Journal of Innovations and Sustainability
ISSN 2367-8151
2024, Vol. 8, No. 3
https://is-journal.com

FINANCING SUSTAINABLE DEVELOPMENT AND THE CIRCULAR ECONOMY: ESSENCE, SOURCES AND BIBLIOMETRIC LANDSCAPE

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Strapchuk, S., & Strapchuk, O. (2024). Financing sustainable development and the circular economy: essence, sources and bibliometric landscape. *Journal of Innovations and Sustainability*, 8(3), 02. https://doi.org/10.51599/is.2024.08.03.02.

Purpose. The purpose of the article is to determine the latest trends in scientific research in the world and the evolution of theories on the issues of financing sustainable development and the circular economy using multi-level bibliometric analysis, based on the capabilities of modern analytical software, as well as providing recommendations for future research.
Results. The research involves a bibliometric analysis of scientific publications indexed in the Scopus database using the key words "financing sustainable development" and "financing the circular economy". The built-in toolkit of the scientometric base made it possible to identify the chronological trends of publications by topic, the rating of authors and the countries they represent, types of scientific works, and the share of belonging to the subject area of research. Further work with analytical data using the VOSviewer software makes it possible to isolate clusters by keywords and identify possible strategic vectors of research with clarification of changes in the trends of scientific interests of authors in time intervals.
Scientific novelty. The scientific novelty is in the further development of studies of conceptual shifts in the financing sustainable development and the circular economy, taking into account world trends in economic development, which is based on a bibliographic analysis of publication activity on the subject of the study, which made it possible to create forecasts of world publication activity for the period until 2026 and to form conceptual provisions on the need for financial support for the ideas of sustainable development and circular economy in agricultural enterprises.
Practical value. The results of the study can be used by scientists, representatives of business and government institutions involved in the research of financing sustainable development and circular economy in Ukraine and the world.
Key words: financing, sustainable development, circular economy, bibliometric analysis.

Introduction. In the context of the transformation of worldview guidelines aimed at sustainable economic growth in an environmentally and socially sustainable manner, the issue of providing capital to enterprises operating on the principles of sustainable development is becoming more relevant. This requires an understanding of the financing processes, their methods and consideration of possible alternative sources of financing.

The limitation of natural resources and the transition to a carbon-neutral way of farming requires financial solutions for launching ecologically clean production. By

combining the efforts of financial institutions and companies that adopt effective innovative industrial practices and take into account the environmental benefits of sustainable development, it is possible to make optimal use of resources with minimal waste generation and minimisation of the negative impact on the environment. Scientific research is focused on the need for a balance between environmental benefits and economic progress [1]. The perspectives of financing sustainable development and the circular economy determine the need to increase transparency through standardisation and reporting, and to increase financial volumes through various institutions and portfolio expansion strategies [2].

In recent years, there has been a significant surge of interest among scientists in the research areas of financing sustainable development and the circular economy, which is confirmed by the increase in the number of publications [3]. This requires a comprehensive review and analysis of existing research to gain a holistic understanding and define future research trajectories, maximising the impact of the combination of sustainable development and the circular economy in various fields.

Review of literature. The main principle of financing sustainable development initiatives and the circular economy is built around obtaining a long-term economic effect under the auspices of environmental and social development [4]. In other words, funding should be targeted at companies that are trying to minimize their negative impact on environmental and social sustainability. Well-managed financing policies can increase the effectiveness of carbon reduction efforts and even turn climate change into a catalyst for favorable national outcomes, contributing to a gradual economic recovery [5].

Financing of sustainable development initiatives is considered by scientists as a type of innovation that involves the use of financial instruments such as green bonds, sustainable loans, and financial mechanisms to support environmentally friendly projects [6]. Some studies have demonstrated the correlation between finance and the environmental and social impacts of its use, based on an in-depth examination of the legal and regulatory framework and the role of regulation in facilitating or impeding the sustainable growth of finance [7]. Studies conducted by Liu et al. [8] consider serious potential in the use of technological innovation and risk management in the framework of sustainable development financing.

Low prices for primary resources are the reason for the further development of linear products, which leads to a lack of interest and low consumer awareness of circular economy products, the distribution of which requires significant financing [9].

As for the financing process itself, in the scientific work of domestic scholars [10], the interpretation of this concept is considered through a combination of the positions of capital suppliers and the positions of enterprises themselves, which are aimed at obtaining and accumulating the necessary amount of capital to meet the needs of operating and investment activities.

