mechanism only when reporting influences behaviour (Jones and Solomon, 2013). The discourse surrounding the establishment of a conceptual and pragmatic foundation for accounting and accountability should be revitalised by integrating biodiversity management into the internal practices, routines and communication of organisations (Raar *et al.*, 2020). Otherwise, as Roberts *et al.* (2020) assert, organisational accountability for biodiversity is likely to remain inconsistent, ambiguous and deceptive. The aforementioned reflections underscore the presence of an active debate within current literature, which may serve as the primary rationale for the classification of biodiversity accountability as the driving theme of the analysis.

4.2.5 Biodiversity disclosure and reporting. Cluster 5, denoted as "Biodiversity Disclosure and Reporting," emerges solely from 2016 onwards. The analysis of the 2000–2015 period reveals the absence of a unified and homogeneous collection of articles pertaining to this theme. Within the 2016–2021 timeframe, the cluster is situated in Quadrant 2 (upper-left), indicating a highly developed and distinct theme with well-established internal connections (high density) but inconsequential external links (low centrality) within the researched domain. The cluster's evolution can be interpreted through two distinct hypotheses. Firstly, the cluster could represent a network of forthcoming research inquiries, eventually transforming into a driving theme over the subsequent year (transitioning from Quadrant 2 to Quadrant 1). Alternatively, it could serve as a point of convergence among other diverse yet interconnected networks (shifting from Quadrant 2 to Quadrant 3). Biodiversity disclosure and reporting have their origins in social and environmental studies (Van Liempd and Busch, 2013; Jones, 2003), with the objective of addressing corporate stakeholders' expectations (Rimmel and Jonall, 2013). These stakeholders exert pressure on companies to report and manage their impacts on biodiversity and ecosystems (Milne *et al.*, 2009). Several studies of this cluster, whilst acknowledging stakeholders' vital role, identify additional factors capable of promoting biodiversity disclosure and reporting. Examples include the organisational size (Mahyuddin *et al.*, 2022; Aggarwal and Singh, 2019; Dias *et al.*, 2019), characteristics of organisational ownership and country-state governance (Roberts *et al.*, 2021) and board gender diversity (Haque and Jones, 2020). Another critical aspect that surfaces from the analysis is the inadequacy of the tools that organisations use for biodiversity disclosure and reporting (Bordt, 2018; Pascual *et al.*, 2015; Edens and Hein, 2013). Frequently, this shortcoming is attributed to the superficial commitment and persuasive rhetoric characterising many

organisations (Boiral, 2016) and their often partial and incomplete reports (Bhattacharyya and Yang, 2019). The information derived from corporate environmental reports influences stakeholders' perceptions (Barker, 2019) and affects the organization's legitimacy (Islam and Deegan, 2010). Consequently, to establish and maintain social consent, companies and other organisations strive to cultivate a general perception that their disclosed actions aligned with stakeholders' expectations within a given framework of norms, values and beliefs (Gaia and Jones, 2017). However, this approach is neither static nor unchangeable. It evolves over time, and organisations must adapt their actions and disclosure accordingly to be perceived as responsive to the environment (Gulluscio *et al.*, 2020; Burritt and Schaltegger, 2010). This adaptation is often challenging, leading some organisations to use strategic communication tactics such as impression management and evocative symbols to gain societal support, maintain or restore legitimacy (Samkin *et al.*, 2014) and affect stakeholders' perceptions (Talbot and Boiral, 2015). The authenticity of corporate biodiversity reporting has been widely debated (Cho *et al.*, 2012) but assessing its accuracy remains challenging (Vola *et al.*, 2021), with voluntary social and environmental disclosure still being insufficient to meet demand (Bhattacharyya and Yang, 2019). However, improvements have been made since the adoption of the G4 guidelines by the Global Reporting Initiative (GRI) (Bhattacharyya and Yang, 2019). For this reason, there is growing interest in biodiversity disclosure and reporting, which is likely to increase in its importance and become a key research topic in the future (moving from Quadrant 2 towards Quadrant 1).

