

## Article

# Mapping Research on Natural Capital Accounting: A Strategic Challenge for Multinational Firms

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**Abstract:** In the contemporary context, characterized by the paramount importance of sustainability, both governments and companies, particularly multinational enterprises (MNEs), play an important role in fostering and overseeing the transformative processes necessary to establish a robust accounting framework for natural capital. The objective of this paper is twofold: firstly, to conduct a comprehensive review of the existing body of literature on this subject and to highlight the importance of avoiding intangible liabilities in MNE from bad practices based on Natural Capital bad practices, and secondly, to outline prospective directions for further research in this domain. To achieve these objectives, we pose two fundamental research questions: (1) What is the current state of knowledge regarding the intangible liabilities and accounting practices of MNEs concerning Natural Capital? (2) How can future research in the field of Natural Capital Accounting be oriented to assist MNEs in accounting for their interactions with Natural Capital? A mixed-method approach is used to address these inquiries. Initially, we substantiate the intrinsic connection between MNEs and the natural environment, utilizing bibliometric techniques to identify the primary themes and areas of focus in the realm of natural capital accounting. Subsequently, we employ in-depth analysis and logical reasoning to propose potential avenues for future research. Additionally, we present a comprehensive model designed to guide forthcoming research endeavors in the domain of natural capital accounting. Among the salient findings derived from our model analysis, it is evident that the inclusion of other environmental factors, such as ecosystem services and biodiversity, should be integral to the overall framework of natural capital accounting. Furthermore, the incorporation of such accounting practices into the day-to-day operations of companies is essential to preserving the natural capital and the reputation of the firms.



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**Keywords:** natural capital accounting; ecosystem services accounting; MNE; bibliometric

## 1. Introduction

Natural resources as raw materials have been unquestionably linked to international business, to FDI, and therefore to multinational corporations. Some of the world's largest corporations have been important investors in the extractive industry and play a key role in the mining of metals and in the extraction of oil and gas. The need for investing in a low-carbon economy (UNCTAD 2010) and the role of Transnational Corporations in Agricultural Production and Development (UNCTAD 2007) has been recognized. Also, UNCTAD (2020) discussed how the forces driving investment change as raw materials progress up the "value chain" to become finished products. In summary, the need for improvements in corporate responsibility (ESG, environmental, social, and governance) has been recognized (UNCTAD 2009).

Institutional development in the global economy is needed to measure and preserve the social and economic value of natural capital. Several steps have been taken to reduce negative externalities in recent decades. The lack of standards and the relatively poor institutional development of certain countries have created situations with high social

and environmental costs. If we go back to the history of MNE operation with natural resources, we find examples of intangible liabilities, defined as negative externalities due to bad practices, corporate irresponsibility, natural disasters, and lack of national institutional development to address the social and economic value of natural resources and the environment. For instance, in the extractive industries sector, we can mention the environmental and social degradation caused by oil spills, such as Shell in the Niger Delta, Chevron-Texaco in Ecuador, ExxonMobil and Petrobras in Chad and Cameroon (UNCTAD 2010), and BP in the Gulf of Mexico, to cite some well-known examples.

Numerous international initiatives have been developed in recent years to promote the concept of sustainable business development. In this context, since 2013, when the 7th Environment Action Program defined natural capital as “biodiversity, including ecosystems that provide essential goods and services, from fertile land and multifunctional forests to productive land and sea, from good quality drinking water and clean air to pollution and climate regulation and protection from natural disasters”, measuring natural capital became a challenge to ensure smart, sustainable, and inclusive growth, leading to a better understanding of the relationship between economy, society, and environment.

Institutions influence firms’ strategies through regulatory, normative, and cognitive channels (Scott 1995, 2005). In other words, institutional factors affect MNE strategy (Ruijs et al. 2019). The strategic decisions of MNE reflect the institutional environment of their countries (Chen et al. 2009). The company as an institution, as well as its specific norms and values, which guide decision-making, constitute institutional ownership advantages that can be transferred to subsidiaries in host countries and influence institutional development in those countries (Hall and Soskice 2001). Therefore, MNE policies and practices are expanding through the value chain (Peng et al. 2008).

The term sustainability encompasses all three dimensions: economic, environmental, and social. Since sustainability performance at the subsidiary level can be globally integrated into the MNE, the adaptation of social and environmental programs to local demands is influenced by the institutional and economic model of the home country, which, in fact, is a determining factor in the overall strategy of the MNE.

Natural capital accounting (NCA) provides a systematic framework for MNEs to define appropriate policies on an informed basis and to measure the natural assets and services of a particular site or ecosystem. The principles of NCA have been recognized by the UN, with the publication of its System of Environmental Economic Accounting (SEEA) in 2021. Its approach has significantly influenced national policy making, leading to the development of NCA frameworks by world powers such as the United States, European Union, and United Kingdom. Essentially, NCA is a means of incorporating nature-related risks and opportunities into financial considerations. It allows nature-related impacts and dependencies to be reflected in monetary balance sheets and profit and loss accounts.

The aim of this paper is to analyze and review the published works on Natural Capital Accounting and to propose future milestones for this line of research. For the elaboration of the roadmap for future research, it has been considered that most of the literature has been published in recent years, noting that, during the early periods, the literature was scarce, even years in which there has been no publication at all, focusing in recent years on natural capital, ecosystem services, biodiversity, valuation of natural capital and natural capital accounting itself. A mixed methodology is applied. A bibliometric technique is used to identify the main topics studied in NCA. Subsequently, an in-depth analysis and logical reasoning are applied to propose a model and future lines of research.

Following the United Nations (2021, SEEA), a review article is “a study that analyzes and synthesizes an existing body of literature by identifying, challenging, and advancing the building blocks of a theory through an examination of a previous body (or several bodies) of work”. This paper presents future avenues for research on how to improve natural capital accounting, including all the milestones mentioned above (ecosystem services, biodiversity, natural capital valuation), and incorporating the reasons why we believe future research should be directed towards achieving these milestones.

To achieve these objectives, the second section analyzes the importance of natural capital accounting for the firm; the third section analyzes the literature reviews that have been carried out on this topic. A bibliometric technique known as co-word analysis is used to identify the main topics studied in this line of research. Based on these results, a proposal for the orientation/direction of future research on digital human resources is presented in the fourth section. Finally, the last section presents the conclusions, contributions, limitations, and future lines of research.

## 2. Why Is NCA Necessary for MNE?

### 2.1. Background to the Relationship between MNE and Natural Capital as a Source of Intangible Liabilities

Explaining the relationship between MNE and Natural Capital as sources of intangible liabilities needs to start from defining what intangible assets are; at least from an accounting point of view, they are related.

Two main sources of intangibles<sup>1</sup> have been considered as relevant determinant factors of Multinational Enterprises (MNE) strategies. On the one hand, the Liabilities of Foreignness associated with operating in a foreign country is based on managing differences (distances) between countries of origin and the country of destination of FDI, which brings cultural and physical distance. It includes six dimensions: (1) education, (2) industrial development, (3) language, (4) degree of democracy, (5) political, ideology, and religion, and (6) institutional distance as research agendas in International Business (IB) (Haji and Ghazali 2018; Hofstede 1980; Kogut and Singh 1988). On the other hand, we face intangible assets (ownership advantages) based on knowledge, as the main sources of the economic capital of MNEs and its competitive advantages (House et al. 2004; Dow and Karunaratna 2006; Dunning 1988).

Thinking on these two types of intangible liabilities, we wonder: are there any types of intangible liabilities related to Natural Capital and MNEs activities? If so, are we missing an important concept and research area in international business about how to account for it? To answer these questions, we make the following considerations. A MNE is competitive if it is able and knows how to produce, commercialize, distribute, and sell goods and services in the market either cheaper or differentiated by nature and quality characteristics from those made by competitors (selling to the same market target). Competitiveness is based on a firm's specific knowledge and capabilities that are incorporated into physical and intangible assets. These types of assets, together with another of a generic type, constitute what can be called Economic Capital of the firm. By nature, those assets can be of a technological character (that allows the manufacture or production of goods and services), commercial (for distribution and selling), and managerial (designing and implementing strategies, assigning resources, coordinating, and controlling). Physical specific assets can be found in all three types of economic capital we have mentioned and, therefore, establish relations with Natural Capital. The relationship between the MNE and Natural Capital nowadays makes it possible, due to its singularity, to consider another kind of intangible asset, the reputation of the firm.

In our understanding, we believe that reputation can be conceptualized as an intangible asset. Reputation is based on public recognition or perception of the quality of activities of the firm by both internal and external stakeholders of the organization (Dunning 2000). However, even if perceptions logically differ between individual stakeholders, they could be understood as a collective perception (Cantwell et al. 2010; Rindova et al. 2005; Bromley 1993). Favorable collective perception may be a source of economic rent, and then there are incentives for firms to maintain and invest in their reputations (Bromley 2000; Dollinger et al. 1997).

Reputation contributes to generating the goodwill of the firm, and a negative reputation may contribute to creating bad will and may also lead to generating intangible liabilities. A positive reputation increases the likelihood that stakeholders will be favorable in contracting with a recognized firm (Connelly et al. 2011; Musteen et al. 2013). Within

this argument, not behaving reliably or honestly can have immediate and long-term consequences, as a decrease in a positive reputation may affect the future actions of other players toward a firm. If the “present value of future income exceeds the short-term profit” of dishonesty, firms will be honest and invest in their reputations.

