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FOOD SECURITY AND ITS CONNECTION WITH ENVIRONMENTAL ECONOMICS AND ACCOUNTING: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

Objective: Map and present the state of the scientific art on food security and its connection with Economics and Environmental Accounting.

Theoretical framework: The limits of economic use of ecosystem services were extrapolated, the evidence of which lies in climate change and subsequent heterogeneous food availability. From this perspective, the accounting and economic impacts of environmental changes are apparently underestimated by industrial chains that exploit natural capital.

Method: A bibliometric analysis of scientific publications was carried out, that were prospected in the Scopus database. 377 scientific publications published between 1986 and 2023 were retrieved. The mining and analysis of the correlation between Economics and Accounting with food security was carried out based on of the co-occurrence of keywords indicated by the authors of the retrieved documents, using the VantagePoint® software.

Results: The results of the bibliometric search show greater progress in research in environmental economics. Conversely, the gaps in the valuation of environmental assets, the absence of validated indicators for the inclusion of natural capital in national accounting systems and the voluntary nature of the disclosure of accounting, financial and socio-environmental data may be the explanations for the lack of connection between food safety and environmental accounting.

Research implications: Scientific advances in the calculation of the Green Gross Domestic Product and/or in the adaptation of the SEEA (System of Environmental-Economic Accounts) methodology can generate accounting and economic data from the organization of stocks of environmental assets and favor the availability of food.

Keywords: Natural Capital, Food Availability, Sustainable Development, Disclosure, Macroeconomics.

SEGURANÇA ALIMENTAR E SUA CONEXÃO COM ECONOMIA E CONTABILIDADE AMBIENTAIS: UMA ANÁLISE BIBLIOMÉTRICA

RESUMO

Objetivo: Mapear e apresentar o estado da arte científica sobre segurança alimentar e sua conexão com a Economia e a Contabilidade Ambiental.

Referencial Teórico: Os limites de uso econômico dos serviços ecossistêmicos foram extrapolados, cujas evidências estão nas mudanças climáticas e posterior disponibilidade heterogênea de alimentos. Nessa perspectiva, os impactos contábeis e econômicos das mudanças ambientais são, aparentemente, subestimados por cadeias industriais que exploram o capital natural.

Método: Executou-se uma análise bibliométrica de artigos científicos, prospectadas na base de dados Scopus. Foram recuperadas 377 publicações científicas publicadas entre 1986 e 2023. A mineração e a análise da correlação entre a Economia e a Contabilidade com a segurança alimentar foi feita a partir da co-ocorrência das palavras-

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chaves indicadas pelos autores dos documentos recuperados, usando o software VantagePoint®.

Resultados: Os resultados da busca bibliométrica mostram um maior avanço das pesquisas em economia ambiental. Em sentido contrário, as lacunas na valoração de ativos ambientais, a ausência de indicadores validados para inclusão do capital natural em sistemas de contas nacionais e o caráter voluntário do *disclosure* de dados contábeis e, financeiras e socioambientais podem ser as explicações para a inexistência de conexão entre segurança alimentar e contabilidade ambiental.

Implicações da pesquisa: Avanços científicos no cálculo do Produto Interno Bruto Verde e/ou na adaptação da metodologia SEEA (*System of Environmental-Economic Accounts*) pode gerar dados contábeis e econômicos a partir da organização de estoques de ativos ambientais e favorecer a disponibilidade de alimentos.

Palavras-chave: Capital Natural, Disponibilidade de Alimentos, Desenvolvimento Sustentável, Disclosure, Macroeconomia.

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1 INTRODUCTION

In any crisis, be it economic or social, the availability of food is always at the forefront to ensure survival, tied to the environment, both for food and for housing and subsistence (Lang, 2020). Adopting a circular economy model for crop and livestock production that meets the demand for food for an ever-growing population is one of the global challenges (Babu et al., 2020).

Life on planet Earth is linked to the capacity to provide ecosystem services, and this has become the concept used to express values attributed to goods and services provided by the environment, such as leisure, food supply and plant pollination (MEA, 2005; TEEB, 2008; Bennett et al., 2015). In this scope is food security, a concept created by the FAO (*Food and Agriculture Organization*), which represents the guarantee of universal access (physical, social and economic) to food in quality and quantity necessary for the health and well-being of society, based on the pillars of availability and accessibility of food and stability in supply (Bishopp and Lynch, 2015; Erokhin, 2017; FAO, 2018).