Financing of circular business projects, as well as any other sustainable initiatives, can be carried out through various sources, including companies' own funds, bank

loans, funds and investors, venture capital and private equity, as well as crowdfunding [11].

Crowdfunding, as a potentially promising area of startup development in the circular economy, involves raising funds by appealing to a large number of people to receive small amounts of money. It should be borne in mind that some crowdfunding platforms provide for the transfer of funds raised for the project only if the required amount is reached.

Grants can also be an important source of investment for startups, as they facilitate the implementation of targeted projects by providing support in the form of financial resources [12].

Private shareholders, or business angels, are usually successful entrepreneurs who invest not only in projects but also provide advisory support. Their investments are often formalized in debt agreements that can be converted into equity if the company is successful.

Venture capital is another important source of financing, characterized by investment horizons of three to five years and several rounds of financing at different stages of a company's development.

Government support, particularly through the European Investment Bank and other special financial institutions, plays a key role in creating a system of long-term financing for circular projects.

International financial institutions and large corporations can also be active participants in financing and supporting circular initiatives, acting as catalysts for global change towards the development of a circular economy.

In recent years, publication activity on sustainable development financing and the circular economy has demonstrated a significant increase, while there are gaps in the literature in terms of a comprehensive analysis of trends in the development of these topics using bibliographic methods. The need for such an analysis is driven by the need for effective processing of substantive and quantitative indicators of scientific papers, which will ensure an objective assessment of the level of relevance of the topic and create forecast expectations for publications in the near future. Through a comprehensive analysis, we try to map the trajectories of research in the field of sustainable development finance by carefully analysing data based on geography, authorship and thematic keywords, and contextualising these results in the existing body of literature in the Scopus database.

Materials and methods. The aim of this study is to determine the latest trends in scientific research in the world and the evolution of theories on the issues of financing sustainable development and the circular economy using multi-level bibliometric analysis, based on the capabilities of modern analytical software, as well as providing recommendations for future research.

The analysis and visualisation of existing scientific networks based on publications in the scientometric database Scopus involved the use of the world-class software product VOSviewer. It is worth noting that the works of Ukrainian scientists [13; 14]

actively use a similar methodological approach, which was the basis for our study.

Results and discussion. Before analysing the publications, the study identified two vectors. The first one is aimed at finding papers containing the terms "financing sustainable development" and the second one – "financing the circular economy". It should be noted that no additional restrictions were applied in the selection process, either by type of document or by subject area.

The search query "financing sustainable development" in the Scopus database as of the beginning of May 2024 found 5475 documents, of which almost 71 % are represented by only six subject areas (Figure 1).

The most frequently cited fields are environmental sciences (17 %), social sciences (15 %), economics, econometrics and finance (10 %), energy (10 %), business, management and administration (10 %) and engineering (9 %). Publications in medicine (8 %), computer sciences (5 %), Earth sciences (4 %), and agricultural and biological sciences (2.5 %) have a slightly smaller share of research aimed at financing sustainable development. The remaining subject areas account for about 10 %.

The first scientific papers on financing sustainable development began to appear in the Scopus database in 1986. Only in 1992 their number reached 10 papers. The last 20 years (2004–2024) were chosen for the study. The papers for 2024 are presented with a time limit as of May and are taken into account in all cases except for dynamics.