When there is a loss of reputation, companies make large investments to recover it, which probably increases risks and financial needs. Therefore, the emergence of intangible liabilities based on the bad praxis of MNE in relation to the Natural Capital may have economic consequences that directly affect the value of the company (Herrera Rodriguez and Ordóñez-Castaño 2020). Therefore, it is possible to assume that a firm may develop intangible liabilities based on damage to the natural environment, which may imply monetary payments to third parties either at a specific time or as a future cash outflow because of applying bad practices, following wrong policies on a continuous basis or due to events as results of concrete activities. Also, no anticipated negative events or hidden implicit contracts may result in potential intangible liabilities that, in the future, may need to become explicit. When intangible liability is related to a bad reputation and less competitiveness, it also has consequences in a reduction of the equity value for shareholders.

When hidden liabilities emerge and contingencies are recorded to support future payments to third parties (fines, compensations, v.gr.), a loss of value of intangible assets can be expected throughout a loss of reputation. Loss of value of specific assets can be interpreted as a loss of a firm’s competitiveness. The decrease in asset value cannot only be reflected in the decrease in the equity of the firm, but it can also be reflected in its liabilities, increasing them at the time that these losses are accompanied by payment obligations to third parties. This fact is also expected to be correlated to a loss of a firm’s reputation.

Under the proposed conceptual approach, we consider that the possibility for the firm to record natural capital accounting can mitigate the intangible liabilities of a firm.

## *2.2. Natural Capital Accounting as a Reflection of Sustainable MNE Development*

The use of the concept of natural capital is a crucial element in productive structures within the value chain that creates wealth and value in both companies and countries. A large part of the decisions taken related to the adoption of the 2030 Agenda are very sensitive to the valuation of natural resources and their scarcity, although they do not always have adequate scientific justification (Statistics South Africa 2020). To avoid this lack of information, the System of Environmental and Economic Accounting Central Framework was published in 2014 (UNEP-WCMC 2014).

To achieve sustainable development, accounting systems must consider the basis for sustainable growth provided by ecosystems and their services (Barton et al. 2017), considering biodiversity as a key factor both for functioning and resilience and for their capacity to provide ecosystem services. However, human activities that result in overexploitation, pollution, land-use changes, and climate change, for example, can decrease the resilience of natural ecosystems (Bertness et al. 2015). Moreover, ecosystem functioning, and the future provision of ecosystem services may be threatened by the current rate of biodiversity loss. In this sense, biodiversity accounting allows trends in ecosystem and species diversity (and the benefits they provide) to be compared with economic and social activity in a spatially explicit way to answer key policy questions (European Union 2015). Establishing linkages between biodiversity and the economy provides an important opportunity to integrate biodiversity into a wider range of decision-making contexts (e.g., sectoral and development policies) (European Union 2016).

For all of the above, natural capital accounting (NCA) can help companies avoid intangible liabilities, helping to assess, understand, manage, and act in relation to nature (NCC 2016). The adoption of NCA by companies is at an early stage but is progressing towards a common framework promoted mainly by the Natural Capital Coalition (NCC 2017) and by the International Integrated Reporting Council (Post et al. 2020). These two

initiatives aim to provide information on the performance and impact of companies on natural capital.

The need to provide recurring information by companies regarding their interaction with natural capital is supported by three key points (Barker 2019):

- **Legal.** The legal requirements included in the EU 2022/2464 Sustainability Reporting Directive (EU 2022) make it mandatory to include information regarding environmental aspects in the description of policies, results, and related risks. These must be incorporated into management reports. Among this information, it is necessary to include “details of the current and foreseeable impacts of the companies’ operations on the environment and, where applicable, the use of renewable and/or non-renewable energy, greenhouse gases, emissions, water use and air pollution”.
- **Economic.** The legitimacy (and reputation) of a company as perceived by society can be linked to the way it reports, as well as to the assumption of public commitments. A good environmental communication policy can lead to a greater and/or better social perception of the company that applies it.
- **Corporate.** This approach considers that the regulatory and coercive framework coupled with market forces explains only part of corporate behavior. Institutional theory defines generally accepted social constructs, including appropriate environmental behavior. A company will be constrained by it to be accepted.

It is necessary to account for both the impacts and dependencies of natural capital to determine potentially significant risks and opportunities. Knowing the state of research development in this area is crucial to determining where research in this field should go.

### 3. Materials, Methods, and Results

The Scopus database was used, and searches were performed in the fields Title, Keywords, and Abstract. The query performed on 10 May 2023 was (TITLE-ABS-KEY (“Accounting” and “natural capital” or “ecosystem services” or “biodiversity”). The search returned 136 documents. The keywords (399) were filtered, so that plurals and singulars of the same words were automatically grouped, and words were also automatically grouped by common synonyms, leaving a total of 393 words or groups of words. We used the Scopus Database instead of the WOS Database because, due to the low number of journals referred to the topic, the number in Scopus (136) was higher than in WOS (112). Table 1 summarizes the data research.

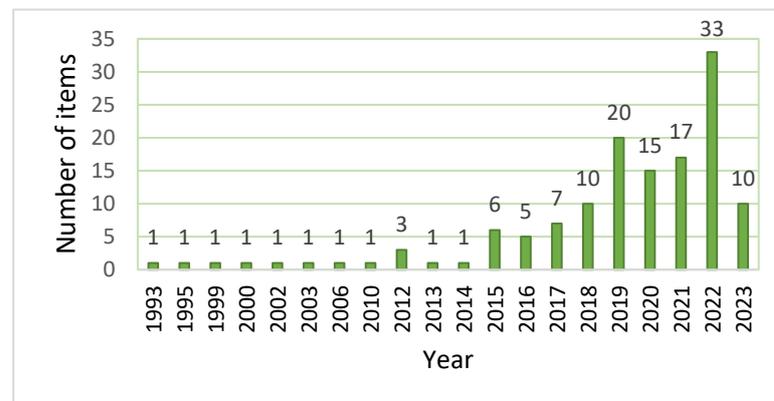
**Table 1.** Data Search.

Database	Scopus
Date of search	10 May 2023
Years	Every year
Search fields	Title, abstract and keywords
Search terms	“Natural capital accounting”
Types of documents	Articles, reviews, lectures, books, and book chapters
Number of documents	136

Source: Own elaboration.

The study started in 1993 because it was the year when the first paper was published. Although research on natural capital accounting began more than 30 years ago, and as Figure 1, shows, most of the articles were published in the last 4 years. Until 2014, contributions were sporadic, and it was not until a year later, coinciding with the signing of the UNFCCC (2018), that scientific production increased considerably, an even greater increase from 2018, the year in which the European Green Pact was enacted, whose objective was to place the EU on the path towards an ecological transition that culminates in reaching climate neutrality by 2050. In that sense, 2022 was the year with the highest scientific output to date, although 2023 is likely to follow the same trend, given that this study only covers

articles published up to the date of the consultation. These data show the growing interest in NCA in the literature.



**Figure 1.** Documents by Year. Source: Own elaboration.

To identify the different topics addressed in the literature on NCA, a co-word analysis was used in conjunction with the SciMat program (Cobo et al. 2012). The analysis criteria were as follows: unit of analysis: words (authorRole=true, sourceRole=true, addedRole=true); network type, co-occurrence (2); normalization measure, equivalence index (2); clustering algorithm, single centers; maximum cluster size, 12; minimum cluster size, 3; evolution measure, inclusion index; overlap measure, Jaccard index.

Callon et al. (1991) proposed the classification of each thematic network into one of the following groups: well-developed and isolated themes (upper left quadrant), emerging or disappearing themes (lower left quadrant), basic and transversal themes (lower right quadrant), and driving themes (upper right quadrant), considering centrality and density measures and thus creating a strategic diagram.

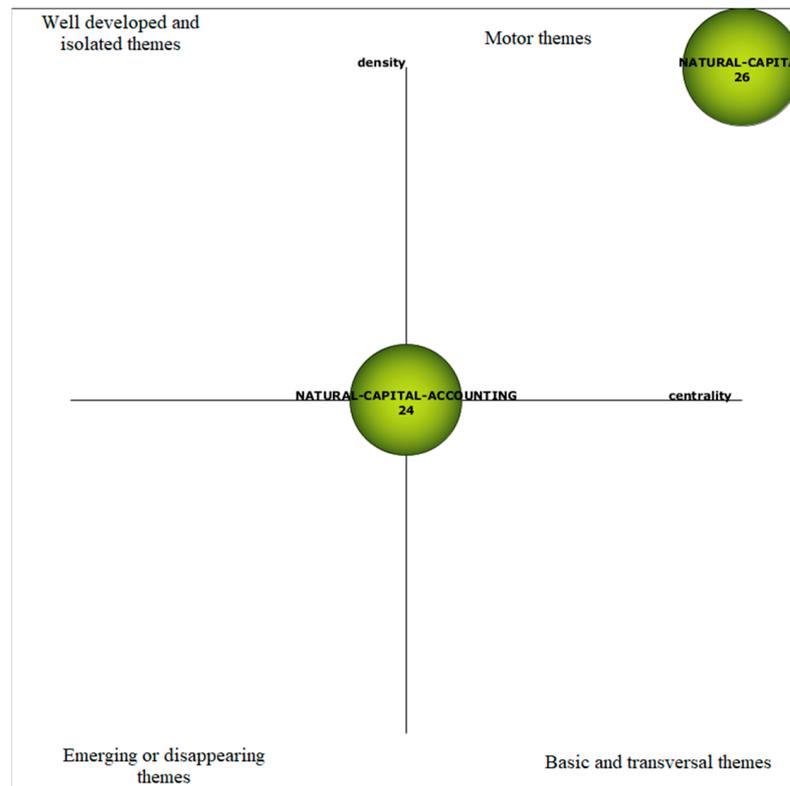
Two approaches were carried out and are presented below: first, an analysis without word clustering and then a new analysis with word clustering by topic.