Biodiversity is the main link to the provision of ecosystem services, with strong anthropogenic pressure that has generated, for example, the 60% drop in vertebrates in the world population since the 1970s and, with an increasing trend (Newbold et al., 2019). In such a scenario, the valuation and valorization of ecosystem services and the fulfillment of international commitments such as the Convention on Biological Diversity and the Nagoya Protocol, in addition to the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs), become crucial tools, aiming at the sustainable management and guarantee of ecosystem services, which will guarantee food security, such as pollination and precipitation (Joly et al., 2011).

Syvitski et al. (2020) attest that limits on the economic use of ecosystem services for food and energy production or the provision of industrial and health services have been exceeded. In the business context, adopting the vision of future depletion of environmental assets and the lack of substitutes, the implementation and evidence of actions of socio-environmental responsibility, became competitive advantages in the light of the positive evaluation of *stakeholders*, customers and market and strategic vision (long term) (Nogueira, Medeiros & Arruda, 2000; Santos, Issifou & Dias, 2022). Thus, Seddon et al. (2020) indicate that technological solutions and social and economic decisions with the environment should

converge on three challenges: mitigating climate change, protecting biodiversity and ensuring the well-being of the human population, including the availability of food.

One of the negative impacts of limiting the economic use of ecosystem services is the availability of food to an increasing global population, where the pressure for food alternatives increases and the need for market adaptations for new social, political and economic scenarios. Adjustments to ensure food security are made for various reasons, among them increasingly unfavorable environmental conditions (increase in environmental temperature, deforestation, emission of greenhouse gases) which are responsible for the consequences of irreversible damage to ecosystems, to the point of not recovering any more and making mitigation actions unsustainable (Carleton and Hsiang, 2016).

Ehrlich and Harte (2015), Bishopp and Lynch (2015) and Goldstein, Turner, Gladstone and Hole (2019) pointed out that the accounting and economic impacts of environmental changes were underestimated by the various industrial segments that use natural capital, which represents the stock of products (water, air, soil, biodiversity and forests, for example) and services (pollination, air quality, rainfall regime, for example) that the environment provides for human survival (Monzoni & Vendramini, 2017). In this context, the objective of this work is to map and present the state of the art science on food security and its connection with the Environmental Economy and Accounting.

2 LITERATURE REVIEW

FAO, IFAD, UNICEF, WFP and WHO (2019) estimate that there are 690 million people in the world (8.9% of the world population) at some stage of food insecurity, such as undernutrition, overweight, obesity or metabolic conditions arising from food imbalances (chronic non-communicable diseases such as diabetes, systemic arterial hypertension and hypercholesterolemia). Bocchi et al. (2020) complement this information by associating access to food with family income and poverty rates, being the biggest bottleneck in food insecurity, the unavailability of protein and high calorie content.

The goal of the Paris Agreement, signed at the United Nations Framework Convention on Climate Change (UNFCCC) during the 21st Conference of the Parties (COP-21), is to halt global warming so that it does not exceed 2°C increase and strengthen climate change adaptation capacity with a focus on food security, low-carbon economy and accounting transparency (Bruno, Frozza & Fraga, 2017; Lipper, Cavatassi, Symons, Gordes & Page, 2021).

The study by Van Dijk, Morley, Rau and Saghai (2021) developed five scenarios covering diverging and at the same time plausible socioeconomic futures between 2010 and 2050. The authors concluded that food availability is directly associated with climate change: food demand has grown from 30% in 2010 to 62% in 2050. Thus, Erokhin (2017) pointed out that in 2016, the main causes of food insecurity were natural disasters and extreme temperature events, particularly in countries with inadequate capacities to respond to these climatic events, in addition to poor food distribution, increased demand for food in the world and instability in domestic crop and livestock farming.

Ehrlich and Harte (2015), Bishopp and Lynch (2015), Carleton and Hsiang (2016) and Goldstein et al. (2019) point out the consequences of climate change in farming chains for food security:

- Increased incidence of biotic (agricultural pests) and abiotic (temperature extremes and rainfall irregularities, for example) stresses that negatively impact the farming and agro-industrial sectors, which in turn increase the final price of food for the consumer;
- Increased land use in farming activities, which lead to a drop in the quality and quantity of water available;

- soil degradation and fertility loss due to erosion;
- soil contamination through excessive use of pesticides;
- Loss of native biodiversity and decrease of genetic diversity of cultivated plants, increasing subsequent costs of processing;
- Loss of control of agricultural pests as a result of climate change;
- Reduction of pollinating animals due to changes in air humidity, food availability and excessive use of agrochemicals;
- Increased dependence on marginal crops and pastures;
- Low access to information by small farmers, including family farming and traditional communities.