5. Discussion and implications

Our findings reveal that biodiversity accounting includes five thematic nodes. "Natural Resource Management" (Cluster 1) has declined in relevance within the biodiversity scientific domain, with articles emphasising the need for effective natural resource management and accounting to support conservation policies. In Cluster 2, "Biodiversity Economic Evaluation", the economic assessment of natural resources is considered the best approach to confirm the significance of ecosystem services for human welfare and environmental sustainability. However, this thematic domain does not represent a developed research area. "Natural Capital Accounting" (Cluster 3) is identified as a means to systematically integrate biodiversity into decision-making and development policies. Several recent and valuable studies are reinvigorating this cluster, which risks disappearing before long. Cluster 4, "Biodiversity Accountability", has been a driving theme since 2000, with an increase in interest among researchers in corporate biodiversity accountability. However, accounting studies indicate that it remains underdeveloped as effective accountability mechanisms require stronger ecological knowledge and interdisciplinary collaboration among biodiversity scholars and practitioners. "Biodiversity Disclosure and Reporting" (Cluster 5) is a recent sub-area that highlights growing stakeholders' pressure on companies to report and manage their impact on biodiversity. Accurate reports turn out essential for maintaining organisational legitimacy. However, as organisations often use inadequate tools for biodiversity disclosure and reporting, the authenticity of corporate statements is currently the subject of extensive debate.

Through an analysis of the historical development of themes within the research domain, we have identified the key critical issues that define each sub-area of the literature on biodiversity accounting. Table 3 illustrates these issues. By taking these criticalities into account, valuable insights can be gleaned for practitioners and researchers in the field of biodiversity accounting. Our goal is to offer interrelated implications for managers, policymakers and scholars, which can be achieved by outlining three primary areas of

Table 3.
Clusters' positioning and thematic criticalities

Label	Features 2000–2015	2016–2021	Criticalities
Natural resource management	– High centrality – High density – Low impact	– Low centrality – Low density – Low impact	• Stakeholders' scepticism and erosion of corporate social legitimacy due to the use of impression management techniques by companies (Adler *et al.*, 2017; Lafreniere *et al.*, 2013) • Poor integration of knowledge related to the several disciplinary sectors of the biodiversity accounting research (Mouysset *et al.*, 2011)
Biodiversity economic evaluation	– Low centrality – Low density – Low impact	– n/a – n/a – n/a	• High complexity for companies in economically assessing biodiversity due to the changing evaluation purposes (Mace, 2019), need of institutional coordination, heterogeneity of data requirements and methodologies (Brandon *et al.*, 2021) • Inadequacy of most indicators in considering the specificities of the interconnection among human beings, natural resources, territories and nature (Sobkowiak *et al.*, 2020)
Natural capital accounting	– High centrality – Low density - Low impact	– Low centrality – Low density – Low impact	• Disconnection between natural capital information and corporate practices (Vola *et al.*, 2021) • Stakeholders' scepticism and erosion of corporate social legitimacy due to the use of impression management techniques by companies (Boiral and Heras-Saizarbitoria, 2017; Boiral, 2016; Bansal and Kistruck, 2006; Bansal and Clelland, 2004)
Biodiversity accountability	– High centrality – High density – High impact	– High centrality – High density – High impact	• Lack of corporate non-financial tools to plan, control and assign responsibility in accountability processes (Raar *et al.*, 2020; Cuckston, 2013; Carnegie and West, 2005) • Weak ecological knowledge due to the lack of interdisciplinary collaboration among scholars and practitioner in crafting accountability practices for biodiversity (Smith *et al.*, 2020; Russell *et al.*, 2017; Polasky *et al.*, 2015)
Biodiversity disclosure and reporting	– n/a – n/a – n/a	– High centrality – Low density – Low impact	• Inadequacy of corporate tools to disclose and report on biodiversity (Bordt, 2018; Pascual *et al.*, 2015; Edens and Hein, 2013) • Stakeholders' scepticism and erosion of corporate social legitimacy due to the use of impression management techniques and evocative symbols by companies (Talbot and Boiral, 2015; Islam and Deegan, 2010)

Source: Authors' elaboration

intervention: adjusting evaluation tools, integrating ecological knowledge and establishing corporate social legitimacy.