### 3.1. Bibliometric Analysis of AQL without Word Clustering

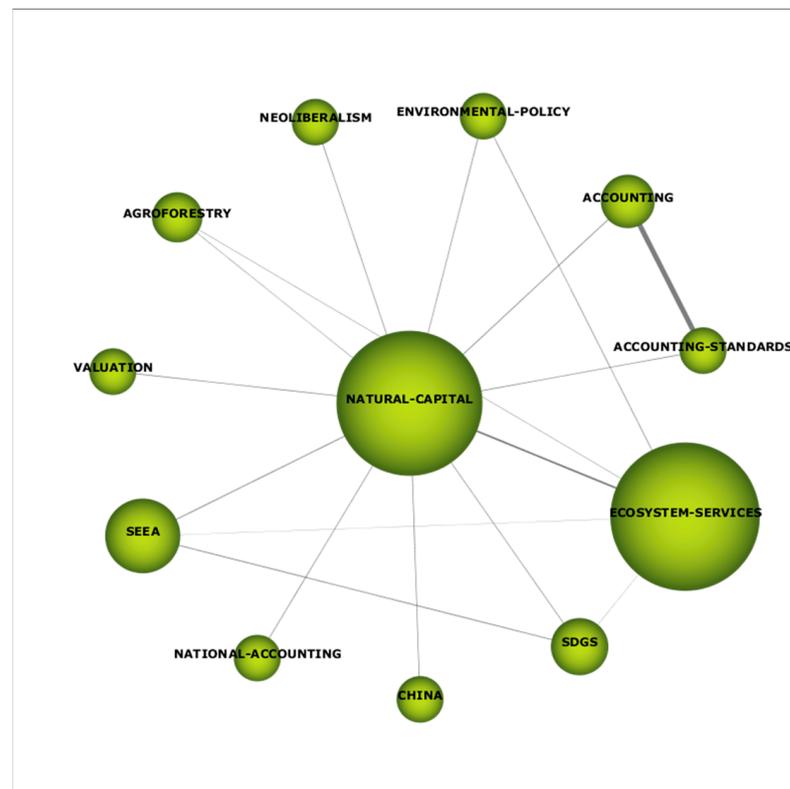
In the first analysis, all words were considered, excluding plurals and misspellings. The following figure shows the results for the entire 1993–2023 period without word groups, where “Capital-natural” is a driving theme and “Capital-natural-accounting” is a recurring theme that can be included in all four themes.

Once the bibliometric analysis was carried out, we analyzed the most cited articles, which means articles that have been cited more than 10 times. In these articles, we analyzed the aim of the paper, the main conclusions, and the proposed future research in order to obtain information to build our model of lines of future research.

Our conclusions after analyzing the articles shown in Figures 2 and 3 are that the most common subject is natural capital future research is that it should revolve around economic and social assessments, building on existing economic impact assessment approaches and extending this approach to other types of ecosystems. In this sense, it should include more detailed models that support decision-making that incorporate the implications of moving from screening to the implementation of results, including how to measure and monitor the effect of different actions. Extending SEEA improvements and implementing rules that allow the evaluation of whether the accountability between companies and governments is following these institutional changes can allow information to be analyzed more effectively and translated into policy and management responses. Table 2 summarizes and analyzes the main authors, citations and papers belonging to cluster network for natural capital in all period 1993–2023 without word groups to explore the proposed future research in these articles.



**Figure 2.** Strategic diagram for all periods 1993–2023 without word grouping. Source: Own elaboration. From Scimat.



**Figure 3.** Cluster network for natural capital in all periods 1993–2023 without groups. Source: Own elaboration based on Scimat.

**Table 2.** Main authors, citations, and papers belonging to cluster network for natural capital in all periods 1993–2023 without word groups.

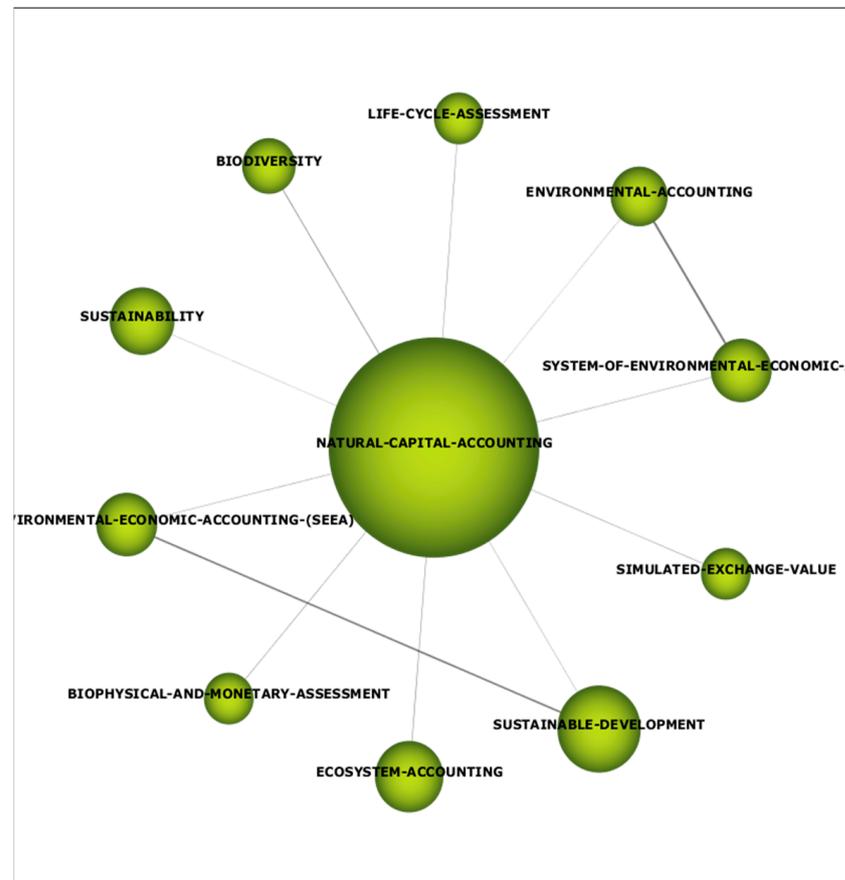
Authors	Title	Citations	Aim of the Paper	Main Conclusions	Proposed Future Research
Vardon et al. (2018)	How The System Of Environmental-economic Accounting Can Improve Environmental Information Systems And Data Quality For Decision Making. Environmental Science And Policy 89:null 83–92 (2018)	35	In this paper, it is contrasted for two case studies (Guatemala and Netherlands) how the SEEA (System of Environmental-Economic Accounting) can improve information systems and data quality for decision-making and distil lessons for the development of the European Shared Environmental Information System.	One of the main conclusions is that the use of SEEA increases data quality, providing a coherent and comprehensive framework and resulting in a suite of information on the environment and the economy relevant to government and others.	The SEIS (Shared Environmental Information System) and SEEA are potentially complimentary and reinforcing. In the short term, those producing accounts in Europe would be able to draw on the information in the SEIS, and those populating the SEIS would see how information and analytical products are using their information. In the longer term, this should lead to both improvements in the information system and enable it to more effectively influence decision-making.
Kjaer et al. (2015)	Application Of Environmental Input-output Analysis For Corporate And Product Environmental Footprints-learnings From Three Cases. Sustainability (switzerland) 7:9 11438–11461 (2015)	33	In this article, the authors demonstrate and contrast an approach in which we use a hybrid environmental input-output (EIO) database as the basis for corporate and product environmental footprint accounts, including the entire supply chain.	The greatest strength of the EIO approach was that it analyzed the feasibility of the total supply chain impacts and allowed the identification of critical points in both direct and indirect operations. Using available financial data as a starting point made the first assessment quick and relatively easy. On the other hand, for the companies and organizations with large upstream environmental footprints, the analyses supported advancing their sustainability agenda to include supply chain impacts.	Future research should include more detailed models that support decision-making that incorporates the implications of moving from screening to implementation of results, including how to measure and monitor the effect of different actions.
Ruijs et al. (2019)	Natural Capital Accounting For Better Policy. Ambio 48:7 714–725 (2019).	26	This paper summarizes lessons on the institutional integration of the SEEA and its use in improving policy decisions affecting natural capital. It draws on discussions held at two Policy Forums organized by the World Bank Wealth Accounting and Valuation of Ecosystem Services program and the United Nations Statistical Division.	The main conclusion that the authors reach in this study is that all countries have concluded that the institutional arrangements necessary to translate the NCA (natural capital accounts) into policies, as discussed in this paper, are important.	Future lines of research should focus on contrasting the effects of the investments and efforts made by countries to apply all strategies, so that the NCA is fully effective, efficient, and integrated into a country's decision-making.
Vardon et al. (2019)	Putting Biodiversity Into The National Accounts: Creating A New Paradigm For Economic Decisions. Ambio 48:7 726–731 (2019).	19	The authors contrast, for the cases of Australia and Botswana, how the integration of information on biodiversity, resource use, and economics through accounting can help create a new decision-making paradigm and enable a new policy framework with the spending on biodiversity conservation and sustainability seen as an investment, not at cost.	In both cases of study, the results are positive for biodiversity accounting to become a mainstreamed part of decision-making, accounts must be expanded to cover larger areas (e.g., river basins, countries), include more comprehensive metrics describing biodiversity, and be updated regularly, ideally annually.	It will have to be evaluated whether the accountability between companies and governments in making these institutional changes can allow information to be analyzed more effectively and translated into policy and management responses.

