

An algorithmic historiography of biodiversity accounting literature

Biodiversity
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literature

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Abstract

Purpose – The study aims to shed light on the historical and contemporary trends of biodiversity accounting literature, while simultaneously offering insights into the future of research in this sector. The paper also aims to raise awareness among accounting researchers about their role in preserving biodiversity and informing improvements in policy and practice in this area.

Design/methodology/approach – The Bibliometrix R-package is used to carry out an algorithmic historiography. The reference publication year spectroscopy (RPYS) methodology is implemented. It is a unique approach to bibliometric analysis that allows researchers to identify and examine historical patterns in scientific literature.

Findings – The work provides a distinct and comprehensive discussion of the four distinct periods demarcating the progression of scientific discourse regarding biodiversity accounting. These periods are identified as Origins (1767–1864), Awareness (1865–1961), Consolidation (1962–1995) and Acceleration (1996–2021). The study offers an insightful analysis of the main thematic advancements, interpretative paradigm shifts and theoretical developments that occurred during these periods.

Research limitations/implications – The paper offers a significant contribution to the existing academic debate on the prospects for accounting scholars to concentrate their research efforts on biodiversity and thereby promote advancements in policy and practice in this sector.

Originality/value – The article represents the first example of using an algorithmic historiography approach to examine the corpus of literature dealing with biodiversity accounting. The value of this study comes from the fusion of historical methodology and perspective. To the best of the authors' knowledge, this is also the first scientific investigation applying RPYS in the accounting sector.

Keywords Biodiversity accounting, Algorithmic historiography, Bibliometrics, Reference publication year spectroscopy (RPYS)

Paper type Literature review

1. Introduction

The fate of the world relies on biodiversity as humankind's survival is heavily dependent on natural resources (Khan, 2021; Cuckston, 2021), whose extreme exploitation (Corvino *et al.*, 2021) provoked the most severe man-made species extinction (Jones and Solomon, 2013) and unsafe environmental degradation (Polasky *et al.*, 2015). The depletion of natural resources, which poses one of the greatest threats to living beings (Mahyuddin *et al.*, 2022; Adler *et al.*, 2021), is widely recognised as a serious issue in both academic and policy literature (Ferreira, 2017; Zhong *et al.*, 2016), leading to the promotion of special issues of journals (Appendix 1),



organisation of events (Table A2) and conferences (Table A3), establishment of *ad hoc* organisms (Table A4) and implementation of socio-political tools (Table A5).

From an accounting perspective, the development of social and environmental practices to safeguard nature has been being a matter of concern for many years (Raar *et al.*, 2020; O'Dwyer and Unerman, 2020). Nowadays, corporate social and environmental responsibility are dominant in many organisations' reporting strategies, with a particular emphasis on biodiversity (Sun and Lange, 2023; Roberts *et al.*, 2020). The contemporary study of biodiversity accounting began with the article by Jones (1996), "Accounting for biodiversity: a pilot study", which underlined the need to collect, classify, physically aggregate, evaluate in both monetary and non-monetary terms, publish and make visible data on wildlife to assess organisations' environmental performances (p. 288). Given the increasing frequency and severity of natural hazards, effective accounting and management of biodiversity are crucial (Dallimer *et al.*, 2020) to safeguard the variety of life on earth, including individuals and other living species, communities and societies, economies and ecosystems (Barbier, 2019; Earthwatch Institute, 2002).

This paper aims to raise awareness among accounting researchers about their role in preserving biodiversity (Carnegie and Napier, 2019), as their contribution has been underestimated thus far (Jones and Solomon, 2013). Additionally, given that the World Economic Forum has been declaring the loss of biodiversity as one of the top five global risks to society since 2015 (Hassan *et al.*, 2022; Mahyuddin *et al.*, 2022), this issue is socially relevant. Moreover, the ineffectiveness of the socio-political tools internationally implemented has been widely discussed, with several scholars highlighting the need for more concrete solutions to address the decline in nature (Anthony and Morrison-Saunders, 2023; Boiral, 2016; Gray and Milne, 2018; Smith *et al.*, 2019). Finally, the ongoing global condition, with the Covid-19 pandemic being linked to humanity's invasion of biodiversity and habitat destruction (Ceballos *et al.*, 2020), makes the need for an effective accounting and management of biodiversity even more pressing.

To address these issues, the paper reviews the biodiversity accounting literature through a theoretically informed analysis of primary studies (Rinaldi *et al.*, 2018; Massaro *et al.*, 2015, 2016; Petticrew and Roberts, 2008; Gray *et al.*, 1995), with a focus on answering two research questions (RQs): RQ1 "When did biodiversity accounting literature first appear and how has it evolved to date?" and RQ2 "What could the future path of biodiversity accounting research be?". To answer the research questions, the Reference Publication Year Spectroscopy (RPYS) methodology was used. Through the analysis of citation frequency, RPYS allows researchers to map the intellectual history of a given scientific field, identifying any key contributions and revolutionary discoveries (Carnegie and Napier, 2017; McBride and Verma, 2021).

Our study reveals that the history of biodiversity accounting literature can be traced back to the work of Barrington (1767). It also provides a distinct and comprehensive explication of the four distinct historical periods demarcating the progression of scientific discourse relating to biodiversity accounting. These periods are identified as Origins (1767–1864), Awareness (1865–1961), Consolidation (1962–1995) and Acceleration (1996–2021). This algorithmic historiography offers an insightful analysis of the main thematic advancements, interpretative paradigm shifts and theoretical developments of the biodiversity accounting literature that occurred over these periods. The findings provide a significant contribution to the current academic discourse on the prospects for accounting scholars to concentrate their research efforts on biodiversity and thereby promote advancements in policy and practice in this sector.

The remainder of the paper is structured as follows. Section 2 illustrates the research design and describes the method, data search and analysis. Section 3 shows and debates the findings. Section 4 concludes the paper.

2. Methods

2.1 Algorithmic historiography

We carried out an algorithmic historiography to understand the evolution of biodiversity accounting literature, identify temporal trends and patterns, as well as trace the chronological network of citations in this area (Garfield *et al.*, 2003; Garfield, 1979, 2004; Shibata *et al.*, 2008; Liu *et al.*, 2016; Batistič and Van der Laken, 2019). Algorithmic historiography provides a visual analysis of literature patterns and trends over time (Porch *et al.*, 2015; Budler *et al.*, 2021; Atkins and McBride, 2021; Napier, 2020; Carnegie and Napier, 2017; Parker, 2015), allowing to investigate the development of a research field by chronologically ordering the most important scientific contributions and examining the historical network of citations inside those publications. By focussing on a set of the most cited publications, this method offers more insightful hints than a reconstruction carried out manually (Ramos-Rodríguez and Ruiz-Navarro, 2004; Lucio-Arias and Leydesdorff, 2008; Kranakis and Leydesdorff, 1989).