5.1 Adjusting evaluation tools

Biodiversity accounting faces a significant challenge due to the inadequacy of tools and indicators used to evaluate natural capital and the interconnectedness between people and natural resources (Sobkowiak *et al.*, 2020). To address this issue, professionals need to improve evaluation methods for natural ecosystems and develop approaches to assess ecosystem assets, such as estimating the economic life of natural capital by integrating physical data with economic-financial values (Atkinson and Obst, 2017). Biodiversity disclosure and reporting present a key challenge for companies, as conventional methods are unsustainable (Vegera *et al.*, 2018a; Rimmel and Jonall, 2013; Milne *et al.*, 2009). To enhance the reliability and robustness of accounts, several studies emphasise the need to educate companies to accept environmental stewardship and ecocentrism (Atkins and Maroun, 2018), with the adoption of the deep ecology philosophy suggested to address ecological challenges arising from worsening environmental conditions (Samkin *et al.*, 2014). This philosophy entails abandoning the anthropocentric approach and adopting an eco-centric one, attributing intrinsic value to all living beings (Ikeke, 2020).

However, changing corporate approaches is demanding, and achieving the goal of enhancing biodiversity accounting requires support from policymakers. Recent initiatives, such as the GRI guidelines and the EU 2020 biodiversity strategy, aim to improve the disclosure of biodiversity initiatives. However, companies are still not reporting their actual impacts on the environment, fostering a symbolic rather than substantive engagement (Haque and Jones, 2020). Despite the growing number of enacted regulations, the use of biodiversity accounting in the political field remains underdeveloped (Barker, 2019), with frameworks bogged down by bureaucratic issues (Grilli *et al.*, 2021). This impasse results from the mismatch between the "accounting push" and "policy pull" (Vardon *et al.*, 2016), with natural capital accounting and biodiversity accountability perceived in isolation from other political tools and not integrated into broader government actions aimed at fostering and maintaining legitimacy (Guerry *et al.*, 2015). Moreover, the proliferation of different international frameworks undermines the credibility of accounts, discouraging their adoption in political decisions (Vardon *et al.*, 2016).

Measuring the impact of biodiversity on society is difficult due to a lack of serious academic attention, with scholars on the fringes of the practice of biodiversity reporting (Tregidga, 2013). Scholars should refine tools for measuring and guiding effective natural resource conservation actions and promote biodiversity accounting within the wider social and environmental reporting and corporate social responsibility discipline to enable understanding of the complex relationship between nature and organisations (Jones and Matthews, 2000). Furthermore, academia and business schools should raise awareness of and promote positive change through research to prevent further biodiversity loss (Roberts *et al.*, 2021), with accounting researchers acting as providers of solutions to biodiversity problems by directing their attention to those tools capable of supporting decisions in a variety of circumstances (Burritt and Schaltegger, 2010).

5.2 Integrating ecological knowledge

Problems in biodiversity accounting arise due to poor integration of ecological knowledge (Mouysset *et al.*, 2011). "Stronger" ecological knowledge is essential to understand whether society is proceeding towards truly sustainable development (Smith *et al.*, 2020; Polasky *et al.*, 2015). An interdisciplinary collaboration among professional accountants, ecologists

and environmentalists in designing and crafting diverse accounts and accountability practices for biodiversity would be helpful to achieve this objective (Russell *et al.*, 2017). Strengthening ecological knowledge would enhance accountability practices (Polasky *et al.*, 2015) and reduce the complexity for companies when assessing biodiversity economically (Brandon *et al.*, 2021; Mace, 2019). Promoting a more integrated knowledge of how to manage and account for natural resources would enable companies to better analyse risks and opportunities, demonstrate market leadership and mitigate their environmental impact (de Boer and van Bergen, 2012). By integrating several forms of knowledge and values, companies can improve natural resource management and accountability to support biodiversity economic evaluation (Smith *et al.*, 2020).

Under a political profile, integrating diverse and sometimes competing spheres of ecological knowledge would make the flow of ecosystem services resilient for future generations facing evolving socioeconomic and climatic uncertainty (Monge and McDonald, 2020). Institutionalising ecological knowledge would facilitate the drafting of international biodiversity programs and the restructuring of funding models of national agencies that monitor natural capital (Bradford, 2018). Ecological knowledge institutionalisation would also allow for the creation of public–private science-management partnerships for integrated natural resource management and safe intervention spaces for innovators in terms of economic resources and structures. Integrating ecological knowledge in institutional policies would provide monetary recognition to truly environmental-friendly organisations as well as encourage the transition to sustainability (Van Noordwijk, 2019).