Table 2. Cont.

Authors	Title	Citations	Aim of the Paper	Main Conclusions	Proposed Future Research
Stage and Uwera (2018)	Prospects For Establishing Environmental Satellite Accounts In A Developing Country: The Case Of Rwanda. Journal Of Cleaner Production 200:null 219–230 (2018).	19	In this study, the authors analyze, for the case of Rwanda, whether, after having discussed the satellite accounting work, positive effects have been evident, focusing on resources where policy makers had already begun to identify key economic trade-offs between different applications and where, as a result, the collection of economic statistics had already been improved. It seems likely that this approach could lead to more durable satellite accounts and that a similar approach would be feasible in many other countries.	Under the SEEA framework, the keys to selecting which of these resources or sectors can focus efforts to begin with and that have been identified in this work are: the potential contribution of the resource/sector to growth and development objectives, the potential of the resource /sector to inhibit growth if not adequately addressed, its impact on macroeconomic indicators of long-term growth prospects and finally its relevance to planning and policy across the economy.	It is pending that Rwanda uses, for energy and forests, the evaluation criteria established in this paper that were applied for, for example, water and land.
Farrell et al. (2022)	Applying Ecosystem Accounting To Develop A Risk Register For Peatlands And Inform Restoration Targets At Catchment Scale: A Case Study From The European Region. Restoration Ecology 30:8 null-null (2022).	12	The objective of the paper, under the framework of the System of Environmental Economic Accounting–Ecosystem Accounting (SEEA EA) is to propose the development of a risk register for peatlands in two contrasting catchments in Ireland, based on available information related to stocks of peatlands, peatlands (extent and condition), and flows (services and benefits), as well as knowledge of pressures.	As a main conclusion, we can highlight the limitation of available data related to the contribution of peatlands to water supply in Ireland, as well as the priority service in the United Kingdom Peatland Accounts and limited data on water flow regulation.	Future lines of research revolve around economic and social assessments, building on existing economic impact assessment approaches and extending this approach to other types of ecosystems. On the other hand, for each type of ecosystem, the ecological nonlinearities, and thresholds of each type of ecosystem must be recognized, which requires a continuous and interdisciplinary effort on the part of ecologists, social scientists, and economists.
Zhang et al. (2022)	Natural Capital Accounting Of Cultivated Land Based On Three-dimensional Ecological Footprint Model—A Case Study Of The Beijing-tianjin-hebei Region. Frontiers In Environmental Science 10:null null-null (2022)	11	Taking into account that an increase in environmental inequality has been recorded in the Beijing-Tianjin-Hebei region (2009–2016), the authors review and evaluate the use of natural capital from cultivated land in this region, despite obtaining great environmental benefits.	The paper concludes that under the strategic role of Beijing-Tianjin-Hebei integration and development, equity in the utilization of natural capital of cultivated land has improved in each city in the region. However, it is necessary to make efforts to improve the natural capital flows of cultivated lands and to strengthen the ecological protection of cultivated lands.	It highlights the need to collaboratively develop the ecological protection and function of regional cultivated land and promote the sustainable use of natural capital and coordinated regional development in accordance with local conditions and conditions. The application of quantitative methods will be crucial to determining whether positive or negative spillovers have been identified.

Source: Own Elaboration.

Once this analysis was completed, clusters for the two topics were prepared. Figure 4 shows the cluster for “Natural Capital Accounting” and we can see a star-shaped network characterized by the presence of keywords correlated with the cluster theme. The main themes are clearly ecosystem services correlated with environmental policy. Different natural capital accounting systems also appear, such as SEEA and SDGS. Other accounting terminology is also observed in the network. However, despite the importance detected in the literature review, biodiversity does not appear as part of the network of published articles on natural capital.



**Figure 4.** Cluster Network for natural capital accounting for all periods 1993–2023 without clusters. Source: Own elaboration through Scimat.

After analyzing the articles shown in Table 3 related to Natural Capital Accounting, we conclude that the two most cited papers focus on the need to identify the type of distribution function of the relationship between biodiversity and ecosystem conditions/services and how to extend it beyond case studies to multiple situations.

**Table 3.** Main authors, citations, and papers belonging to cluster network for natural capital accounting in all periods 1993–2023 without word groups.

Authors	Title	Citations	Aim of the Paper	Main Conclusions	Main Contributions for Future Research
Lai et al. (2018)	Bridging The Gap Between Ecosystem Service Indicators And Ecosystem Accounting In Finland. Ecological Modelling 377 51–65 (2018)	29	In this paper, the authors evaluate how progress in ecosystem services indicators could contribute to ecosystem accounting within the scope of environmental and economic accounting in Finland applied for two cases: water and fish provisioning ecosystem services in marine ecosystems.	The case studies that have been contrasted show that the ES indicators were not originally designed from an accounting perspective and could be used to compile ecosystem accounts following the SCEE-EEA statistical framework.	The pilot also highlights that, as future lines of research, statistical methods can be used to contrast and show if there are data gaps or discrepancies in the definitions of variables.
Kotsiras et al. (2020)	Integrating Plant Diversity Data Into Mapping And Assessment Of Ecosystem And Their Services (maes) Implementation In Greece: Woodland And Forest Pilot. Forests 11:9 null-null (2020)	19	This paper is one of the first to integrate biodiversity data into the implementation of the Mapping and Assessment of Ecosystems and their Services (MAES) and the natural capital accounting process. Applied to the case of Greece.	There is no linear relationship between biodiversity, the condition of ecosystems and their services. On the other hand, areas of importance have been identified shows the individual and societal well-being, human inputs, and other ecosystem assets).	Based on the results of the article, the objective of future lines of research is to identify the type of distribution function of the relationship between biodiversity and ecosystem conditions/services. For example, logistic regression, tangential functions, or even the application of machine learning techniques.

Source: Own Elaboration.

The clustering “natural capital accounting” appears for all periods in 1993–2023, and without clustering words, many keywords appear. The keywords “SEEA” and “sustainable development” are strongly correlated with each other, as well as with “environmental accounting”. We note the appearance of biodiversity at the core of this analysis.

### 3.2. Bibliometric Analysis of AQL without Word Clustering

Subsequently, due to the scarcity of topics originating from the analysis performed without grouping, the same analysis was carried out considering the groupings shown in Table 4.

**Table 4.** Thematic groups and words of the groups.

Thematic Groups	Words of The Group
Ecosystems-nature	Green-Blue-Areas, Green-Recovery, Three-Dimensional-Ecological-Footprint, Ecosystem-Capital, Environmental-Sustainability, Invasive-Species, Ecosystem-Capacity, Ecosystem-Potential, Green-Amenities, Ecosystem, Green-Growth, Ecosystem-Restoration-Targets, Phytogeography, Marine-Ecosystem, Ecosystems, Ecosystem-Mapping, Green-Economy
Ecosystem services	Aquatic-Ecosystem-Services, Aries, Cices, Common-International-Classification-Of-EcosystemServices-(Cices), Ecological-Economics, Ecosystem-Based-Management-And-Monitoring, Ecosystem-Conceptual-Model, Ecosystem-Condition, Ecosystem-Extent, Ecosystem-Functions, Ecosystem-Health, Ecosystem-Service, Ecosystem-Service-Providers, Ecosystem-Services, Ecosystem-Services-(Es), Ecosystem-Stocks-And-Flows, Green-Supply-Chain, Industrial-Ecology, Intermediate-Ecosystem-Services, Multi-Parametric-Optimization-Of-Ecosystem-Services-Production, Parks, Urban-Ecosystems, Urban-Planning, Urban-Political-Ecology
Company-Economy	GDP, GEP, Biophysical-And-Monetary-Assessment, Business, Business-Models, CGE, CGE-Model, Computable-General-Equilibrium-Model, Corporate-Accountability, Economic-Valuation, Environmental-Economics, Environmental-Markets, Financial-Valuations, Invest, Investments, Market-Based-Instruments, Methods-Of-Economic-Assessment, Monetary-Quantity, Monetary-Valuation, Monetary-Value, Monetary-Value, Principles-Of-Economic-Assessment, Productivity-Gains, Shadow-Price, Simulated-Exchange-Value, Simulated-Exchange-Values, Trade-Offs, Transnational-Corporations, Valuation, Valuation-Methods, Value-Generalization, Wealth
Natural capital	Natural-Capital, Natural-Capital-(Nc), Natural-Capital-Approach, Natural-Capital-Indicators, Natural-Capital-Indicators, Physical-Quantity

Table 4. Cont.