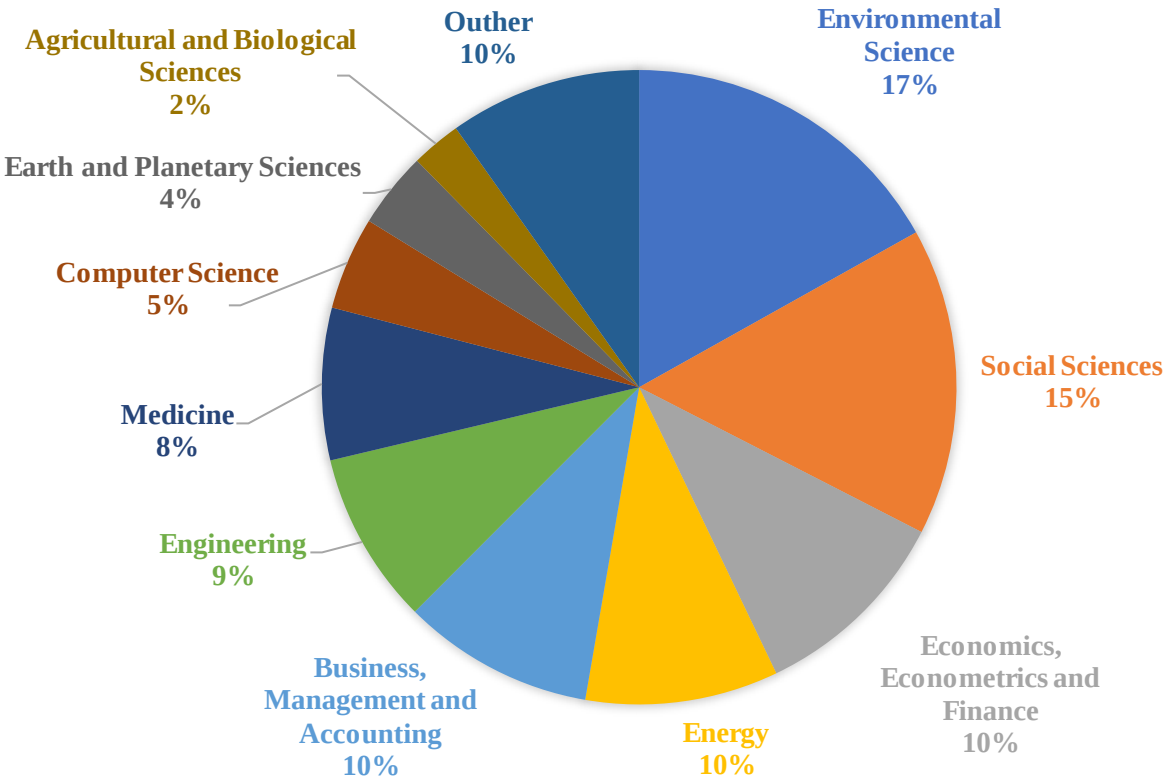

Figure 1. Structure by subject areas of publications by the search query "financing sustainable development" (5475 documents)

Source: compiled by the authors based on the Scopus database.

Over the analysed period of 2004–2023, there was an increase in publication activity (Figure 2).

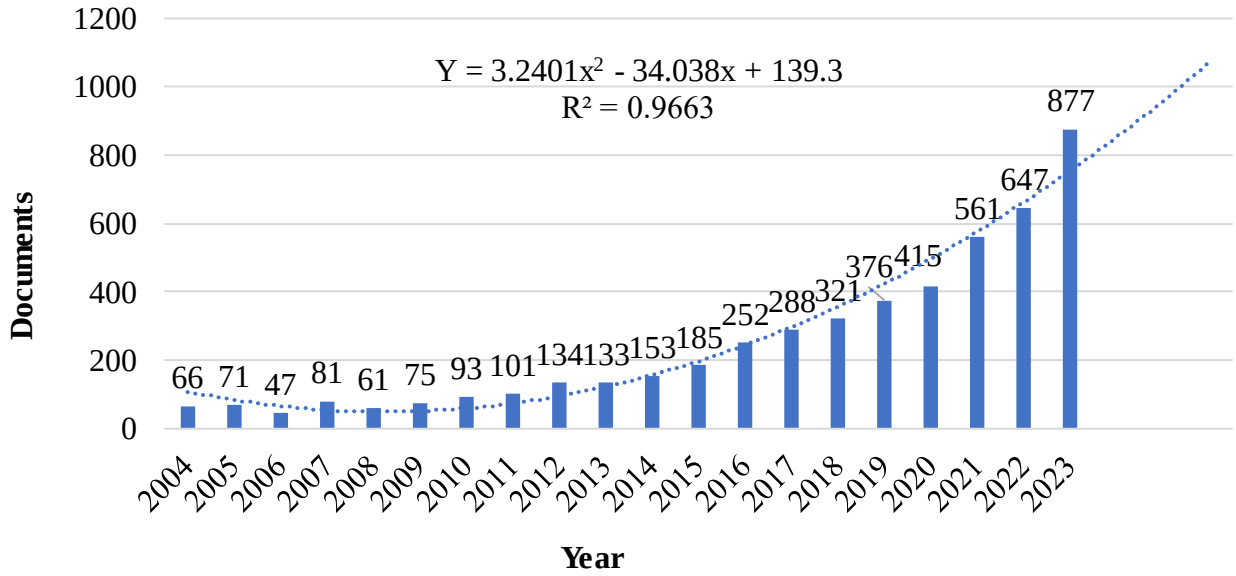

Figure 2. Dynamics and forecast of the number of publications in the Scopus database for the search query "financing sustainable development" (TITLE-ABS-KEY (financing AND sustainable AND development) for the period 2004–2023 (5232 documents)

Source: compiled by the authors based on the Scopus database.