Implementing these actions requires an interdisciplinary approach (Mouysset *et al.*, 2011) committed to recognising and investigating the interdisciplinary pluralism of values that interact between natural and social systems (De Groot *et al.*, 2003). Researchers should strive to find solutions to current challenges by synergistically integrating existing skills and experience in all economic and environmental disciplines (Atkinson and Obst, 2017; O'Dwyer and Unerman, 2020). Studies in which economists and natural scientists collaborate in an intrinsically interdisciplinary effort (Brandon *et al.*, 2021) would foster the understanding of the importance to protect and conserve natural wealth, biological productivity and biodiversity (Barbier, 2019). Greater involvement by accounting scholars is desirable to move research towards a better knowledge of what companies and political institutions are doing and should do to contribute to a more sustainable future (Gulluscio *et al.*, 2020). Accounting scholars should propose new frameworks for planning, controlling and reporting companies' engagement in protecting, maintaining and enhancing biodiversity for both current and future generations, ensuring thorough accountability (Raar *et al.*, 2020), which requires more than just financial representation (Cuckston, 2013; Carnegie and West, 2005).

5.3 Establishing corporate social legitimacy

The increasing recognition of the environmental crisis has been driving companies to disclose more information on biodiversity (Bhattacharyya and Yang, 2019). However, companies must move beyond solely focusing on economic and reputational benefits and implement strategies that properly manage and account for natural resources (Hassan *et al.*, 2020; Mace, 2019; Adler *et al.*, 2018, 2017; Siddiqui, 2013; Rimmel and Jonall, 2013). The demand for more reliable forms of biodiversity accounting and accountability from stakeholders requires companies to acknowledge their responsibilities towards the ecosystem, mitigate negative operational impacts and contribute positively to biodiversity (Mahyuddin *et al.*, 2022; Gaia and Jones, 2017; Samkin *et al.*, 2014). To achieve this goal, companies should limit the use of impression management, which erodes their social

legitimacy and prevents the development of long-lasting relationships with stakeholders (Adler *et al.*, 2017; Boiral, 2016; Bansal and Clelland, 2004). Companies must avoid manipulating the presentation of social and environmental information to project a favourable image of their performance, as such conduct increases stakeholders' scepticism (Cho *et al.*, 2012; Bansal and Kistruck, 2006).

Preserving ecological biodiversity by establishing the social legitimacy of companies entails not only the corporate sphere but also the political scope (Rimmel and Jonall, 2013). Government institutions and policymakers must intervene in a more structured and organised way to safeguard natural capital and hinder environmental degradation (Khan, 2021). They should direct natural resource management policies towards waste prevention, more efficient and sustainable economic and market development and a solid planning of investments in environmental matters (Amoako-Tuffour, 2016). Institutional commitment should be defined in a coordinated manner between different levels of government, starting from local contexts and linked to well-defined national development policies and long-term extra-national planning objectives (Barbier, 2019). Integrating natural capital accounting into governmental policies allows for biodiversity economic evaluation and fosters corporate legitimacy for ecology in the economic discourse of sustainability (Guerry *et al.*, 2015; Bansal and Clelland, 2004).

Accounting researchers should trigger this cultural transformation by helping companies to demonstrate their commitment to environmental sustainability, enabling them to gain social legitimacy and acceptability (Boiral and Heras-Saizarbitoria, 2017; Hsiao *et al.*, 2022). Accounting has the potential to shape and construct reality as an emancipatory mechanism that raises stakeholders' awareness of corporations' impact on natural capital and resources (Jones and Solomon, 2013). This means that accounting academics could help identify new key literature gaps, systematise data to support environmental strategies and policies, process "boundary" information to guide the evolution towards a sustainable future, produce scientific evidence of human progress in terms of welfare and well-being, as well as develop and promote a universal standard to ensure uniformity and reliability in sustainability reporting (Aggarwal and Singh, 2019; Turner *et al.*, 2019). Accounting research should play a leading role in connecting the business and natural worlds, ushering in a wave of innovation that will be essential to preserving the basis of our future prosperity (Barbier, 2019).