Thematic Groups	Words of The Group
Natural capital accounting	Ecosystem-Accounting, Ecosystem-Services-Accounting, Ecosystem-Services-Accounting-Tables, Environmental-Accounting, Environmental-Accounting, Environmental-Accounts, Environmental-Economic-Accounting, Environmental-Profit-And-Loss, Green-Accounting, Natural Capital Statements, Natural-Capital-Account, Natural-Capital-Accounting, Natural-Capital-Accounting, Natural-Capital-Accounts, Ocean-Accounting, Seea, Seea-Central-Framework, Seea-Ecosystem-Accounting, Seea-EEA, System-Of-Environmental-Economic-Accounting, System-Of-Environmental-Economic-Accounting-(Seea), System-Of-Environmental-Economic-Economic.
Sustainable development	2030-Agenda-For-Sustainable-Development, Biopower, Blue/Green-Infrastructure, Conservation, Conservation-Planning, Ecological-Compensation, Ecological-Restoration, Environmental-Knowledge, Environmental-Monitoring, Flood-Control, Land-Use-Management, Measuring-Sustainable-Development, National-Indicators, National-Set-Of-Indicators, National-Wealth, Nature-Repair-Markets, Negative-Carbon-Emissions, Pro-Environmental-Behavior, Renewable-Energy, Restoration, Sdg, Soil-Retention, Sustainability, Sustainable-Business-Development, Sustainable-Development, Urban-Green
Accounting	Accounting, Accounting-Standards, Accounting-Tables, Assets, Cost-Benefit-Analysis, Debt, Ep&L, Equity, Extent-Account, National-Accounting, National-Accounts, Private-Sector-Accounting, System-Of-National-Accounts, Wealth-Accounting
Climate change	Atmospheric-Transport-Model, Climate-Action, Climate-Change, Climate-Change-Reversal, Climate-Damages, Coastal-Threats, Land-Degradation, Loss-Of-Life, Sea-Level-Rise-(Slr)
Environmental policy	Biosurveillance, Coal-Phase-Out, Corine-Land-Cover, Crop-Provision, Ecological-Land-Classification, Environmental-And-Social-Governance, Environmental-Decision-Making, Environmental-Policy, Environmental-Policy-And-Management, Fossil-Fuel-Permits, German-Climate-Policy, Governance, Life-Ip-4-Natura, Local-Environmental-Policy, Marine-Protected-Areas, Nd-Gain, Neoliberalism, Policy, Public-Engagement, Public-Policy, Saltmarsh-Management, Society-Of-Ecological-Restoration-Standards, Supply-Side-Climate-Policy, Waste-Management, Water-Framework-Directive, Water-Management, Water-Provision

Table 4. Cont.

Thematic Groups	Words of The Group
Biodiversity	Aquatic, Biodiversity, Biodiversity-Conservation, Biodiversity-Conservation-Strategies, Biodiversity-Trading, Bush-Encroachment, Coastal-Wetlands, Crop-Pollination, Environment, European-Biodiversity-Strategy-To-2020, Everglades, Greek-Flora, Hambach-Forest, Land, Landscapes, Mangrove, Marine-And-Coastal-Habitats, National-Parks, Natural-Areas, Ndvi, Peatlands, Pollination, Potential-Natural-Vegetation, Rangeland-Condition, Species-Distribution-Modelling, Water, Wave-Attenuation, Windbreak
Natural capital assessment	Choice-Experiment, Ecological-Value, Ecosystem-Assessment, Ecosystem-Asset, Ecosystem-Asset-Value, Ecosystem-Services-Valuation, Environmental-Assessments, Environmental-Assets, Environmental-Impact-Assessments, Fegs-Cs, Hydrological-Assessment, Hydrologic-Models, Integrated-Economic-Environmental-Modeling-(Ieem)-, Platform, Life-Cycle-Assessment, Maes-Process, Natural-Capital-Assessment, Valuing-Ecosystem-Services, Wealth-Accounting-And-The-Valuation-Of-Ecosystem-Services
National initiatives	Africa, Australia, Beijing-Tianjin-Hebei-Region, Central-Kalimantan, China, Europe, Gansu-Province, Guanzhong-Region, Italy, Mediterranean-Sea, Myanmar, Rwanda, Scotland, Small-Island-Developing-States, United-Kingdom, Us-Federal-Agencies, Xi'an-City
Carbon footprint	Air-Pollution, Biodiversity-Offsetting, Carbon-Credits, Carbon-Footprint, Carbon-Footprint, Carbon-Sequestration, Ecological-Footprint, Environmental-Footprint, Footprint, GHG, Social-Cost-Of-Carbon
Technology	Artificial-Intelligence, Big-Data, Circuit-Theory, Cyborg-Landscapes, Data-Quality, Digital-Design-Methodologies, Digital-Twins, Hybrid-Environmental-Input-Output-Database, Information-And-Communications-Technology-(Ict), Information-Systems, Satellite-Imagery
Agriculture	Agriculture, Agroforestry, Bioproductive-Area, Cultivated-Land-Resources, Ecological-Carrying-Capacity, Ecological-Productive-Area, Extractive-Industries, Farm-Forestry, Fisheries, Forest-Management, Land-Water-Biomass-Resources, Land-Water-Biomass-Resources, Natural-Resource, Natural-Resources, Regenerative-Agriculture, Resource-Rent, Wool

Source: own elaboration

Following Callon et al. (1991) and in order to identify the knowledge structure of the topic studied, the results of the co-word analysis are presented. Figure 5 presents the strategic diagram obtained from this analysis using word groups for the period (1993–2023), including the number of documents in which each topic is addressed, represented by the size of the circle.

For the entire period analyzed (1993–2023) with word groups, the driving theme, as Figure 6 shows, is “Natural-capital-accounting”, while the theme “carbon footprint”, as Figure 7 shows, is positioned as the basic theme and driving theme.



Figure 5. Strategic diagram for all periods 1993–2023 with word clusters. Source: Own Elaboration.

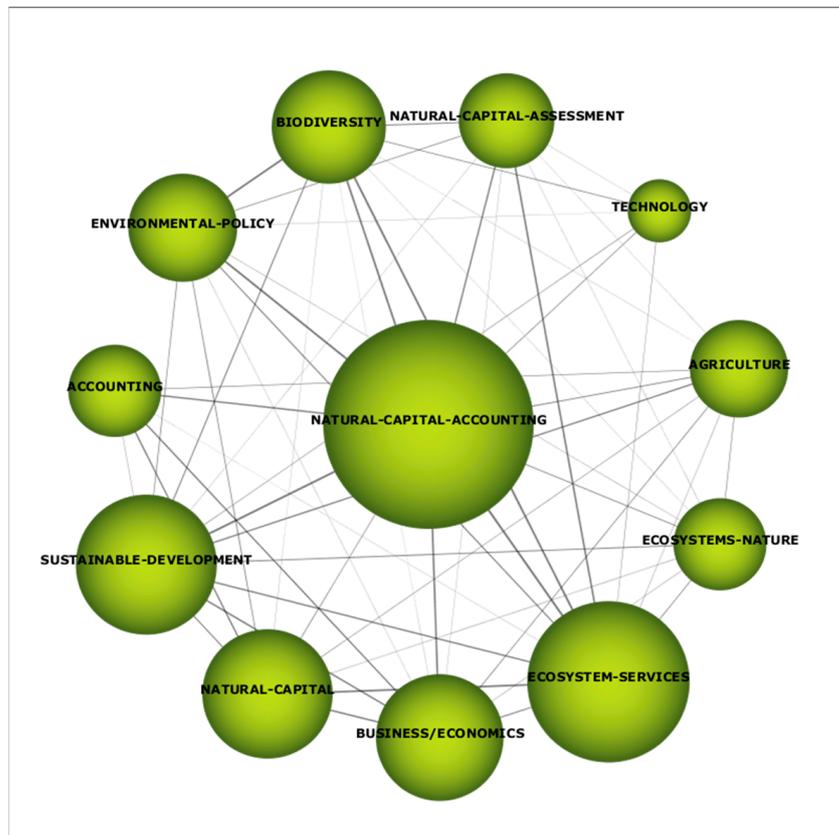
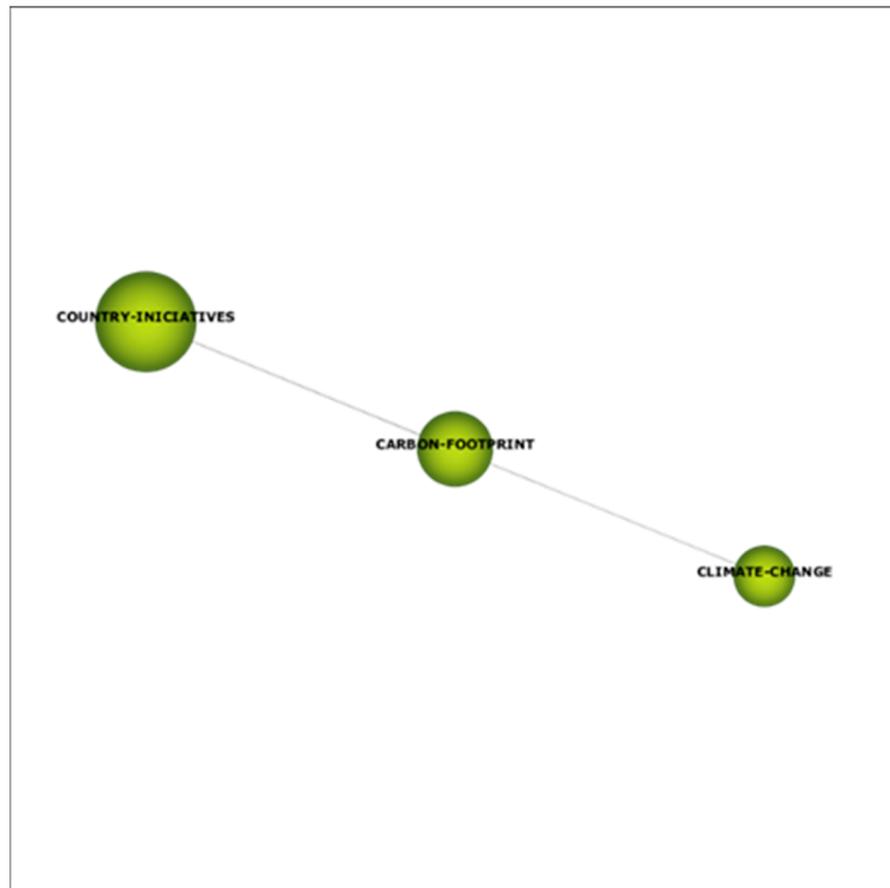


Figure 6. Cluster Network “Natural-capital-accounting” in all periods (1993–2023) with word groups. Source: Own elaboration. SciMat Results.