The Accounting and Economic Sciences refers to indicators and data that allow to evaluate financial issues involved in the production and supply of food, performance indicators of public and private organizations, in environmental topics, as well as in Socio-Environmental Responsibility and inclusion of natural capital in the calculation of macroeconomic aggregates and in national accounting systems. In short, in the scope of environmental security, financial and economic data allow to evaluate the effectiveness of public policies and support the farming sector for the supply of food at affordable costs to society (Moura, 2016), contemplated in the scope of the Anthropocene (Bebbington & Rubin, 2022).

The involvement of Accounting Sciences with environmental issues dates from the 1970s, with studies that indicated that the inclusion of environmental indicators in corporate management, would help in the solution of financial and accounting problems, and that would reflect their positioning in the market (Ribeiro, 2010). The preponderant involvement of the Economic Sciences with intellectual development, promoted by the Club of Rome starting from the population theory of Thomas Malthus, has as one of its exponents the publication of the report "The Limits of Growth", in 1972. This report presented a new perception that the environment is no longer untouched and infinite and proposing that the exploitation of environmental assets should be done in a controlled manner in the face of the imminence of sewage (Gois, Issifou & Anjos, 2022; Santos et al., 2022).).

Natural capital is a group of capital types that are relevant and add value to organizations (others are: financial, manufacturing, intellectual, human, social and relationship), natural capital being what has no explicit economic value and that have no substitutes (Nogueira et al., 2000; Monzoni & Vendramini, 2017). There are shortcomings in the measurement and subsequent allocation of values which, in turn, will generate inaccurate data in national accounts and company accounts, not counting the over-exploitation of natural capital due to the lack of limit parameters (Nogueira et al., 2000; Monzoni & Vendramini, 2017). Thus, the monetarization and valuation of natural capital are not carried out to the satisfaction, due to the lack of indicators that allow the inclusion of the environment and its degradation in national accounting systems, besides the difficulty in establishing already developed indicators and the relative intangibility of environmental assets (Nogueira et al., 2000; Monzoni & Vendramini, 2017; Gois & Nogueira, 2020; Dasgupta, 2021; King et al., 2021). The management of expectations with the precision and feasibility of monetary evaluation of environmental assets, is difficult by limiting access to real data and by individual interests in obtaining financial value (Vogl et al., 2017).

Dasgupta (2021) complements Nogueira et al. (2000) and Monzoni and Vendramini (2017), *reinforcing the problems of the mentioned distortions when presenting global health data per capita*, between 1992 and 2014. From national accounts that attest to the 100% growth in production capital, 13% increase in human capital and 40% fall in natural capital (stocks for forestry, fish farming and agriculture), which is not accounted for and which, may negatively impact the farming sector and, consequently, the availability of food at affordable costs.

Alternatives to address food insecurities are developed and applied worldwide, whether to offer other protein options or to stimulate the economic landscape, trade balance and the availability of affordable food. Maggio, Van Criekinge and Malingreau (2015) list more alternatives:

- Development of new systems of agricultural production, with greater income at lower costs and with technical and economic viability;
- Promoting rural development and management, including tools for property management and strengthening logistics chains for transporting products at competitive costs;
- Development of a demand-driven food system in which production and consumption are balanced at local, regional and global levels;
- Alignment of food demand to sustainable precepts, promoting changes in consumer behavior.

3 MATERIALS AND METHODS

Bibliometry is a quantitative analysis of a set of scientific publications for the analysis, evaluation and monitoring of Research, Development and Innovation (PD&I) activities, to correlate scientific data with technological data (Ribeiro, 2017; Santos et al., 2018). This bibliometric study has an exploratory and quantitative character, focusing on evidence to explain or predict phenomena from evidence present in formal documents (Popper, 2008). Starting from this premise, scientific articles were prospected and retrieved in the *Scopus* database that presented the keywords "food safety", "environmental economy" and "environmental accounting" in the English language.