2.2 Data collection

We followed the PRISMA protocol to search, synthesise and evaluate current research (Moher *et al.*, 2009; Tranfield *et al.*, 2003). The search database used was Web of Science (WoS), which provides comprehensive coverage of literature across diverse scientific areas, with over 20.000 sources and a vast number of citations (Aria *et al.*, 2020). Even if there is an ongoing debate (Harzing and Alakangas, 2016; Vieira and Gomes, 2009; Bar-Ilan *et al.*, 2007) on the adequacy of WoS compared to its main alternative, i.e. Scopus, WoS is considered to be superior in terms of source classification accuracy and information quality (Aria *et al.*, 2020; Kulkarni *et al.*, 2009). The dataset including the scientific contributions was extracted from WoS on May 10, 2022.

We informed our search protocol to intercept all those scientific contributions that, in the broad field of environmental sustainability, focused on accounting for biodiversity. Our line of reasoning started from considering the term biodiversity as involving both ecological and social systems, i.e., “the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it” (Gaston and Williams, 1996). “We understood the concept of biodiversity as referring to the whole range of activities traditionally connected with studying, inventorying and accounting living resources” (Lévêque and Mounolou, 2004). We supposed that this conception indirectly underlines the link to accounting when dealing with biodiversity. We agreed with considering accounting for biodiversity as gathering, categorising, combining, assessing, reporting, disclosing and making wildlife data accessible to evaluate the environmental organisations’ performance (Jones, 1996). The search query was structured by enclosing expressions with a similar meaning to biodiversity accounting. In detail, the “extinction accounting” concept was included as an extension of accounting for biodiversity (Atkins and Maroun, 2020, p. 1840). The concepts of “natural asset” and “natural capital” were also included, respectively as a conceptual frame whose biodiversity represents a sub-category and as a level of biodiversity (Jones, 1996). The search string was enriched with the notion of “natural resource” as a key element of environmental disclosure (Cuckston, 2018, p. 3) and reporting (Raar *et al.*, 2020; Weir, 2018). Thus, the words “disclosure” and “report” were also used in the query. Another term included was “accountability” as recent studies (Venturelli *et al.*, 2023; Adler *et al.*, 2021; Roberts *et al.*, 2021b) jointly deal with the concepts of biodiversity accounting and accountability. The complete search query launched on the database is detailed below:

(biodiversity OR extinction OR “natural asset” OR “natural capital” OR “natural resource”) AND (accounting OR disclosure OR report OR accountability).

Our query initially returned a total of 45,669 scientific contributions. Subsequently, various inclusion and exclusion criteria were applied to the results (Tommasetti *et al.*, 2020). We included only journal articles and reviews (Polese *et al.*, 2017) indexed in the subject categories “Business,” “Business Finance,” “Management,” and “Economics” (Lardo *et al.*, 2022). To allow for the replicability of the analysis to an international audience, only papers written in English were selected (Polese *et al.*, 2017). We considered only items published after 2000, given the substantial increase in publication trends on biodiversity accounting since then (Lardo *et al.*, 2022), and before 2022, as the year was still ongoing at the time of drafting this paper. We finally screened abstracts and full-texts (Adams and Larrinaga, 2019; Manetti *et al.*, 2021), excluding publications with limited focus on biodiversity, marginal contribution to scientific knowledge, or inadequate practical implications (Palumbo *et al.*, 2021). The final dataset included 517 scientific papers (Figure 1).

2.3 Data analysis

The data was analysed by using the Bibliometrix R-package, which provides a comprehensive set of tools for bibliometric research and algorithmic historiographies. It is based on the open-source R language, which provides robust statistical algorithms, high-quality numerical routines and integrated data visualisation tools (Aria and Cuccurullo, 2017). The algorithmic historiography was performed by using the Bibliometrix web-app, “Biblioshiny”, which has an intuitive and well-organised interface that includes a diverse range of bibliometric analyses also accessible to users without coding skills (Agbo *et al.*, 2021; Secundo *et al.*, 2020). We applied RPYS, an algorithmic historiography technique visualised through a system of Cartesian axes, where the abscissa axis represents time, while the ordinate one indicates the cited references of the selected publications. RPYS is a powerful quantitative technique for identifying key contributions and revolutionary discoveries in a field (Leydesdorff *et al.*, 2014). It uses algorithms to trace the intellectual history of scientific fields by analysing the frequency with which references are cited in publications over time (Marx *et al.*, 2017). The evolution of this frequency can be represented by swaying curves, and data spectrograms can be created to calculate the deviation per year of the number of cited references from the five-year period median (Wray and Bornmann, 2015). RPYS is used in various scientific sectors, but no prior study has used it in the accounting sector.

3. Results and discussion

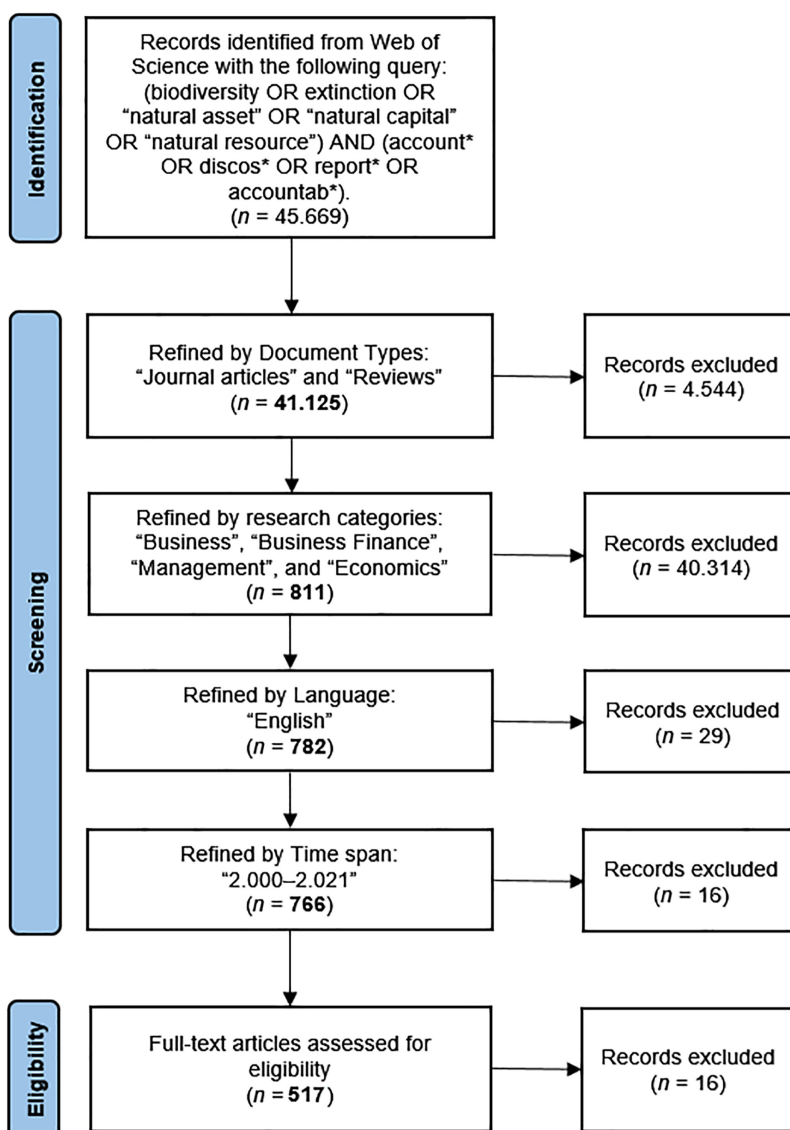
3.1 Overview

A sample of 517 scientific contributions on biodiversity accounting, published from 2000 to 2021, was collected from 140 journals. 503 were published as journal papers while 14 as review articles. 1,297 scholars are involved in these publications, with 105 of them having worked as a single author at least once. Table 1 provides an overview of the main dataset features.