**Figure 7.** Cluster Network for “Carbon Footprint” in all periods (1993–2023) with word groups. Source: SciMat Results. Own elaboration.

The authors’ analysis shows more than ten papers cited more than 10 times and fewer than 10 references in this cluster. The most cited papers belong to this cluster based on Natural Capital Accounting after grouping words, as shown in Table 5. In all of these papers, the authors analyzed how to approach Natural Capital Accounting from a macroeconomic perspective more than from a microeconomic one, which means the low research developed regarding MNE and Natural Capital Accounting.

**Table 5.** Main authors, papers, and times cited to cluster network for natural capital accounting.

Authors	Title	Citations	Aim of the Paper	Main Conclusions	Main Contributions for Future Research
Wackernagel et al. (1999)	National Natural Capital Accounting With The Ecological Footprint Concept. <i>Ecological Economics</i> 29:3 375–390 (1999).	978	This study presents a simple framework for national and global natural capital accounting. It demonstrates an accounting framework that tracks national economies' energy and resource throughput and translates them into biologically productive areas necessary to produce these flows. This calculation has been applied to over 52 countries.	The used framework based on the carbon footprint offers a cheap and rapid natural capital appraisal for nations with which human demands can be compared with nature's available supply for human use.	The described calculation framework becomes a starting point for more complete national and regional accounting of an ecological flows and services. As footprints do not measure people's quality of life, the other imperative for sustainability, they need to be complemented by future research on social indicators to cover progress toward sustainability comprehensively.
Schaefer et al. (2015)	Nature As Capital: Advancing And Incorporating Ecosystem Services In United States Federal Policies And Programs. <i>Proceedings Of The National Academy Of Sciences Of The United States Of America</i> 112:24 7383–7389 (2015).	105	Incorporating ecosystem services considerations into decision-making processes supports functional, resilient ecosystems, healthy people and communities, and robust economies, aiding efforts to address a wide range of societal challenges. This paper specifically proposes an ecosystem services approach that enables a more thorough and explicit examination of the impacts and anticipated trade-offs of a policy or decision by predicting or measuring the resulting positive or negative changes in services.	The widespread adoption of ecosystem services approaches in planning and regulatory contexts could drive a fundamental shift in environmental governance, positively Given the power of ecosystem services concepts, principles, and applications to influence national economies and further the achievement of natural resource conservation and sustainability goals, additional policy direction and financial capital to support these activities will likely result in a major return on investment.	The identification of research needs is based on the development of new analytical methods and valuation approaches that incorporate ecosystem services concepts into a wide range of policies and practices.
Islam and Managi (2019)	Green Growth And Pro-environmental Behavior: Sustainable Resource Management Using Natural Capital Accounting In India. <i>Resources, Conservation And Recycling</i> 145:null 126–138 (2019).	48	The authors conduct an accounting process for India's NC to measure sustainability to ensure that future generations will have the equal total wealth per capita accessible to them as that available to the present generation	The authors identify that environmental knowledge is an important determinant of individuals' PEB in India. In the policy analysis, they evaluated the challenges to achieving sustainable development goals (SDGs) using NC accounting in India. Finally, they recommend several policy implications to maintain NC at a sustainable level and to achieve SDGs.	NC estimation in this study was very conservative and limited to regional data set. The study can be extended to other countries/regions that can also improve the calculations if the value of minerals is not severely undervalued because the process is strictly controlled by government rules. Data scarcity also refrained from including several important inputs of NC, e.g., wildlife, biodiversity, and water, that can be included in future research.
Fletcher et al. (2019)	Natural Capital Must Be Defended: Green Growth As Neoliberal Biopolitics. <i>Journal Of Peasant Studies</i> 46:5 1068–1095 (2019).	41	This article describes how NCA initiatives may compel some local people to value ecosystem services in financial terms, yet in most cases this perspective remains partial and fragmented in communities where such initiatives produce a range of unintended outcomes.	The authors demonstrate that the ideal neoliberal vision informing NCA is rarely if ever wholly realized in practice, its biopolitics clearly does circulate discursively and manifest materially, if only partially, in its influence on local (self-)perceptions and land use in the short term.	While the analysis includes only two specific cases, anecdotal evidence from other sites suggests that the common dynamics identified are not limited to these and the need of additional research is clear.

Table 5. Cont.

Authors	Title	Citations	Aim of the Paper	Main Conclusions	Main Contributions for Future Research
Mace (2019)	The Ecology Of Natural Capital Accounting. Oxford Review Of Economic Policy 35:1 54–67 (2019).	30	This article explores how natural capital is fundamentally an emergent feature of structures and functions of the natural environment. Therefore, its valuation and metrics for reporting on its condition and the way that it is represented in accounts need to reflect these defining features and not rest solely on measurable flows of goods and services.	The article propose using the quality of fundamental ecological processes and functions which properly represent the functioning and capabilities of the natural capital system upon which society and the economy depend instead on the quality or quantity of flows of goods and services, on the geographical distribution of particular ecosystems or land/sea uses, and by reference to ecosystem services delivered by particular ecosystems.	The key features of natural systems that need to be taken seriously into account in natural capital accounting are to do with the complex system properties of the natural environment. Future lines of research should include the study of the non-linearities in benefit–asset relationships, the irreversibilities, multifunctionality, adaptability, and resilience of natural systems.
Ruijs et al. (2019)	Natural Capital Accounting For Better Policy. Ambio 48:7 714–725 (2019).	26	In this paper, for the first time, a framework for national and global natural capital accounting is presented, the objective of which is to demonstrate, in the case of Italy, that it is necessary to create and delimit an accounting framework that verifies the performance of energy and resources, converting them into biologically productive areas necessary to produce these flows. This calculation has been applied to more than 52 countries. With this framework, based on the concept of ecological footprint, human consumption can be compared with the production of natural capital at a global and national level.	The footprint is an accounting tool that can aggregate ecological consumption in an ecologically meaningful way. This is what we need to know to achieve sustainable development, securing people’s quality of life within the means of nature. From the perspective of governments, the underlying hypothesis is that the quality of people can be improved via pillars of the welfare state and reduce humanity’s footprint through three procedures: increasing the productivity of nature per unit of land, better use of harvested resources and rational consumption by people, and avoiding the acquisition of cars and disposable products.	As future lines of research, the calculation framework proposed in this paper can be a starting point for a more complete national and regional accounting of ecological flows and services. On the other hand, ecological footprints can become an easy-to-read measurement tool for ecological sustainability.
Obst (2015)	Reflections On Natural Capital Accounting At The National Level: Advances In The System Of Environmental-economic Accounting. Sustainability Accounting, Management And Policy Journal 6:3 315–339 (2015).	23	This article makes a consensus on the reflections on the need to displace GDP as the main measure of progress, well-being and/or economic well-being in political circles. It does so by reflecting on the role of accounting frameworks in measuring GDP, and from this position analyzes the potential of expanding these frameworks through natural capital accounting.	From an official statistics perspective, the adoption of the SEEA Central Framework as an international statistical standard has brought renewed energy to the integration of environmental issues, which would benefit the natural capital accounting work currently being carried out. This would be the main contribution in the future.	Specifically, in the area of ecosystem accounting, much research and evidence is needed regarding the assessment of ecosystem conditions, integration across spatial scales, measurement and valuation of ecosystem services, and finally, definition of ecosystem degradation and its assignment to economic units.
Marais et al. (2019)	A Natural Capital Approach To Agroforestry Decision-making At The Farm Scale. Forests 10:11 null-null (2019).	21	The mail objective of the paper is to review the current state of knowledge on natural capital accounting and subsequently evaluate how such an approach can be effectively applied to demonstrate the agricultural-scale value of agroforestry assets. On the other hand, we also contrast the merits of applying a natural capital approach to agroforestry decision-making and present an example of a conceptual model for the valuation of agroforestry assets at the agricultural scale.	The results obtained highlight that there is potential for this framework to be usefully applied to demonstrate the capacity of agroforestry systems to provide sustained private benefits to agricultural businesses. Quantitative methods for valuing ecosystem services should be chosen to suit the purpose of the valuation and the types of services. Natural capital accounting can be applied to communicate the wide range of values that farmers can derive from agroforestry assets, thus encouraging appropriate levels of investment.	To usefully apply a natural capital approach to agroforestry decision-making at the agricultural scale, future lines of research should seek to develop appropriate conceptual models for agroforestry systems, supported by evidence-based reviews; these models could be useful to improve consistency in the valuation of agroforestry assets, guide decision-making at the farm or paddock scale, and support the development of quantitative decision-making tools. As the evidence base for the value of natural capital in agriculture continues to grow, the methods and tools for measuring this value are also improving.