The search strategy ("*(TITLE-ABS-KEY ("food security*") AND TITLE-ABS-KEY ("environ* econom*" OR "econom* environ* ") OR TITLE-ABS-KEY ("environ* account*" OR "account* environ*") AND (LIMIT-TO (DOCTYPE , "ar"))*") retrieved 377 documents. The search was made on 29/03/2023 and no deadline for publication of the documents was used until that time. It was chosen not to include literature reviews, book chapters, publications in conference proceedings and editorials.

The *VantagePoint*® software (Search Technology) was used for data mining and cleaning, which allows to eliminate redundancies and implant minimum criteria for inclusion or exclusion of terms for later interpretation of bibliometric data (Miles, Saritas, Sokolov, 2016). In this article, to assess the state of the art of scientific research in food security in the economic and accounting fields, the keywords of the documents retrieved, the years of publication and the publishing countries were selected and mined. Similar terms were grouped into broader ones and those with an occurrence less than 5 were eliminated.

The 377 documents had 2,836 keywords. After the mining and data cleansing, there were 16 keywords that refer to Food Security, Environmental Economy, Environmental Accounting and social, political, technological and environmental factors inherent to the topics under study (Table 1):

Table 1: Sixteen key words mined from the documents retrieved from the search for scientific publications on food safety, environmental economics and accounting between 1986 and 2023

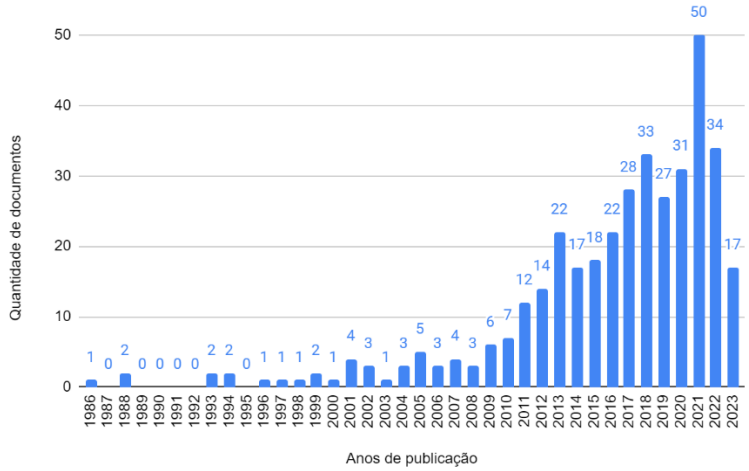
Descending order	Quantity of documents	Keywords
1.	270	Food security
2.	222	Sustainable development
3.	219	Agriculture and Livestock
4.	164	Environmental economics

5	101	Climate change and GHG emissions
6	95	Soil and land use
7	88	Food chain
8	85	Natural resources and biodiversity
9	81	Policies
10	78	Livelihood of the society
11	68	Water management
12	44	Energy production and consumption
13	36	Waste management
14	16	Biotechnology
15	12	ST&I (science, technology, and innovation)
16	6	Environmental accountability

Source: prepared by the authors.

4 RESULTS AND DISCUSSION

The documents recovered were published between 1986 and 2023. During this period, the Brundtland Report (1987), the eight Millennium Development Goals - MDGs (2000 to 2015) and the fifteen Sustainable Development Goals - SDGs (2015 to 2030) were launched. Graph 1 shows an increase in publications from 2011 onwards, corresponding to the last four years of the MDGs, the same period as the United Nations Conference on Sustainable Development (Rio+20) in 2012, the subsequent publication of the SDGs in 2015 and the signature in 2015 and the validity from 2016 of the Paris Agreement.



Graph 1: Histogram of the number of documents retrieved in the years of publication (prepared by the authors).
Source: prepared by the authors.

The recovered documents were published in 93 countries, on all continents, with emphasis on the United States of America, China, United Kingdom, Italy, Australia, Germany and the Netherlands (Figure 1). The global scope of scientific publications addressing the link between food security, accounting and environmental economics reflects the actions and targets proposed by the SDGs and ongoing by FAO to ensure climate-change-aligned food security.