The collected scientific production indicates a remarkable increase in the number of articles on biodiversity accounting over time. The trend is presented in Figure 2, which shows a growing number of publications on the topic with peaks in the years 2006–2007, 2011, 2013–2014 and 2018–2019.

The first peak in 2006–2007 is a result of the declaration of the future establishment of the International Year of Biodiversity during the 61st session of the 2006 United Nations General Assembly.

The peak in 2011 comes from the emphasis placed on biodiversity in the previous year, when the International Year of Biodiversity was established. In addition, 2011 marked the start of the Decade of Biodiversity proclaimed by the United Nations General Assembly.



Source(s): Authors' elaboration. <http://www.prisma-statement.org/>

Figure 1.
PRISMA diagram

The peak in 2013–2014 is a consequence of a special issue entitled “Accounting for biodiversity” that the Accounting, Auditing and Accountability Journal (AAAJ) promoted in 2013 [1]. This special issue attracted seven submissions with a wide array of methodological approaches, including content analysis, case studies and discussions of financial approaches to biodiversity. Three papers (Cuckston, 2013; Siddiqui, 2013; Freeman and Groom, 2013) focused on forest biodiversity. Two papers (Van Liempd and Busch, 2013; Rimmel and Jonäll,

AAAJ
36,6

1670

Description	Results
<i>Main information about data</i>	
Timespan	2000:2021
Sources	140
Documents	517
Average years from publication	9.14
Average citations per documents	31.16
Average citations per year per doc	2.77
References	24,494
<i>Document types</i>	
Article	503
Review	14
<i>Document contents</i>	
Keywords Plus (ID)	1,228
Author's Keywords (DE)	1,732
<i>Authors</i>	
Authors	1,297
Authors of single-authored documents	105
<i>Authors collaboration</i>	
Single-authored documents	117
Co-Authors per Documents	2,83

Table 1.
Dataset information

Source(s): Authors' elaboration

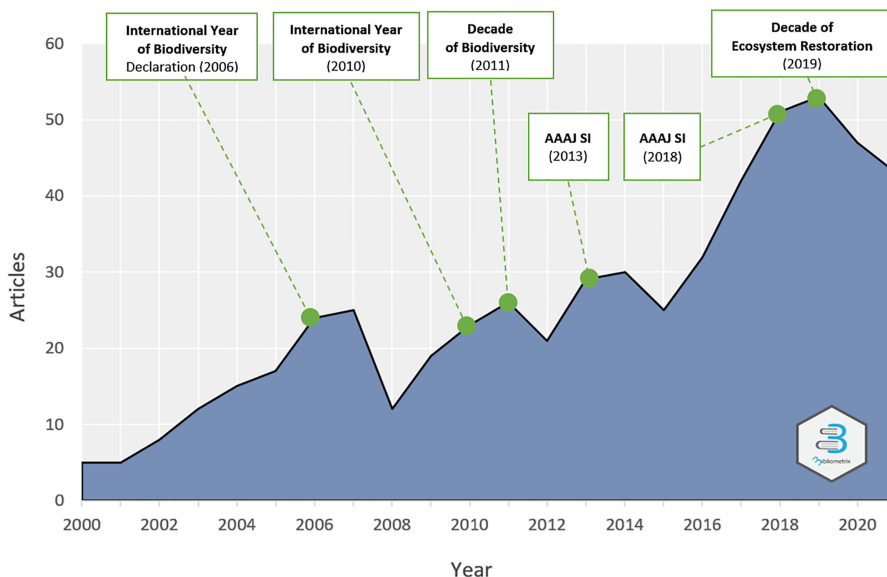


Figure 2.
Annual scientific
production

Source(s): Authors' elaboration

2013) provided complementary views based on the content analysis of biodiversity reporting and disclosures in Scandinavia, while another article (Tregidga, 2013) analysed the biodiversity reports of a New Zealand company.

The fourth peak in 2018–2019 represents a surge in publications on biodiversity accounting, due to both the special issue “Extinction accounting and accountability” that the AAAJ promoted in 2018 and the 2021–2030 Decade on Ecosystem Restoration that the 74th General Assembly of the United Nations proclaimed during its session on 1 March 2019 [2]. In the nine articles including the 2018 AAAJ’s special issue, a variety of methodologies was employed, including mixed methods, literature review and single and multiple case study analyses. Notably, only four of these articles were focused on biodiversity-related subjects. Of these, three articles (Gray and Milne, 2018; Cuckston, 2018; Weir, 2018) dealt with species extinction, whilst a fourth work (Adler *et al.*, 2018) addressed the issue of threatened species. The remaining articles dealt with subjects unrelated to biodiversity.

3.2 Historiography of biodiversity accounting

The history of biodiversity accounting may be explored starting from the late 18th century, when the topic was first organically discussed. Four distinct periods can be identified: Origins (1767–1864); Awareness (1865–1961); Consolidation (1962–1995); and Acceleration (1996–2021). Figure 3 shows the results of the RPYS summarising this historical evolution.

3.2.1 Origins: 1767–1864. Biodiversity accounting arose in the second half of the 18th century, when the emergence of Physiocracy drew attention to biodiversity-related issues (Quesnay, 1768). Physiocrats placed agriculture at the centre of economic activity as a means of producing basic goods, in contrast to the product processing and exchange by industry and trade (Cleveland, 1999). There were also the first to use the expression *laissez-faire*, which became the cardinal principle of Liberalism (Smith, 1795). During this period, characterised by the industrial revolution and its associated pollution, as well as by the consequences of the Napoleonic wars, Ricardo (1821) developed the “Theory of comparative advantages”, whilst Malthus (1836) identified the scarcity of resources as a limit to economic development. Darwin’s (1859) “Theory of the Evolution of Species” was published in the mid-19th century. The rise of Transcendentalism gradually changed the view of relationships between humans, nature and society, fostering the adoption of a less anthropocentric perspective. Thoreau (1854), who anticipated the methods and findings of ecology and environmentalism, emphasised the influence of wilderness on human affairs.

The main thematic areas of the first hundred years of biodiversity accounting literature include: “nature diaries”; “natural resource depletion”; and “land use”.