To avoid the influence of fluctuations, we align the polynomial trend with the second-order parabolic equation, resulting in the expression $y = 3.2401x^2-34.038x+139.3$, which means that the initial rate of decrease of the indicator is 34.038 units, the further acceleration of the change in annual publications is 3.2401, and the equalised annual volume is 139.3 documents with $R^2 = 0.9663$. This indicates a high level of probability of further growth in the number of publications until 2026.

Scientists from China, the United States of America, and Great Britain lead the ranking of countries in terms of the number of publications containing the term "financing of sustainable development" (Figure 3).

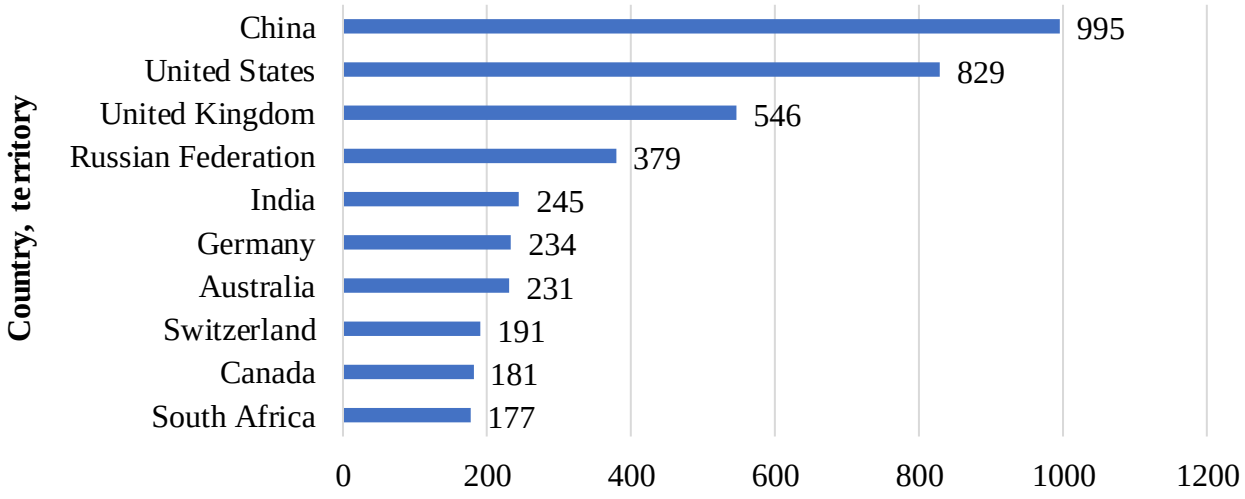

Figure 3. Ranking of countries (TOP-10) by the number of publications by the search query "financing sustainable development"

Source: compiled by the authors based on the Scopus database.

Researchers from Ukraine, whose works are indexed in the Scopus database, with a contribution of 109 publications, are ranked 21st in the above ranking.

It is worth paying attention to the organisations that have the most publications on financing sustainable development (Figure 4).