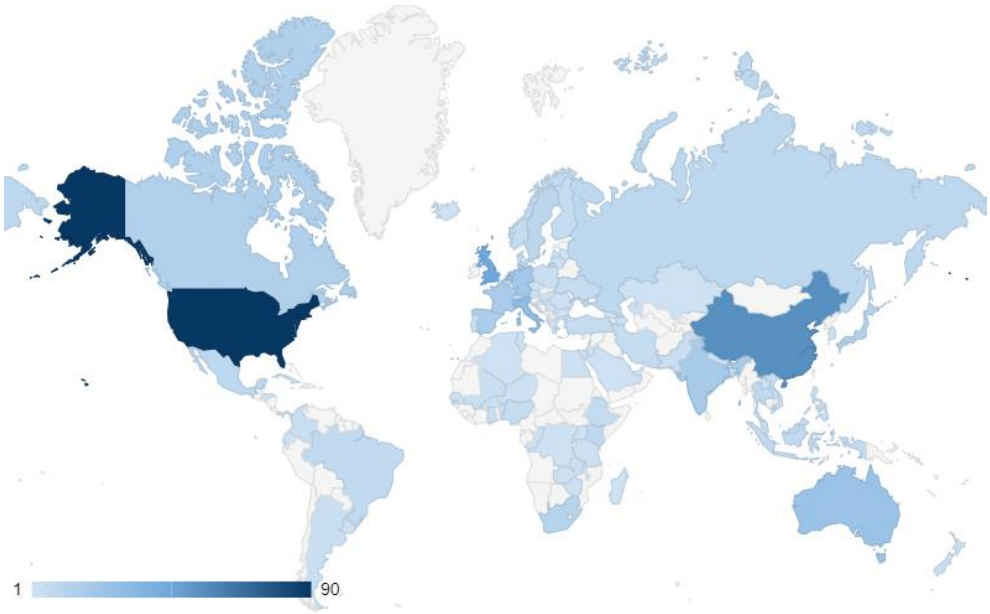
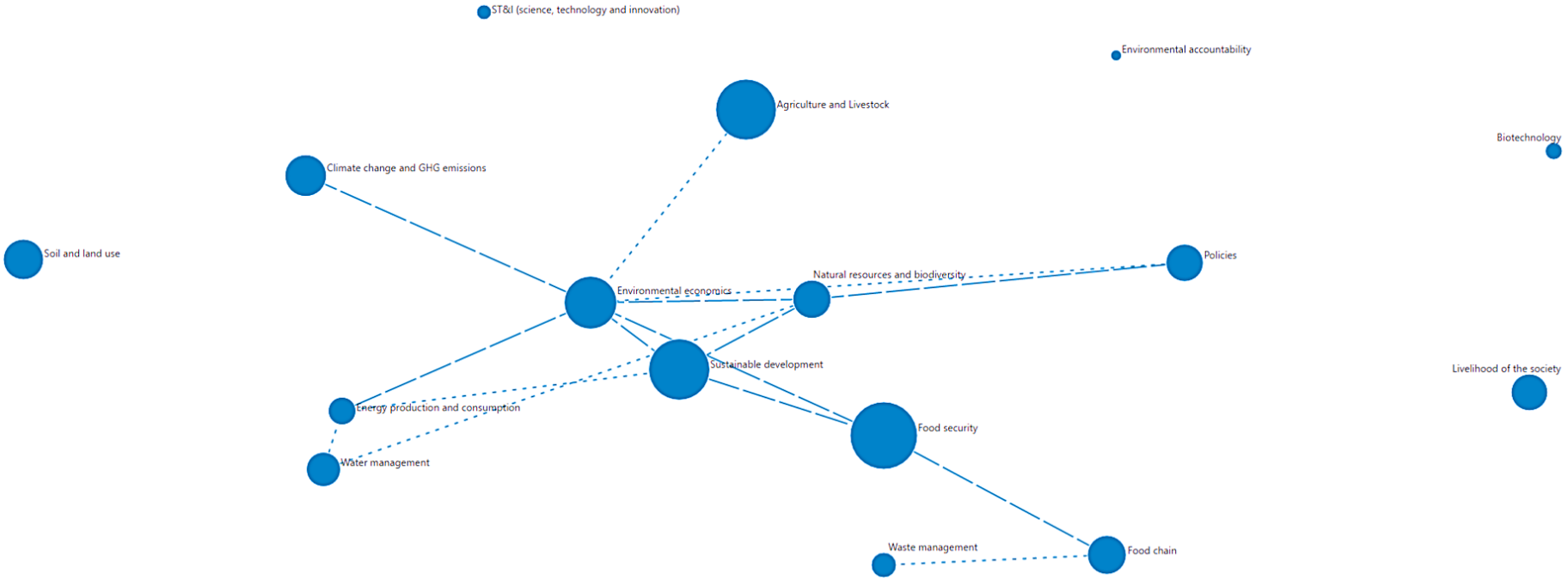


Figure 1: Map of distribution of publications in 93 countries.
Source: elaborated by the authors.