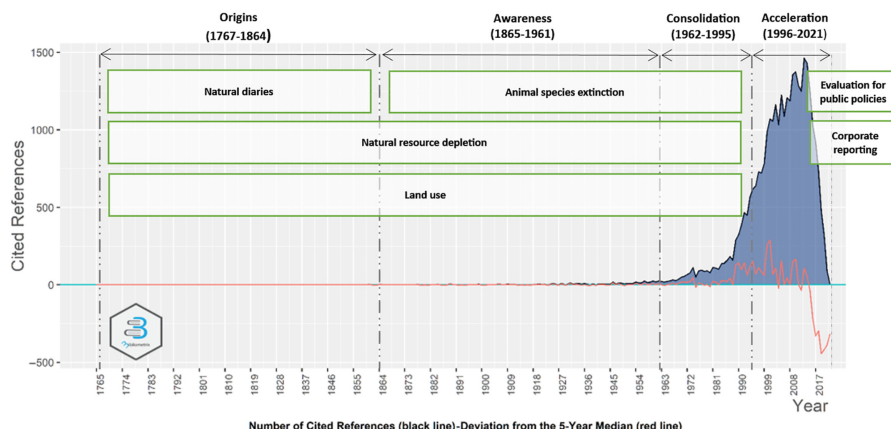


Figure 3.
RPYS 1767–1864

Source(s): Authors’ elaboration

3.2.1.1 Nature diaries. The earliest form of biodiversity accounting consisted of writing nature diaries, which were used to collect, record and catalogue data on nature and living species (Atkins and Maroun, 2020). The first author to draft a natural diary was Barrington (1767), who wrote “The Naturalist’s Journal”, an account of perches in a pool of Merionethshire and trout in a river of Cardiganshire. Later, White (1774) drew up the “Naturalist’s Journals”, a natural diary on flora and fauna, judged a milestone of contemporary biodiversity reporting (Atkins and Maroun, 2020). In the early 1800s, given the high demand for wood from shipbuilders, Israel Adolf Ström commissioned the first forest management plan (Slottsarkivet, 1807) to draft an oak population report within the Stockholm National Urban Park in Sweden. Some years later, Ström (1822) also drafted a textbook entitled “Förslag till en Förbättrad Skogshushållning I Sverige” – i.e., “Proposal for an Improved Forest Management in Sweden” –, which remained the only Swedish book on the topic for over 100 years “Nature Notes for 1906”, published posthumously under the title “The Country Diary of an Edwardian Lady”, was the first example of accounting for biodiversity in a sense adhering to the contemporary meaning (Atkins and Maroun, 2020).

3.2.1.2 Natural resource depletion. At the end of the 18th century, the interest in biodiversity progressively moved to the theme of natural resource depletion. Malthus (1798) developed the so-called “Malthusian trap”, acknowledging the population increase as a cause of natural resource exhaustion, economic decline, poverty, starvation and wars (Good and Reuveny, 2006). Say (1814) enriched the debate on biodiversity by focussing on the relationship between natural resources, population growth and economic activities. Ricardo (1817) also dealt with the risks associated with natural resource depletion in his essay “On the Principles of Political Economy and Taxation”, predicting that the uncontrolled increase in the number of people would have led to the scarcity of natural resources and the cessation of economic growth (Jayasuriya, 2015). In his book “Man and Nature”, Marsh (1864) highlighted the danger of Earth’s destruction due to an over-exploitation of global natural resources.

3.2.1.3 Land use. From the mid-1820s, land use became a key theme in the still rudimentary debate on biodiversity accounting. von Thünen (1826) laid the foundation of Land Use Theory in “The Isolated State”, the first treatment of spatial economics, economic geography and natural wage (Fujita and Krugman, 1995). Auguste Walras (1833, 1837) introduced the notion of natural capital understood as the result of two main productive forces, e.g., land use and labour (Missemer, 2018). Walras believed in natural capital nationalisation, considering the private ownership of land as the main cause of poverty. Consistently, Jones (1849), a British socialist publicist, emphasised the significance of natural capital for collective well-being and advocated for the sharing of land use and ownership. Walras’s son, Leon, promulgated land nationalisation to increase productivity, advocating that the rents would have been sufficient to support the national economy, without the need for other taxes (Walras, 1860).

3.2.2 Awareness: 1865–1961. The second half of the 19th century marked a turning point in the relationship between humans and nature, as a tumultuous economic and urban growth began to encroach upon large natural spaces. Numerous environmental associations were founded to safeguard biodiversity, such as Sierra Club in 1892 and Wildlife Conservation Society in 1897 in the United States or Commons Preservation Society in 1865, Royal Society for the Protection of Birds in 1889, National Trust in 1895 and Naturschutzbund Deutschland in 1899 in Europe (Bevilacqua, 2014). The impulse of Urban social ecology by the Chicago School in the early 20th century led ecological and sociological research toward analysing the relationship between humans and the natural world. UNESCO also played a decisive role in promoting nature conservation by establishing the International Union for the Conservation of Nature in 1945 and introducing the Man and the Biosphere program in 1968 (Di Valentina, 2011). In the mid-20th century, important environmental organisations, such as The Nature Conservancy in 1951 and the World Wide Fund for Nature (WWF) in 1961, were established.

In this second period, “natural resource depletion” and “land use” continued to raise concerns, while “animal species extinction” emerged as a new threat to biodiversity.

3.2.2.1 Natural resource depletion. The depletion of natural resources kept representing a topic of concern in the early 19th century. In “My First Summer in The Sienna”, [Muir \(1911\)](#) emphasised the need to preserve an untouched wilderness for purposes greater than human use. In his work “The Economics of Exhaustible Resources”, [Hotelling \(1931\)](#) underlined the need to introduce stringent regulation on the exploitation of natural resources to avoid irreparable planet devastation, invigorate national wealth ([Bollfras, 1878](#); [Pigou, 1952](#); [Ramsey, 1928](#); [Lindahl, 1933](#)) and safeguard natural capital ([Fisher, 1896, 1906](#)). [Keynes \(1936\)](#) considered the destruction of natural resources as one of the worst crimes of capitalism, whilst [Sagui \(1946\)](#) deemed mineral resource depletion as an adverse consequence of capitalist development. [Whitaker \(1941\)](#) saw natural resource protection as a challenge to any forward-looking community, region, or nation.

3.2.2.2 Land use. With the end of the first colonial era, some existing rights for land use were questioned, whilst, through an evolution of national legal systems, several colonial governments recognised new rights to land users ([Colson, 1870](#)). Greater emphasis was placed on improving agricultural productivity, which was expressed as a result of land allocation, reversibility of land uses in response to market conditions, shift to more land-intensive crops and influence of private ownership on land stewardship ([Gordon and Richardson, 1880](#)). Growing pressure was put on converting more market-accessible lands to urban development ([von Thünen, 1875](#); [Hansen, 1959](#)), e.g. for recreation, which became one of the main forms of land use over considerable areas ([McMurry, 1930](#)). Land use began to be more rigorously mapped to illustrate economic conditions and the ways in which populations earn a living ([Sauer, 1919](#)). This emphasised the role of geographers for land-use urban and socio-economic planning ([McMurry, 1936](#); [Applebaum, 1952](#); [Haar, 1959](#)).