Table 5. Cont.

Authors	Title	Citations	Aim of the Paper	Main Conclusions	Main Contributions for Future Research
Boehnert (2016)	The Green Economy: Reconceptualizing The Natural Commons As Natural Capital. Environmental Communication 10:4 395–417 (2016).	20	This paper describes and analyzes the trajectory of environmental decision-making through different processes from the perspective of the green economy. Examines various conceptualizations of economic approaches to the environment and considers the philosophical, methodological, and political issues associated with the green economy project.	The most important theoretical conclusion focuses on highlighting that as the concept of natural capital is transformed, the intellectual work of the environmental movement is used to promote a project that denies its ideological foundations. It is up to environmental movements to distinguish the ways in which neoliberalism works to obscure its own processes through the co-option of environmental language. It is true that this conclusion is likely to be considered an expert opinion or value judgment.	Future research should explore the core features of ecosystems and ensure that these fundamental functionalities and capabilities are maintained for future generations and not squandered in present-day endeavors to maximize a small set of currently highly valued services.
Li et al. (2022)	Assessment Of Physical Quantity And Value Of Natural Capital In China Since The 21st Century Based On A Modified Ecological Footprint Model. Science Of The Total Environment 806:null null-null (2022).	17	The objective of this paper is to improve the accounting of the value of the ecological footprint model, to do so it selects national hectares (nha) as the unit of measurement and includes freshwater and pollution footprints. The dynamic changes in natural capital for the period 2000–2018 were calculated and analyzed for 31 provinces of the Republic of China.	Since the beginning of the 21st century, in China have experienced exponential growth, which has generated excessive consumption of resources that accompanies this growth, represented by urbanization and industrialization. Therefore, environmental pollution and resource depletion are serious, and it is difficult to relieve ecological pressure. The ecological pressure in China is spatially distributed in the order East > Center > West. Among China's provinces, Shanghai, Tianjin, and Beijing face the most notable ecological challenges, while Jilin, Qinghai, and Tibet face low ecological pressures.	As future lines of research, the same theoretical framework can be applied with the quantitative methods used to contrast the results in other economies whose growth has been significant in recent years.

Source: Own Elaboration.

Analyzing the articles, we find that the authors emphasize the importance of advancing the understanding and application of natural capital accounting (NCA) for comprehensive sustainability assessment. The described framework, while serving in some cases as a foundation for national and regional ecological flow and services accounting, is acknowledged as requiring supplementation with social indicators to holistically measure progress toward sustainability, accounting for people's quality of life. The identification of research needs is underscored, particularly in developing analytical methods and valuation approaches that integrate ecosystem services concepts into various policies. Although articles include specific cases, the need for additional research is evident, exploring common dynamics for all contexts. Key features of natural systems, such as non-linearities, irreversibilities, multi-functionality, adaptability, and resilience, are highlighted as critical considerations in NC accounting. In this approach, future research is urged to develop conceptual models and decision-making tools, ensuring consistency in asset valuation and supporting sustainable practices. Additionally, ongoing research should explore the core features of ecosystems, aiming to maintain fundamental functionalities for future generations. Lastly, the suggested theoretical framework is proposed for application in contrasting results across economies with significant recent growth, underlining the universality and adaptability of the approach in diverse contexts.

When analyzing the "Natural-capital-accounting" sub-network (Figure 7), it contains a wide network of terms that correlate with each other, with the most notable relationships being those related to sustainable development, ecosystem services, and the business economics of natural capital. It also shows how important collaborative work in the environment is for the improvement of natural capital accounting, which is shown through the connections between the terms "environmental policy", "sustainable development", and "biodiversity", which will be the pillars of the model developed.

After analyzing the articles shown in Table 6 related to Carbon Footprint, we conclude that the main future lines of research, according to these authors, should go beyond EQS and focus specifically on ecosystem accounting. They stress the need for comprehensive research and testing of ecosystem assessment, spatial integration, measurement, and valuation of ecosystem services. In addition, it calls for defining ecosystem degradation and its allocation to economic units. The need to develop indicators related to biodiversity, regulation, and maintenance of ecosystem services is identified in the context of the Natural Capital Investment Framework (NCIF). The development of interrelationships between indicators is considered crucial to address the issues of resource efficiency and depletion. The authors stress the importance of future research to provide guidance on the application of natural capital indicators to ensure consistency and comparability across countries for which pilot testing of the NCIF is recommended to understand its usefulness in different governance contexts. Considering global sustainability efforts, future lines of inquiry abound on the imperative need to combine the adoption of new NCA standards with unprecedented public spending on economic recovery to drive sustainable development. Future research must have a multidisciplinary effort, involving collaboration between individuals and institutions, to promote the integration, trust, and use of NCAs in decision-making processes.

**Table 6.** Main authors, citations, and papers belonging to cluster network for carbon footprint in all periods 1993–2023 with word groups.

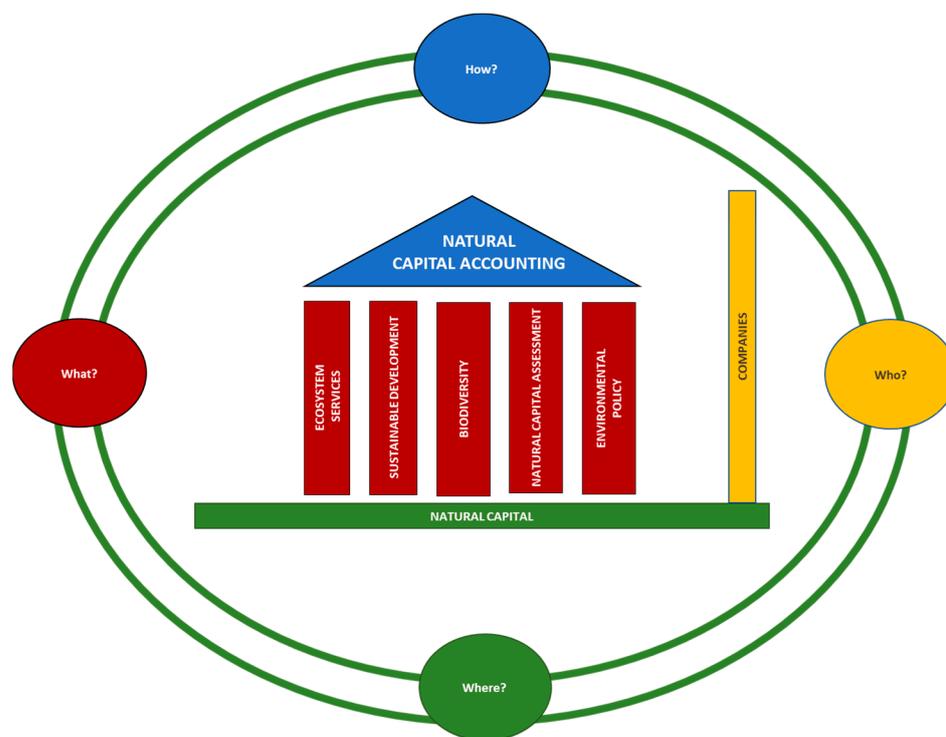
Authors	Title	Times Cited	Aim of the Paper	Main Conclusions	Main Contributions for Future Research
Obst (2015)	Reflections On Natural Capital Accounting At The National Level: Advances In The System Of Environmental-economic Accounting, Sustainability Accounting, Management and Policy Journal 6:3 315–339 (2015).	23	The authors present some reflections on the relative lack of “success” in displacing GDP as the leading measure of progress, well-being, and/or economic welfare in policy circles. It does so by reflecting on the role of accounting frameworks in the measurement of GDP and, from this position, discusses the potential of extending these frameworks via natural capital accounting.	There are important issues concern measurement and integration, such as the need for widely adopted international classifications of land use, land cover, and ecosystem types to support time-series and cross-country comparisons that require further investigation. Other issues relate to particular topic areas where the application of accounting principles is not well-established or has some particular challenges that need to be developed.	The paper shows a range of potential areas of NCA engagement. Particularly in the area of ecosystem accounting, there is much required research and testing in relation to the assessment of ecosystem condition, integration across spatial scales, the measurement and valuation of ecosystem services, the definition of ecosystem degradation and its allocation to economic units, and other areas.
Fairbrass et al. (2020)	The Natural Capital Indicator Framework (ncif) For Improved National Natural Capital Reporting. Ecosystem Services 46:null null-null (2020).	14	The paper introduces the Natural Capital Indicator Framework (NCIF) alongside example indicators, which provides an illustrative structure for countries to select and organize indicators to assess their use of, and dependence on, natural capital. The NCIF sits within a wider context of indicators related to natural, human, social, and manufactured capital, and associated flows of benefits.	Natural Capital emphasizes the need for national governments to value and account for natural capital in decision-making to avoid economic development that is dependent on unsustainable depletion of natural resources. Despite a range of initiatives and tools, such as natural capital accounting, there currently exists no comprehensive approach to natural capital.	According to this paper, future work is required to develop indicators for biodiversity as a condition of natural assets, regulation and maintenance ecosystem services, and marine assets. Inter-relationships between indicators across the NCIF may highlight issues such as efficiency and resource depletion, and this needs to be investigated. Guidance on applying natural capital indicators will be required to allow consistency and comparability among countries and an overall understanding of the state of natural capital, and the NCIF needs to be pilot tested to understand in what governance contexts it is useful.
Yamaguchi and Managi (2019)	Backward- And Forward-looking Shadow Prices In Inclusive Wealth Accounting: An Example Of Renewable Energy Capital. Ecological Economics 156:null 337–349 (2019).	13	Attaching weights to the list of capital assets is crucial in inclusive wealth accounting and sustainability assessments. These weights, or shadow prices, can be constructed in theory by looking prospectively at future social profits that the capital in question is expected to yield. In practice, however, both backward- and forward-looking shadow prices are used. This study confirms that these two approaches are theoretically equivalent under strong assumptions and reviews how and why the two approaches are taken.	The shadow prices of capital assets in wealth accounting should reflect their forward-looking income, as they represent their contribution to the well-being of future generations. In practice, however, the backward-looking approach is also used for practical reasons, particularly to avoid uncertainty. The authors have shown that these two shadow prices should be equivalent under simple assumptions and that current wealth accounting employs both approaches—the backward-looking approach for produced capital and the forward-looking approach for natural capital.	The paper is focus on the Renewable Energy Capital, so important research can be developed considering other sectors and the implications on the policy front.