The 16 keywords listed in Table 1 were plotted on an autocorrelation map, which shows the relationship of the keywords to each other forming clusters and the connections to each other (Graph 2). The number of documents retrieved is directly proportional to the node size, which represents each keyword. The lines, on the other hand, represent similarities between each node and their thickness represents the number of documents that show the connected keywords (Thavorn, Gowanit, Muangsin & Muangsin, 2021). Thus, the largest nodes are the keywords ‘Food security’, ‘Sustainable development’, ‘Environmental economics’ and ‘Agriculture and Livestock’, which are more closely linked to each other and have the terms ‘Climate change and GHG emissions’, ‘Energy production and consumption’, ‘Natural resources and biodiversity’ and ‘Policies’.

The greater number of documents retrieved with the term "Environmental economics" reflects the existence of connections of different intensities. The connections of the term "Environmental economics" with greater representativeness refer to climate change, energy production, food security and sustainable development. "Agriculture and livestock" and "Policies" have weak connections. Waste management, water management, natural resources and biodiversity and the food chain have no connection with environmental economics. In the margin of the self-correlation map (Figure 3) are the terms "Environmental accountability", "Biotechnology", "Livelihood of the Society", "Soil and land use" and "ST&I (Science, Technology, and Innovation")", without connections to other keywords and representing isolated publications for each term and without self-correlation.

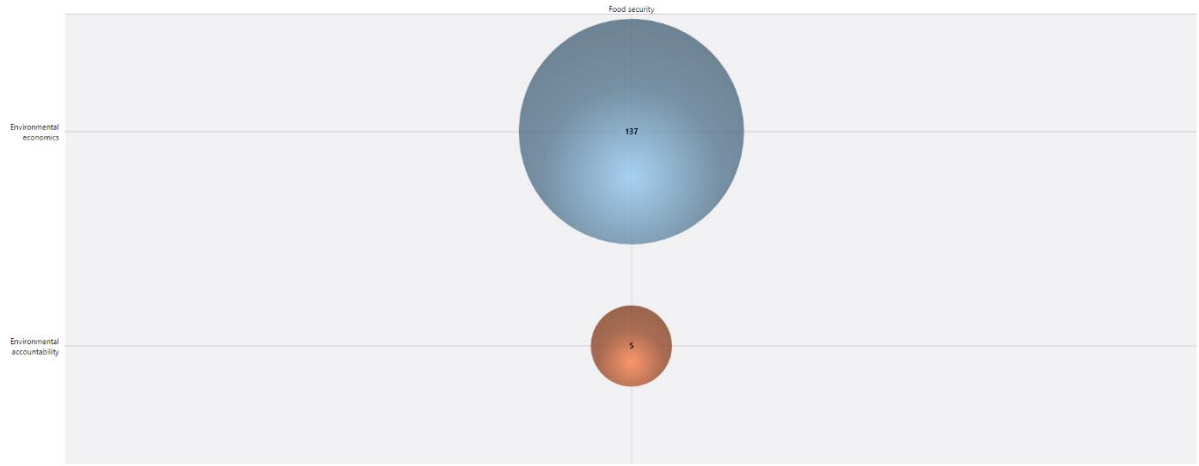


Graph 2: Self-correlation between the 16 keywords obtained from mining in the VantagePoint® software of keywords in scientific publications on food security, environmental economics and environmental accounting between 1986 and 2023.
Source: prepared by the authors.

Skaf, Buonocore, Dumontet, Capone and Franzese (2019) and King et al. (2021) describe Environmental Accounting and the Environmental Economy as tools for assessing environmental costs, food production, even more for a population growth horizon, reaching more than 9 billion people by 2050. The results show a growth in the quantity of publications, associating food security with economy and environmental accounting, as well as the interdisciplinarity of environmental sustainability and its link with the production and availability of food, in accordance with the temporal evolution of the concept of sustainable development.