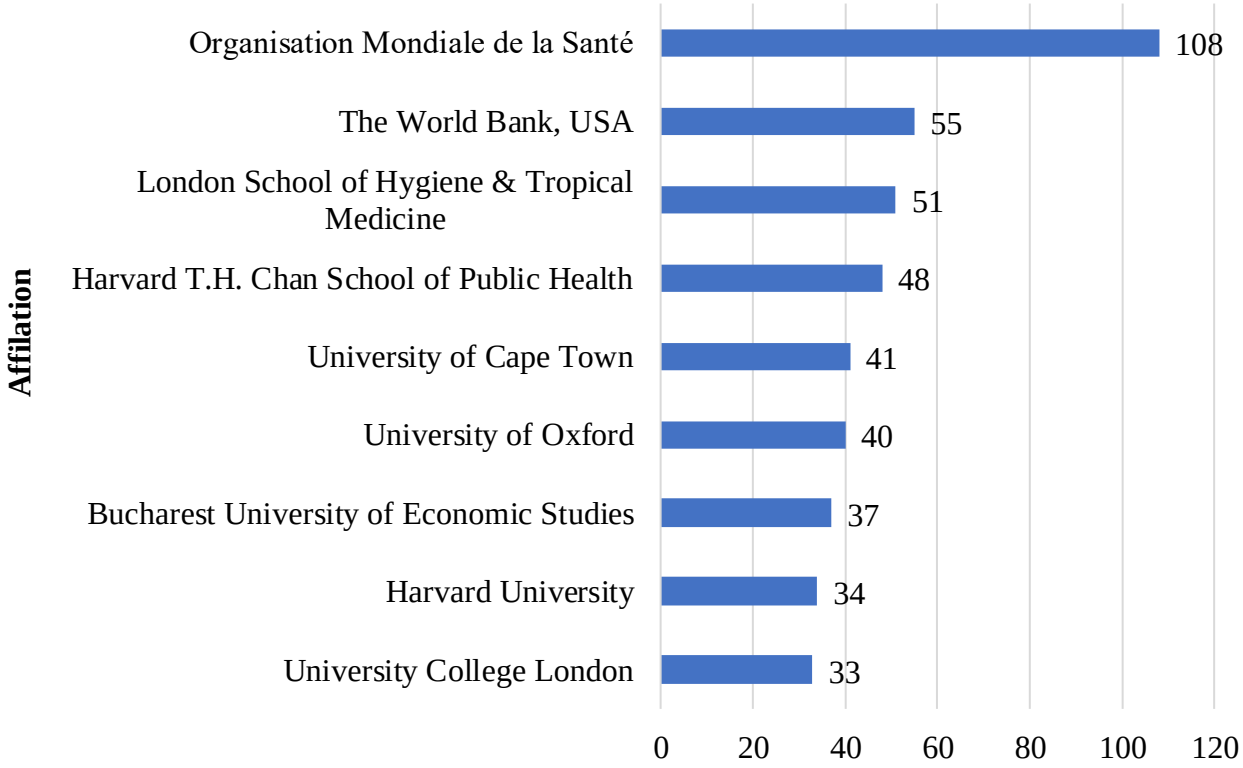

Figure 4. Ranking of institutions (TOP-10) that studied the topic of "financing sustainable development"

Source: compiled by the authors based on the Scopus database.

The World Health Organisation leads the ranking with 108 publications (mainly medical topics), the World Bank with 55 publications (mainly economic and social sciences), the London School of Hygiene and Tropical Medicine with 51 publications, the Harvard T.H. Chan School of Public Health with 48 papers, and the University of Cape Town with 41 papers. The leading journals with the largest number of publications on the above-mentioned topics are Sustainable Development in Switzerland – 239 publications, Journal of Cleaner Production – 83 publications, etc.

To obtain a graphical visualisation of the most commonly used terms related to financing sustainable development in publications for the period 2004–2024, the VOSviewer software was used. The software product works with data from the vast majority of scientometric databases and builds networks based on the mathematical theory of graphs, clustering, and scientific visualisation techniques.

Links between objects are built on the basis of the following characteristics:

1) co-presence of words in one article. Term analysis is useful as a tool for quick visualisation in the subject area. The keywords for analysis are either used as specified by the authors themselves or extracted from titles and annotations using the Text Mining algorithm;

2) co-authorship ratio, direct citation, co-citation, and bibliographic linking also form a system of links. These techniques allow us to establish the semantic proximity of publications, authors, countries and journals and help us visualise scientific and thematic groups.

At the initial stage of file processing, VOSviewer identified 21604 keywords from 5475 documents from the Scopus database, of which 536 threshold values with a frequency of repetition of more than 20 times were identified. Further processing involved narrowing down the existing list by excluding synonyms and words that had no meaningful significance for the study, which led to the identification of five main clusters, followed by normalisation by association strength.

Figure 5 shows the system of relations between terms. The font size and the size of the circle demonstrate the frequency of keywords in publications. The colour indicates the cluster to which the selected terms belong. The words of the respective clusters are marked in red, green, blue, yellow and purple, and the lines indicate the links between the terms.