3.2.2.3 Animal species extinction. Focussing on the decline of bison in [Allen \(1876\)](#) was the first to deal with the extinction of animal species, followed by [Dodge \(1877\)](#), who wrote about the decline of buffalo populations during the conquest of the West. [Hornaday \(1889\)](#) also warned of the risk of bison extinction in his work “The Extermination of American Bisons”, which was considered the first account of species extinction. Despite the recognition of the negative effects of buffalo extinction, the problem kept persisting, as [Day \(1960\)](#) highlighted in “The Great Buffalo Hunt”. [Lotka \(1920\)](#) theorised about the continuous oscillation of animal species populations, contributing to the development of ecology as a science ([Kingsland, 2015](#)). [Gordon \(1954\)](#), [Schaefer \(1957\)](#), [Beverson and Holt \(1957\)](#) addressed the issue of human-caused depletion of water species in their works on fisheries management.

3.2.3 Consolidation: 1962–1995. The years ranging from 1962 to 1995 consolidated the recognition of the damage of human activities on biodiversity, such as the marine pollution caused by the sinking of the oil tankers Amoco Cadiz in 1978 and Exxon Valdez in 1988, the accidents at the nuclear power plants Three Mile Island in 1979 and Chernobyl in 1986, the first scientific evidence of damage to the ozone layer caused by air pollutants and the spread of the “mad cow disease” between 1986 and 1992 that called into question the methods of intensive breeding and agriculture. Legitimacy theory was established as a means for organisations to justify their right to exploit natural resources ([Parsons, 1960](#); [Maurer, 1971](#); [Dowling and Pfeffer, 1975](#)). Several environmental parties were founded, and many countries strengthened their environmental laws. In 1972, the first global environmental summit “United Nations Conference on the Human Environment” was held in Stockholm, while in 1976, the Greenpeace Foundation was established. In the 1980s, Deep ecology, which attributed an intrinsic value to all living beings and advocated for a harmonious relationship between humans and nature, and challenged the traditional anthropocentric view of humans as superior to nature ([Naess, 1984](#)). Simultaneously, Stakeholder theory emerged as a means for organizations to consider the public welfare in addition to their goal of profit

maximisation. In the Western world, neo-liberal ideology inspired market-based environmental policy reforms. The European Environmental Agency was founded (1983), the Intergovernmental Panel on Climate Change published its first report (1990), Sweden introduced the first carbon tax in history (1991) and the first international convention on biodiversity (i.e., the “United Nations Conference on Environment and Development”) took place in Rio de Janeiro in 1992. Since the 1990s, organizations began to increasingly use Impression management tactics to show their commitment to the natural environment, inflate their environmental performances, neutralise unethical behaviour and raise environmental legitimacy among stakeholders (Elsbach and Sutton, 1992; Elsbach, 1994; Suchman, 1995).

“Natural resource depletion” continued to be the most debated topic in this period, with scholars focussing on “land use” and “animal species extinction”.

3.2.3.1 Natural resource depletion. The exploitation of natural resources remained a major concern as commodity prices stopped declining after the end of the Second World War (Krutilla, 1967; Naya, 1967; Slade, 1982). In the report “The Limits to Growth”, Meadows *et al.* (1972) expressed the importance to foster an economically and ecologically sustainable condition, while Solow (1974) advocated the need to implement public policies for natural resource management. Cropper (1976) highlighted the risk of catastrophic events from sudden resource depletion, which Ehrlich (1981) considered an existential threat to human civilisation. These concerns led the United Nations World Commission on Environment and Development to draft a document in 1987 for a global strategy to manage natural resources, also considering the population growth projections (Bilsborrow and DeLargi, 1990). Hart (1995) proposed a natural resource-based approach that combined pollution prevention, product stewardship and sustainable development (Markandya and Pearce, 1988). Gray (1992) claimed the adoption of an anthropocentric approach for the sustainable development of society, shifting from Deep ecology to Deep green.

3.2.3.2 Land use. In her [1] book “Silent Spring”, which is considered a milestone in the modern environmental movement, Carson (1962) described the negative environmental consequences of the massive use of pesticides in agriculture, which were deemed capable of doing significant damage to wildlife, especially to birds and fishes (Borlaug, 1972). Lowrance *et al.* (1986) underlined the importance to develop forms of agricultural sustainability to cope with increased demands for food due to continuous population growth. Lockeretz (1988) argued that this goal could be achieved only by employing sustainable agriculture techniques with great intellectual rigour. In the early 1990s, the land was widely considered essential to quality of life, human existence and society’s well-being (Reganold *et al.*, 1990).

3.2.3.3 Animal species extinction. The mistreatment and mass extermination of animals drew society’s attention in the mid-1970s. Singer (1975), the initiator of the “Animal protection movement”, argued for a radical change in human behaviour to avert the risk of the extinction of many species, such as the adoption of vegan diets and the abolition of vivisection. Brown (1984) proposed a model to measure the number of endangered species that were deemed valuable for moral, ecological and aesthetic purposes. Animal preservation was also a central theme in the early 1990s due to the evidence that the number of species had halved in the previous fifty years (Hart, 1995).

3.2.4 *Acceleration: 1996–2021.* The period 1996–2021 saw an acceleration of the scientific debate on biodiversity accounting (Jones and Matthews, 2000), mainly due to Jones’ contribution (1996), who stressed the importance to gather, classify, physically assemble, assess in both monetary and non-monetary terms, report and disclose wildlife data to allow for the evaluation of organizations’ environmental performances (p. 288). The widespread desire to protect biodiversity and the environment was reflected in national and international legislation and agreements, cultural initiatives, philosophical reflections and public campaigns. Biodiversity accounting continued to be explored through the lens of ontological view-based theories (Roberts *et al.*, 2021a; Chen and Roberts, 2010; Gray, 2010).

The conceptual underpinning mostly employed kept pivoting on Legitimacy theory (Bhattacharyya and Yang, 2019; Adler *et al.*, 2017, 2018; Cho *et al.*, 2015; Rimmel and Jonäll, 2013; Cho and Patten, 2007; Patten, 2002), Stakeholder theory (Gaia and Jones, 2017, 2019; Boiral and Heras-Saizarbitoria, 2017), Deep ecology (Maroun and Atkins, 2018; Christian, 2018; Samkin *et al.*, 2014; Jones and Solomon, 2013) and Impression management (Zhao and Atkins, 2021; Hassan *et al.*, 2020; Boiral, 2016; Solomon *et al.*, 2013; Atkins *et al.*, 2018). Within the broader scope of Impression management literature, Greenwashing emerged as a relatively new theoretical framework (Hassan and Guo, 2017) [3] to explain the unscrupulous corporate selective disclosure of positive actions resulting in misleading and biased reporting (Mahoney *et al.*, 2013; Lyon and Maxwell, 2011) to promote the perception of environmentally friendly strategies when arguably they were not (Lewis, 2016), influence stakeholders' perceptions and gain legitimacy (Hassan *et al.*, 2020). Institutional theory-based frameworks were also used to highlight the economic-ecological conflict in applications of biodiversity accounting (Haque and Jones, 2020; Gaia and Jones, 2019; Weir, 2019; Jones and Solomon, 2013).