Skaf et al. (2019) and King et al. (2021) point out that approaches to food security should be made from an interdisciplinary perspective (economic, social and environmental barriers) and multi-criteria (fossil fuel consumption, water demand, energy demand and control of greenhouse gas emissions). Also to be included in the discussion are agriculture (also extending to cattle raising) and biotechnology/genetic engineering, for collaborating directly in guaranteeing food security by generating cultivars and animal breeds adapted to biotic and abiotic stresses, allowing the expansion of the agricultural frontier and making biotechnology accessible. The results presented in Figure 2 indicate partial realization of the notes of Skaf et al. (2019) and King et al. (2021), with a greater focus on climate change.

Although the connections between environmental sciences and economic and accounting sciences date back to the 1970s, coupled with the interdisciplinary character of sustainable development, the results of this study show low cooccurrence of environmental accounting compared to environmental economics (Graph 3).



Graph 3: Map of co-occurrence of "food security" with "Environmental economics" and "Environmental accountability".
Source: prepared by the authors.

The results also reinforced the notes of Ehrlich and Harte (2015), Bishopp and Lynch (2015) and Goldstein et al. (2019) on the underestimation of accounting and economic impacts on natural capital exploitation. This dichotomy is clear by stratifying countries with publications only on environmental economy (Figure 2) and environmental accounting (Figure 3) (both interlinked with food security).

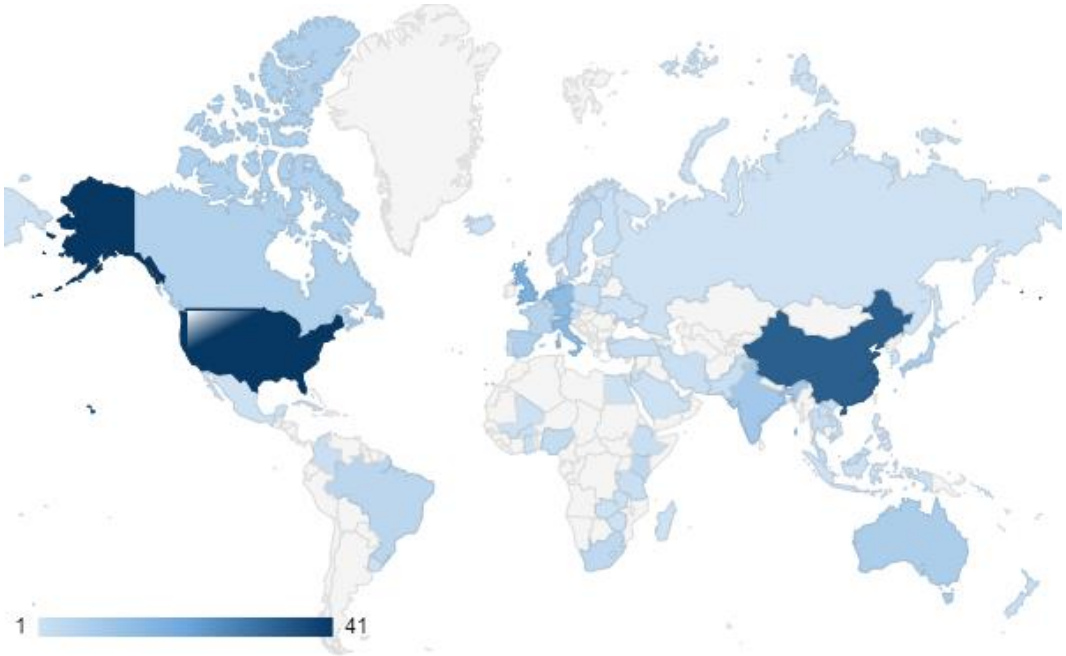


Figure 2: Countries with publications on environmental economics only.
Source: elaborated by the authors.