Table 6. Cont.

Authors	Title	Times Cited	Aim of the Paper	Main Conclusions	Main Contributions for Future Research
Judd and Lonsdale (2021)	Applying Systems Thinking: The Ecosystem Approach And Natural Capital Approach Convergent Or Divergent Concepts In Marine Management?. Marine Policy 129:null-null (2021).	13	Using the unifying framework of Drivers, Activities, Pressures, State, Impact, Welfare, Response, and Measures of ecosystem Approach and NCA, authors propose that the requisite steps and underlying data to assess environmental status or natural capital status are broadly the same and that efficiency, transparency and utility of assessments will be improved if these concepts converge.	Applying this approach will help to standardize workstreams around common lists, thus providing efficiencies and comparability between assessments irrespective of the underlying methodology (or discipline). It also helps to provide a common vocabulary with components that will be equally meaningful to natural, social, or economic scientists. Applying a simple unifying schematic such as this supports the priorities of the UN Decade of the Ocean Science for Sustainable Development, as it facilitates collaboration and integration of environmental, social, and economic disciplines.	The approach is intended to facilitate the seamless incorporation of the Natural Capital Approach into marine policies and strategies originally wholly focused on the Ecosystem Approach. Following this rationale, it is anticipated that the incorporation of the Natural Capital Approach into national and international marine policy systems can be seen as a natural extension of existing data flows and assessment outputs, rather than requiring a completely new assessment strategy.
Wu et al. (2020)	The Use of Land Natural Capital in The Guanzhong Region Based on A Revised Three-dimensional Ecological Footprint Model.	10	Based on the revised three-dimensional ecological footprint model, this study used three scales including product, land use type, and region to quantitatively calculate the land use ecological footprint size and footprint depth of the Guanzhong region and its respective municipalities from 1995 to 2015.	The main conclusions of the study are that the land use ecological footprint of the Guanzhong region showed a trend of increasing first and then decreasing. The five large cities in the Guanzhong region were in the situation of ecological deficit, and construction land was the main land use type occupied by natural capital flows, while grassland, cropland, and construction land were the main land use types of natural capital stocks.	This paper opens the possibility to carry out similar studies in other cities/countries using the same methodology.
Vardon et al. (2023)	From COVID-19 To Green Recovery With Natural Capital Accounting. Ambio 52:1 15–29 (2023).	10	After COVID-19, the economic recovery is now an opportunity to rebuild natural capital alongside financial, physical, social, and human capital for long-term societal benefit, as current decision-making is dominated by economic imperatives and information systems that do not consider society's dependence on natural capital and the ecosystem services it provides.	NCA is a potential catalyst for Green Recovery, but a critical next step is necessary to ensure purposeful action, which will require investment in information. Although accounts are proliferating and some underpinning data are improving over time, account production is still dependent on basic data collection and appropriate expertise.	As the world is turning to sustainable models, it is imperative to turn the combined adoption of the new NCA standards and the unprecedented levels of government spending for economic recovery, to move along the sustainable development pathway. Many options are available to make such a Green Recovery a reality. To achieve this, a multidisciplinary effort is needed with people and institutions working together to promote NCA so that it is embedded, trusted, and used in decision-making.

Source: Own Elaboration.

The “Carbon footprint” network (Figure 8) for all periods in 1993–2023, shows that the most important keywords in the group are “national initiatives” and “climate change”. The keywords are strongly correlated with carbon footprint. The cluster of words “country initiatives” includes a list of countries and regions using different approaches to combat climate change and reduce carbon emissions. The “carbon footprint” network has gained prominence in recent years due to the enormous growth in the number of environmental policies that have taken place in the last 10 years.



**Figure 8.** Research Avenues Model for NCA. Source: Own elaboration.

#### 4. Discussion

Based on the previous analysis, which shows us the absence of decisive results in the bibliometric analysis carried out shows that this is still a young line of research that needs to be further developed in different areas.

We develop a model to define, based on the most valuable characteristics (the what, the where, the who, the how), the main avenues of research in NCA.

The pillar underpinning our model, “what”, is the companies’ own need to define their relationship with natural capital, as shown in Section 2 of this article.

The cross-cutting issue, “the who”, indicates that it is the company that is the driver of change; of course, it is the one that has the capacity to introduce in its information collection, analysis, and valuation practices the necessary procedure for natural capital accounting and, therefore, the one that is able to assimilate the change driven by government agendas towards a zero carbon economy.

The ceiling of the model is “the how”. The implementation of all the changes we are obliged to make will only be possible through the implementation and improvement of 5 items in the daily processes of companies: firstly, the relationship with ecosystem services and sustainable development, secondly, the relationship with biodiversity, followed by environmental policies, and finally, the valuation of natural capital, to be able to achieve the accounting of this asset.

Therefore, to answer the research question posed, “How to orient/direct future research on natural capital accounting?”, the line of research to be addressed is established

for each thematic group of the analysis, according to the results obtained in the model, as well as the research question to be posed.

As a development of the model and after analyzing all results, Table 7 summarizes our proposal of lines of future research.

**Table 7.** Lines of Future Research based on the Research Avenues Model.

Thematic Groups	Lines of Research	Question of Research
Ecosystem Services	The dependence of natural capital on supply chains and product life cycles is determined by the combination of detrimental effects on ecosystems, on the one hand, and direct and/or indirect beneficial impacts on human welfare, on the other, opening here an important line of research. It is therefore proposed to advance research on Studying the application of life-cycle based approaches in EQS to quantify detrimental impacts using specific characterization models and environmental impact category indicators. Research in ecosystem services accounting constitutes an emerging field where to propose theoretical and methodological developments in different directions, defining concepts and methods aligned with the principles of accounting, ecology and economics.	How to account for ecosystem services?
Sustainable development	Consistent sustainable development requires additional, non-alternative indicators that incorporate ecological thresholds through corresponding accounting prices and that can simultaneously be practically feasible.	Which are the indicators linked to sustainable development to be incorporated in NCA?
Natural capital assessment	NCA is an approach to improve decision making through the (complex) valuation of natural resources, with potential applications at the individual, organizational and political scales, with future lines of research around values, valuation complexity, digital technology and future regulatory developments around NCA.	Which valuation methods have to be developed to measure natural capital at different organizations?
Environmental policy	The identification of environmental policies is fundamental. Further research is needed to identify environmental policies that will boost business productivity.	How can companies be institutionally driven to natural capital accounting?
Biodiversity	There is a clear need to further develop accounting methodologies to estimate how different ways of operating companies can worsen or improve their impact on biodiversity.	How to estimate the impact of business performance on biodiversity?

Source: Own Elaboration.

## 5. Conclusions

The main contribution of this paper is to point out the low degree of development of research in the topic of Natural Capital Accounting at the microeconomic level and the need for it to record and avoid intangible liabilities in all the Natural Capital Scope.

The paper analyzes the relationship among Intangible Liabilities, Natural Capital, and Reputation for MNE and the need to study this topic to record the impact of MNE in Natural Capital, as a new or not deeply studied concept in International Business research. We identify the sources of this implicit intangible liability coming from the Natural Capital that it may be related to the competitiveness of the firm. We also argue the correlation expected between the behavior of the firm regarding natural capital and the specific and singular intangible assets such as Reputation.

This paper also contributes to determining the relevance of firms' reputations and their connection to natural capital accounting to avoid intangible liabilities. An efficient record of natural capital will be reflected in the value of the firm and in another singular and important intangible asset: its reputation. In this respect, a loss or gain in reputation should be correlated to the competitiveness of the firm. A reduction in the reputation might be due

to bad practices, bad decisions, and bad relationships between the firm and natural capital that may lead to intangible liabilities with the obligation of future payments to third parties. Thus, the depreciation of intangible assets such as natural capital has an influence on a reduction of equity value, and in certain cases due to contingencies, intangible liabilities may possibly emerge.

Based on this, NCA research is essential in a world where natural resources are becoming increasingly scarce. Traditional accounting does not adequately reflect the degradation and depletion of these resources, which underestimates the associated risks and threats. Natural Capital Accounting provides critical information for business decision-making and policies that promote sustainability. MNEs can use this information to assess the environmental impact of their operations and design strategies to minimize that impact across both their subsidiaries and their supply chain.

In summary, Natural Capital Accounting research presents an important field of inquiry and is central to addressing contemporary environmental, economic, and social challenges.

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## Notes

<sup>1</sup> We only cite some of the main representatives authors on these topics.

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