Two main thematic areas of interest stood out: biodiversity evaluation for public policies and corporate biodiversity reporting.

3.2.4.1 Biodiversity evaluation for public policies. The evaluation of biodiversity for public policies gained prominence at the end of the 20th century as a means of informing political decisions for ecosystem conservation (Costanza *et al.*, 1997). The concept was initially framed to consider the economic value of biodiversity assets (Freeman and Groom, 2013; Erwin *et al.*, 2010), although there was some disagreement about the need for it (Wale and Yalaw, 2010) as environmental problems rooted in the very essence of society (Gray and Milne, 2018). With the increasing concern about the decline of biodiversity in the new millennium, growing emphasis was paid to identifying specific areas for policy intervention (Weir, 2018; Hossain, 2017; Rodríguez and Young, 2000) and adopting evidence-based evaluations of the state of the environment (Kingsford *et al.*, 2009). The biodiversity evaluation of natural asset inventories (Jones and Matthews, 2000) was seen as a way to respond to stakeholders' demands for greater transparency in the assessment of the impacts of environmental disasters and to improve governments' negotiating capacity in environmental issues (Brandon *et al.*, 2021; Weiskopf *et al.*, 2020; Siddiqui, 2013; Green *et al.*, 2005). Two approaches for biodiversity evaluation (Nunes and Van den Bergh, 2001; Bräuer, 2003) were developed: monetary, based on economic indicators and biological, based on species and ecosystem richness indices. A comprehensive suite of factors was introduced for assessing the value of biodiversity (Albertazzi *et al.*, 2021; Driscoll *et al.*, 2018), including biotic and abiotic indices such as species richness or rarity and ecological context or condition (Regan *et al.*, 2007).

3.2.4.2 Corporate biodiversity reporting. Corporate biodiversity reporting emerged in the late 1990s as a response to the growing concerns about environmental degradation (Jones, 1996) and the need for companies to provide structured and easily accessible information about their impact on biodiversity (Aggarwal and Singh, 2019; Skouloudis *et al.*, 2019; Harrison *et al.*, 1997). Analysts, asset management organizations, institutional investors (Cuckston, 2013) and other market-oriented institutions began to consider biodiversity disclosures and activities when ranking companies (Haque and Jones, 2020). Global institutions and governments increased their efforts to influence corporate initiatives and their effects on biodiversity (Mahyuddin *et al.*, 2022; Cubilla-Montilla *et al.*, 2020; Raar *et al.*, 2019; Maroun *et al.*, 2018; Haffar and Searcy, 2018; Boiral and Heras-Saizarbitoria, 2017), also promoting innovative reporting methods (Erin and Bamigboye, 2021; Mace, 2019). This involved incorporating environmental-related risks into formal risk management systems (Atkins and Maroun, 2018), addressing the concerns of multiple stakeholders (Corvino *et al.*, 2021) and enhancing their financial performances (Lambooy *et al.*, 2018) and long-term sustainability (Usher and Maroun, 2018). To meet these challenges (Tregidga, 2013; Beckwith

and Moore, 2001), several guidelines for corporate biodiversity reporting were proposed (Cuckston, 2018; Jones and Solomon, 2013), including a checklist for systematic biodiversity assessment (Atkinson *et al.*, 2000) and a framework for recording, valuing and reporting biodiversity (Jones, 2003) or removing arbitrary and ad hoc information about ecological integrity and its threats (Lee *et al.*, 2005). However, despite these efforts, many companies failed in this regard (Hassan *et al.*, 2020; Gaia and Jones, 2019; Boiral, 2016; van Liempd and Busch, 2013) as their biodiversity reports mainly focused on financial value creation (Hassan *et al.*, 2021; Maroun and Atkins, 2018), were compiled for only reputational reasons (Van Liempd and Busch, 2013) and included limited and generic information (Ette and Geburek, 2021; Amato *et al.*, 2019; Rimmel and Jonäll, 2013). This lack also regarded the largest and most successful companies (Murillo-Avalos *et al.*, 2021; Reimsbach *et al.*, 2020; Atkins *et al.*, 2018; Adler *et al.*, 2017, 2018).

4. Conclusions

This study carries out an algorithmic historiography to analyse biodiversity accounting literature. It combines historical method and perspective to produce accurate interpretations of the scientific research in the biodiversity accounting area, whilst also informing improvements in policy and practice (Rinaldi *et al.*, 2018; Parker, 2015). By using the cited references as sources, the historical method allows scholars to rigorously analyse published works within the historical context and allows for a comprehensive understanding of the literature. This paper also shows the profitable applications of RPYS in determining the historical origins and intellectual roots of a research field (Marx *et al.*, 2017), making quantifiable statements on the significance of earlier pioneering, prominent and seminal works (Ballandonne, 2019) that are often unknown or forgotten (Marx and Bornmann, 2016). The historical perspective helps to understand how context influences the thematic choices of publications, whilst also allowing for the comprehension of how scientific outputs impacts on society and vice versa.

Our analysis reveals that biodiversity accounting literature first appeared when Barrington (1767) wrote “The Naturalist’s Journal”. This is an element of novelty in literature since the founding of biodiversity accounting is conventionally traced back to 1774 and ascribed to White (Atkins and Maroun, 2020). The analysis also suggests a growing trend in the number of publications on biodiversity accounting over time, with a significant increase since the 21st century due to crucial events. We identify four historical periods in the evolution of the biodiversity accounting literature, each with unique characteristics but also some similarities in terms of thematic topics, theoretical frameworks and paradigms.

We noted the recurrence of some themes: except for nature diaries, which were exclusive to the early period, until 1995, the literature shows high continuity, with studies focussing on natural resource depletion, animal species extinction and land use. Natural resource depletion was considered as a consequence of population growth in the first period (Malthus, 1798; Say, 1814; Ricardo, 1817), capitalist development in the second phase (Fisher, 1896, 1906; Keynes, 1936; Sagui, 1946) and human actions in the third time span, including the Second World War and industrialisation pollution (Krutilla, 1967; Naya, 1967; Slade, 1982). The theme of animal species extinction began in the 19th century and gained more attention in the mid-20th century due to the decline of numerous species. The second period saw a focus on the extinction of bison (Allen, 1876; Hornaday, 1889) and buffaloes (Dodge, 1877; Day, 1960) and depletion of water species (Gordon, 1954; Schaefer, 1957; Beverton and Holt, 1957), while the analysis of the third period showed a growing concern for preserving animal species and their habitats through a radical change in human behaviour, such as the adoption of vegan diets and the abolition of vivisection (Singer, 1975). The scientific debate on land use began in the mid-1820s, with a focus on the notion of natural capital. During the second period, a great deal

of emphasis was placed on improving agricultural productivity (Gordon and Richardson, 1880), converting more market-accessible lands to urban development (von Thünen, 1875; Hansen, 1959) and mapping land use more rigorously (Sauer, 1919). The theme persisted in the mid-20th century due to the negative environmental consequences of companies' behaviour, such as the massive use of pesticides in agriculture (Borlaug, 1972). This stressed the importance to develop forms of agricultural sustainability (Lowrance *et al.*, 1986; Lockertetz, 1988).