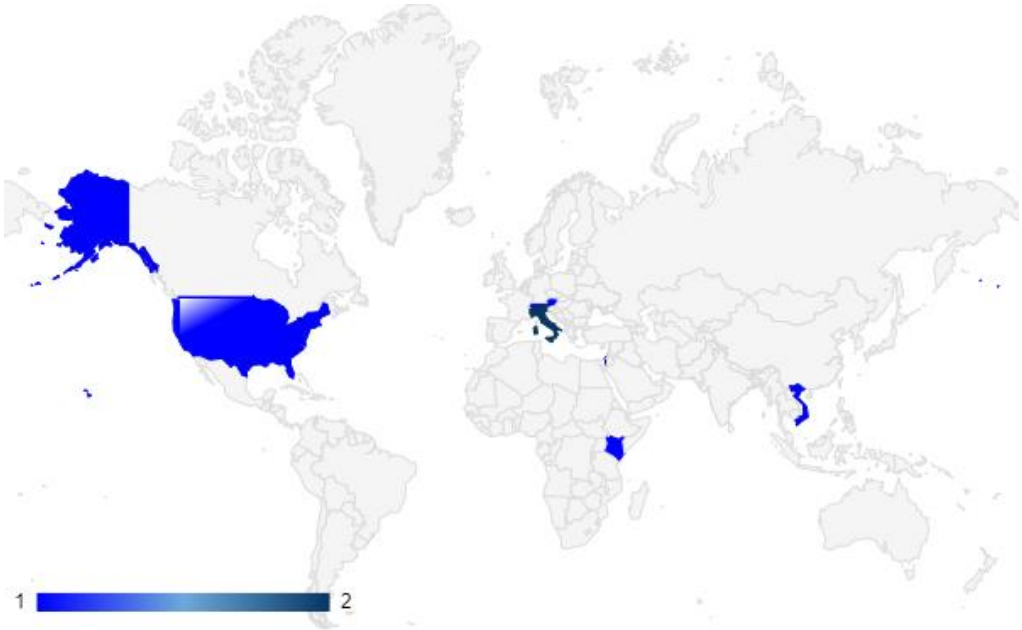


Figure 3: Countries with publications on environmental accounting only.
Source: prepared by the authors.

Evidence of economic, financial and socio-environmental information is the mechanism to present to stakeholders and society the actions for preserving the environment and collaborate to meet the challenges pointed out by Seddon et al. (2020) (mitigation of climate change, protection of biodiversity and guarantee of the well-being of the human population, including that of the next generations). This evidence, despite being one of the pillars of Accounting and extending to the indication of dependent and independent variables for economic analysis, is voluntary and may lead companies to declare information of greater weight in marketing than real data (Golay, Biglino & Truscan, 2012; Freire & Gomes, 2022; Gois et al., 2022) and may be a cause of the low amount of documents referring to Environmental Accounting and the lack of connection with food security.

Even with the development and inclusion of environmental indicators in business management and the improvement of conceptual and methodological indicators in the connection between accounting and environmental sciences, especially in the current climate change context (Ribeiro, 2010; Bebbington & Rubin, 2022), there are still academic bottlenecks such as the limitation imposed by scientific journals that mostly do not include accounting investigations from environmental perspectives (Bebbington & Rubin, 2022).

Corroborating this perspective, Guggisberg (2019) attests that multilateral funds created for climate change mitigation do not provide sufficient transparency in the funded projects, generating data with bias that negatively interfere with the efficiency of the projects and the inadequate allocation of financial and economic resources, particularly those of the government. Associated with inadequate accounting evidence, distortions in the quantification and monetarization of natural capital and/or its degradation lead to failures in the system of national accounts by not including environmental indicators in the calculation of Gross Domestic Product (GDP) and other macroeconomic aggregates (Dasgupta, 2021; Gois & Nogueira, 2020).

5 FINAL CONSIDERATIONS

The results of the bibliometric search show that there are scientific studies that correlate the control of climatic changes and agriculture and cattle raising with the economy of the environment and food security, which favors, in the long term, the Paris Agreement and the targets stipulated at COP 26 (the 26th conference of the parties to the United Nations Framework Convention on Climate Change) and COP 27 (the 27th conference of the parties to the United Nations Framework Convention on Climate Change). The same did not happen with environmental accounting, which did not show any connections between other keywords and remained on the margins of the clusters formed in the self-correlation map. The gaps in the valuation of environmental assets, the absence of validated indicators for inclusion of natural capital in national accounting systems and the voluntary nature of the *disclosure* of accounting and financial and socio-environmental data may be the explanations for the low connection between food security and environmental accounting

The improvement of the calculation of the Gross Domestic Product (GDP) can be a way to strengthen the connections of food security with the Economy and Environmental Accounting and generate effective results in the availability of food coupled with the preservation of the environment. Another plausible path is the advance in research to adapt the SEEA (*System of Environmental-Economic Accounts*) *methodology*, which proposes an organization of the stocks of environmental assets, particularly the γ diversity, which makes it possible to construct flows in ecosystem services and subsequent framing in accounting periods. As a result, indicators are being generated that will succeed in curbing negative actions such as climate change, which have a direct impact on the quality and quantity of food in world society.

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