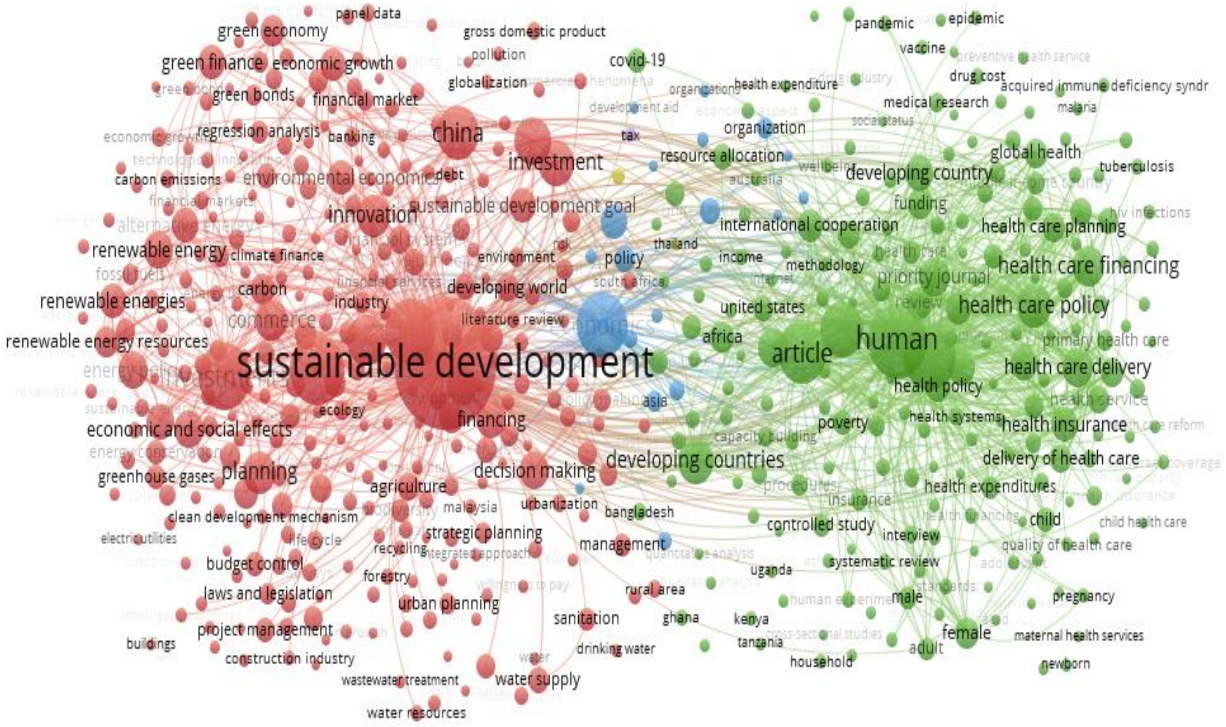

Figure 5. Bibliometric map of the most frequently used terms in publications in the Scopus database on financing sustainable development, 1986–2024 (5475 documents)

Source: compiled by the authors using VOSviewer based on the Scopus database.

The division of 536 keywords into five clusters resulted in a list of words and phrases with different frequency of use and closeness of relationship (Table 1).

According to the bibliometric map, two clusters (red and green) are visually the largest, relating to the areas of sustainable development and social policy. The conventionally created names of the clusters indicate the priority area of research by keywords.

Journal of Innovations and Sustainability
ISSN 2367-8151
2024, Vol. 8, No. 3
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Table 1

Thematically related clusters for the search query "financing sustainable development"

Cluster	Conventional name	Number of words	The most frequently used words in alphabetical order
Cluster 1 (red)	Sustainable development	307	Agriculture (286), carbon (350), climate change (448), commerce (391), economic development (476), environmental protect (443), finance (477), investment (490), sustainability (506), sustainable development (535), sustainable development goals (406)
Cluster 2 (green)	Social policy	207	Education (343), funding (339), government (446), health care financing (318), humans (432), poverty (309)
Cluster 3 (blue)	Economic policy	19	Economics (524), policy (350), sustainable development goals (339)
Cluster 4 (yellow)	Resource management	2	Resource management (152)
Cluster 5 (purple)	Tax	1	Tax (219)

Source: compiled by the authors using VOSviewer based on the Scopus database.