As the theoretical underpinnings, we realised that the literature was originally mainly inspired by macro-economic and philosophical frameworks, including Physiocracy, Liberalism and Transcendentalism. During the second period, with the exception of Urban social ecology, the scientific research appeared stimulated mostly by historical happenings rather than theories. Key historical events characterised also the third period, such as the human-caused environmental catastrophes, foundation of several environmental organisations, strengthening of national environmental laws and organisation of the first global environmental summit. However, the mid-20th century also saw the raise and consolidation of some significant theories, including Legitimacy theory, Deep ecology, Stakeholder theory and Impression management. These theories dominated the biodiversity accounting literature also during the last phase, during which also Greenwashing was used as the theoretical underpinning of several biodiversity accounting studies.

This shift of the theoretical approaches also reflected a change in the interpretative paradigms, which moved from analysing society at a macro level in the first three periods, when studies investigated the human-nature relationship (Darwin, 1859; Muir, 1911; Naess, 1984), to policy-making and corporate reporting in the last phase (Freeman and Groom, 2013; Jones, 1996). Since the end of the last century, biodiversity evaluation emerged as a valuable tool for informing political decisions, whilst corporate biodiversity reporting gained significance in response to increasing worries about environmental degradation. This led governments, global institutions and analysts to consider biodiversity when evaluating companies, with several frameworks for corporate biodiversity reporting proposed (Cuckston, 2013). However, our findings suggest that many companies failed to provide accurate reports (Anthony and Morrison-Saunders, 2023), focussing primarily on financial value creation (Hassan *et al.*, 2021; Maroun and Atkins, 2018), providing limited and generic information in their reports (Ette and Geburek, 2021; Amato *et al.*, 2019; Rimmel and Jonäll, 2013), and viewing reporting as a mere reputational issue (Van Liempd and Busch, 2013) rather than a vital component of their operations. Additionally, the absence of clear guidelines, standardised paths and regulatory frameworks made it difficult for companies to incorporate biodiversity considerations into their business practices (Raar *et al.*, 2020; Weiskopf *et al.*, 2020; Aggarwal and Singh, 2019; Mace, 2019).

This algorithmic historiography can be useful for understanding how concerns around biodiversity accounting evolved over time, helping scholars, managers and policy-makers to preserve nature with sustainable solutions for future generations (Brandon *et al.*, 2021; O'Dwyer and Unerman, 2020; Mouysset *et al.*, 2011).

This paper can serve as a valuable tool for scholars to build a common understanding of the complex and evolving challenges related to biodiversity accounting, conservation and management, as well as to develop effective and sustainable conceptual frames for addressing these challenges. Tracing the evolution of the main themes on biodiversity helps contextualise current debates and practices, along with identify emerging trends and paths, including the development of key topics, theories and approaches. This can also allow researchers to identify gaps in the literature, potential areas for future research and best practices for addressing current and upcoming trails. Moreover, our historiography highlights the importance to foster the interdisciplinary collaboration among scholars of different fields, whilst also underlining the need and opportunity for integrated approaches to biodiversity accounting and management.

Our study also allows managers to identify key drivers and strategies to account for natural resources, minimising the impact of companies' behaviour on the environment and enhancing biodiversity corporate reporting. Being aware of the historical evolution of biodiversity issues, managers can avoid making mistakes such as reporting generic information for only reputational reasons (Ette and Geburek, 2021; Amato *et al.*, 2019; Rimmel and Jonäll, 2013; Van Liempd and Busch, 2013), proactively handle risks (Atkins and Maroun, 2018), seize new opportunities, outline more effective sustainability strategies and anticipate future trends. Furthermore, this historiography suggests that corporate financial value and performances (Hassan *et al.*, 2021; Lambooy *et al.*, 2018; Maroun and Atkins, 2018) depend on companies' commitment to sustainable business practices (Usher and Maroun, 2018).

Our analysis finally informs policy development, implementation and evaluation by providing a historical perspective on biodiversity issues and identifying areas of society's consensus and disagreement (Gray and Milne, 2018), understand the trade-offs in considering the economic value of biodiversity assets (Freeman and Groom, 2013; Erwin *et al.*, 2010), identify areas for policy intervention (Weir, 2018; Hossain, 2017; Rodríguez and Young, 2000) and develop more integrated and effective policy approaches to biodiversity evaluation of natural inventories (Jones and Matthews, 2000). This historiography also suggests the importance for governments to respond to stakeholders' demands for greater transparency in formulating and adopting biodiversity evaluation policies (Brandon *et al.*, 2021; Weiskopf *et al.*, 2020; Siddiqui, 2013; Green *et al.*, 2005).

This article represents the first example of using an algorithmic historiography approach to examine the corpus of literature pertaining to biodiversity accounting. However, it has some limitations, including the use of a single database to search for significant literature on biodiversity accounting and the consideration of only journal articles and reviews as the types of documents.

Notes

1. Following Oppi *et al.* (2021), the authors considered exclusively the special issues promoted by journals included in the newest Academic Journal Guide of the Chartered Association of Business Schools. These ratings, unlike other journal ratings, do not consider merely a weighted average of the metrics but are based on peer reviews, editorials and expert judgements. Other special issues on biodiversity accounting are listed in Appendix 1.
2. The authors did not consider the 2019 special issue titled "Business, Society, Biodiversity, and Natural Capital" of the journal *Business Strategy and the Environment* as, out of the 20 articles that comprised the issue, only one paper (Boiral *et al.*, 2019) focussed on biodiversity-related topics, whilst the remaining works addressed a range of different subjects.
3. The term was coined in 1986 by environmentalist Jay Westerveld to stigmatise the practice of hotel chains that used the environmental impact of laundry washing to invite guests to reduce their towel consumption, when in fact this invitation was mainly economically motivated (Balluchi *et al.*, 2020; Jauernig and Vladislav, 2019).