6. Conclusions

Several bibliometric literature reviews have been conducted in the field of biodiversity accounting to synthesise the relevant literature (Table 4). Zhong *et al.* (2016) explored the natural resource accounting literature using bibliometrics from 1995 to 2014, whilst our study analysed biodiversity accounting literature as a whole from 2000 to 2021. Wang *et al.* (2021) conducted a bibliometric review of the accounting and management of natural resource consumption, but they did not identify any thematic sub-areas. Gamarra *et al.* (2018) investigated accounting methods and tools for measuring biodiversity values, but their findings differed significantly from ours. More recently, Roberts *et al.* (2021) provided valuable insights into biodiversity and species extinction accounting through a systematic literature review.

Differently, our study analyses a larger data set of 525 scientific articles published in 144 different journals over a long time span (2000–2021). The research area is broken down into five thematic sub-areas by using bibliometric coupling, and a content analysis is conducted to understand the formation of the state of the art (Monge and McDonald, 2020; Mace, 2019). The thematic evolution of the biodiversity accounting literature is performed to unfold the

Table 4. Previous systematic reviews and bibliometric analyses on biodiversity accounting

Title	Author (s)	Journal	Year	Type of review	Unit of analysis	Sample dimension	Timespan	Database	Query	Search field
Biodiversity and extinction accounting for sustainable development: A systematic literature review and future research directions	Roberts *et al.*	Business Strategy and the Environment	2021	Systematic	– Journal papers – Book chapters – Books	40	2013-2020	– Science Direct – Elsevier – Emerald – Wiley Online – Taylor and Francis – Springer Link – Business Source – Premier – Google Scholar	"biodiversity accounting" "biodiversity reporting" "biodiversity disclosure" "threatened species reporting"	– Title – Abstract – Keywords
Accounting and Management of Natural Resource Consumption Based on Input-Output Method: A Global Bibliometric Analysis	Wang *et al.*	Frontiers in Energy Research	2021	Bibliometric	– Journal papers	1824	–	– Clarivate Web of Science	("Input Output Analysis" OR "Input Output Model" OR "Input Output Table" OR "Input Output Method" OR "Input Output Framework" OR "IO analysis" OR "IO Model" OR "IO table" OR "IO technique_" OR "IO framework" OR "IO method") AND ("fossil fuel_" OR "natural gas" OR coal OR oil OR energy OR water OR freshwater OR wastewater OR land OR wood OR biomass OR metal OR mineral OR material OR "natural resource") AND (footprint OR use OR consumption OR withdrawal OR demand OR requirement OR extraction)	– Title – Abstract – Keywords

(*continued*)

Table 4.

Title	Author (s)	Journal	Year	Type of review	Unit of analysis	Sample dimension	Timespan	Database	Query	Search field
Accounting for no net loss: A critical assessment of biodiversity offsetting metrics and methods	Gamarra *et al.*	Journal of environmental management	2018	Systematic + semi-structured interviews	– Journals papers – Unpublished studies – Policy and technical reports	–	–	–	"Biodiversity offset*" OR "compensatory mitigation" OR "habitat offset" OR "environmental offset*" OR "conservation bank*" OR "habitat bank*" OR "offset metric*" OR "offset method*" OR "offset gains*" OR "offset benefits*" OR "offset currency*"	–
A bibliometric review on natural resource accounting during 1995–2014	Zhong *et al.*	Journal of Cleaner Production	2016	Bibliometric	– Journal papers – Conference papers – Review papers	2649	1995–2014	– Scopus	"Natural resource accounting" OR "natural resource calculation"	–

Source: Authors' elaboration

main criticalities of the research domain, provide useful insights to inform both practice and research and infer implications for managers, policymakers and scholars by outlining three main areas of intervention.

This study has limitations, including the use of only one database to retrieve the data set and the selection of only journal papers and review articles, excluding other document types such as books, conference proceedings and grey literature. Additionally, we focused on citational impact without considering any social impact index, so assessing biodiversity accounting from other unexplored perspectives, such as social media or policy documents, could be interesting.

Note

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