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Appendix 1

Biodiversity
accounting
literature

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Table A1.
Special issues
promoted by
international scientific
journals

Journal name	Special issue title	Year
<i>Accounting, Auditing & Accountability Journal</i>	Accounting for biodiversity	2013
<i>Ecosystem Services</i>	Biodiversity and Ecosystem Services Finance Solutions: Investing in Nature toward Sustainable Development	2017
<i>Accounting, Auditing & Accountability Journal</i>	Extinction Accounting & Accountability	2018
<i>Journal of Environmental Accounting and Management</i>	Natural capital, ecosystem services, and environmental accounting	2019
<i>Journal of Environmental Economics and Policy</i>	Natural Capital and Natural Capital Accounting	2019
<i>Business Strategy and the Environment</i>	Business, society, biodiversity, and natural capital	2019
<i>Ecosystem Services</i>	Accounting for Natural Capital: lessons learned from applications in Europe and the United States	2019
<i>Social and Environmental Accountability Journal</i>	Accounting and Conservation	2021
<i>Environmental and Resource Economics</i>	The Economics of Biodiversity: Building on the Dasgupta Review	2022
<i>Accounting, Auditing & Accountability Journal</i>	Exploring the Historical Roots of Environmental and Ecological Accounting, Auditing and Accountability	2022

Source(s): Authors' elaboration

Event name	Starting year
UN Conference on the Human Environment	1972
UN Conference on Environment and Development	1992
Earth Overshoot Day	1987
International Day for Biological Diversity	2000
UN General Assembly for Biodiversity Target	2006
Green Development Initiative	2010
International Year of Biodiversity	2010
Cross-sector biodiversity initiative	2013

Table A2.
International events

Source(s): Authors' elaboration

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Table A3.
International
conferences

Conference title	Promoter	Location	Year
The role of finance institutions in accounting for biodiversity and ecosystem services in the Asia Pacific region	United Nations Environment Programme Finance Initiative	Japan	2010
Natural Capital Accounting Conference	The World Bank	Turkey	2015
International Conference on Natural Resources Accounting and Finance	Institute of Finance Management	Tanzania	2015
Business and Biodiversity Forum	SDG Knowledge Hub	Mexico	2016
Natural Capital Accounting; Key for Sustainable Natural Resource Management	Institute of Green Growth Solutions and the Konrad Adenauer Stiftung	Ghana	2017
National conference on natural capital accounting	The World Bank with Philippines National Economic and Development Authority	Philippines	2017
ESMAN Conference on Biodiversity and Natural Capital Accounting	Accounting Resources Centre	Czech Republic	2019
Communicating the Path to Sustainability through Natural Capital Accounting	System of Environmental Economic Accounting	Connecticut	2020
Global Biodiversity Finance Conference	Organisation for Economic Co-operation and Development	Virtual	2020
Natural Capital Investment Conference	Environmental Finance	Virtual	2021
The Natural Capital Finance & Investment Conference	Ecosystems Knowledge Network	Virtual	2021
Natural Capital Accounting and Ecological Product Value Realization	Asian Development Bank	Virtual	2021
Biodiversity and Environmental Challenges for the Financial System	Center for Latin American Monetary Studies	Virtual	2021
National Ecosystem Accounting	Ecosystem Services Partnership	Virtual	2021
Natural Capital Investments Conference	ManagEnergy	Virtual	2021

Source(s): Authors' elaboration

Table A4.
International
organisms

Organisation name	Foundation year
World Organisation for Animal Health	1924
International Union for Conservation of Nature	1948
International Maritime Organization	1948
Nature Conservancy	1951
World Wide Fund for Nature	1961
United States Environmental Protection Agency	1970
International Petroleum Industry Environmental Conservation Association	1974
Greenpeace Foundation	1976
World Resources Institute	1982
Intergovernmental Panel on Climate Change	1988
European Environment Agency	1993
World Business Council for Sustainable Development	1995
Alberta Biodiversity Monitoring Institute	1998
United Nations Office for Disaster Risk Reduction	1999
World Conservation Monitoring Centre	2000
United Kingdom National Biodiversity Network	2000
International Council on Mining and Metals	2001
Global Footprint Network	2003
Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services	2012

Source(s): Authors' elaboration

Tool name	Tool type	Introduction year
Diversity index	Index	1948
International Union for Conservation of Nature Red List	Inventory	1964
Air Pollution Index	Index	1968
National Environmental Policy Act	Law	1969
US Clean Air Act	Law	1972
US Clean Water Act	Law	1972
UN Environment Programme	Program	1972
EU Environment Action Programme	Program	1972
US Endangered Species Act	Law	1973
US Safe Drinking Water Act	Law	1974
US Resource Conservation and Recovery Act	Law	1976
US Convention on Long-Range Transboundary Air Pollution	Convention	1979
Vienna Convention for the Protection of the Ozone Layer	Convention	1985
Montreal Protocol	Protocol	1987
Brundtland Report	Report	1987
US No net loss wetlands policy	Policy	1989
Human Development Index	Index	1990
US Conservation banking	Method	1990
System of Integrated Environmental and Economic Accounting	Framework	1990
Alpine Convention for the sustainable development of the Alps	Convention	1991
US Resource Management Act	Law	1991
U.S.-Canada Air Quality Agreement	Law	1991
Convention on Biological Diversity	Convention	1992
UN Framework Convention on Climate Change	Framework	1992
Ecological footprint	Method	1992
Rio Declaration on Environment and Development	Declaration	1992
UN Agenda 21	Plan	1992
International Cooperative Biodiversity Groups	Program	1993
UN Convention to Combat Desertification	Convention	1994
Basel Convention on Control of Hazardous Waste	Convention	1994
Convention on Nuclear Safety	Convention	1994
Convention on access to environmental information and justice	Convention	1998
Rotterdam Convention on pesticides	Convention	1998
Cartagena Protocol on Biosafety	Protocol	2000
European Landscape Convention	Convention	2000
Native Vegetation Management Framework	Framework	2002
Air Quality Health Index	Index	2005
Millennium Ecosystem Assessment	Report	2005
Happy Planet Index	Index	2006
EU Shared Environmental Information System	Information system	2008
UK National Ecosystem Assessment	Report	2009
EU Biodiversity action plan	Plan	2009
UN Decade on Biodiversity	Program	2010
Natural Capital Declaration	Declaration	2010
Consumption of Ecosystem Capital	Framework	2011
European Regulation Environmental Economic Accounts	Law	2011
Agenda 2030	Plan	2015
Natural Capital Protocol	Protocol	2016
Equator Principles	Framework	2017
UN Declaration on the Rights of Peasants	Declaration	2018
Global Assessment Report on Biodiversity and Ecosystem Services	Report	2019
UN Decade on Ecosystem Restoration	Program	2019

Source(s): Authors' elaboration

Table A5.
International tools

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Gennaro Maione is a researcher in business economics at the Department of Economics and Statistics (DISES) of the University of Salerno, Italy, where he teaches Business Administration and Accounting. He is the author of scientific articles presented at conferences in Italy and abroad and published in national and international journals. His main research interests focus on Sustainability accounting, Environmental accounting and ESG reporting. Gennaro Maione is the corresponding author and can be contacted at: gmaione@unisa.it

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