Thus, the terms studied form the basis of the scientific field of financing sustainable development. When conducting a bibliographic analysis, an equally important factor is the chronology of publications and the appearance of keywords. For this purpose, we created an overlay visualisation broken down by years (Figure 6).

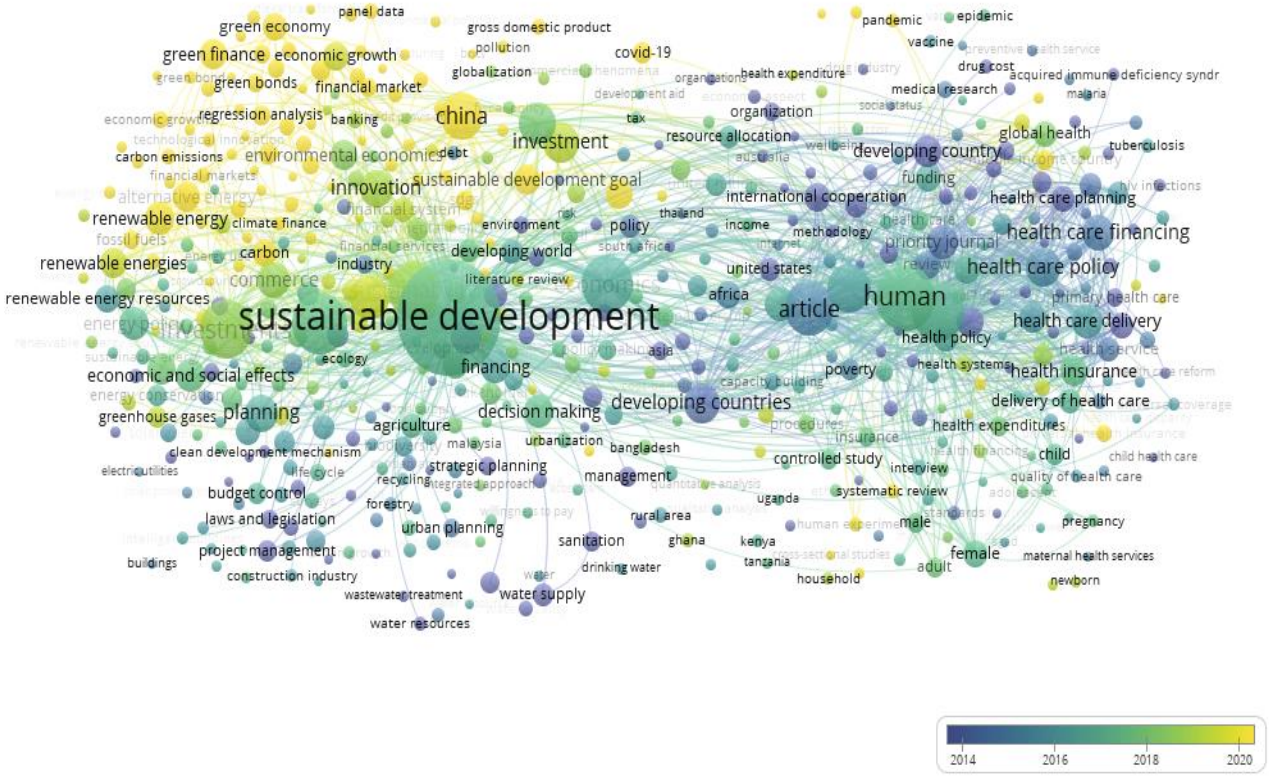

Figure 6. Bibliographic map of the chronology of the use of terms in publications in the Scopus database on financing sustainable development in 1986–2024

Source: compiled by the authors using VOSviewer based on the Scopus database.

The upper left part of the bibliographic map relating to cluster 1 is marked in yellow, which is a sign of relatively recent publications (2020). For this purpose, a legend is used that links the publication date by years to the cluster and content.

For an in-depth study of the processes of financing sustainable development in the context of bibliometric analysis, we have investigated one of the sustainability models – the circular economy. The search query "financing circular economy" in the Scopus database indexed 193 documents for the period 1994–2024 that contained the phrase "financing circular economy" in the title, abstract and/or keywords (TITLE-ABS-KEY).

In general, over the past nine years, we have observed a rapid increase in the number of publications on the financing of the circular economy, with 53 documents indexed in 2023, which is four times more than in 2020 (Figure 7).

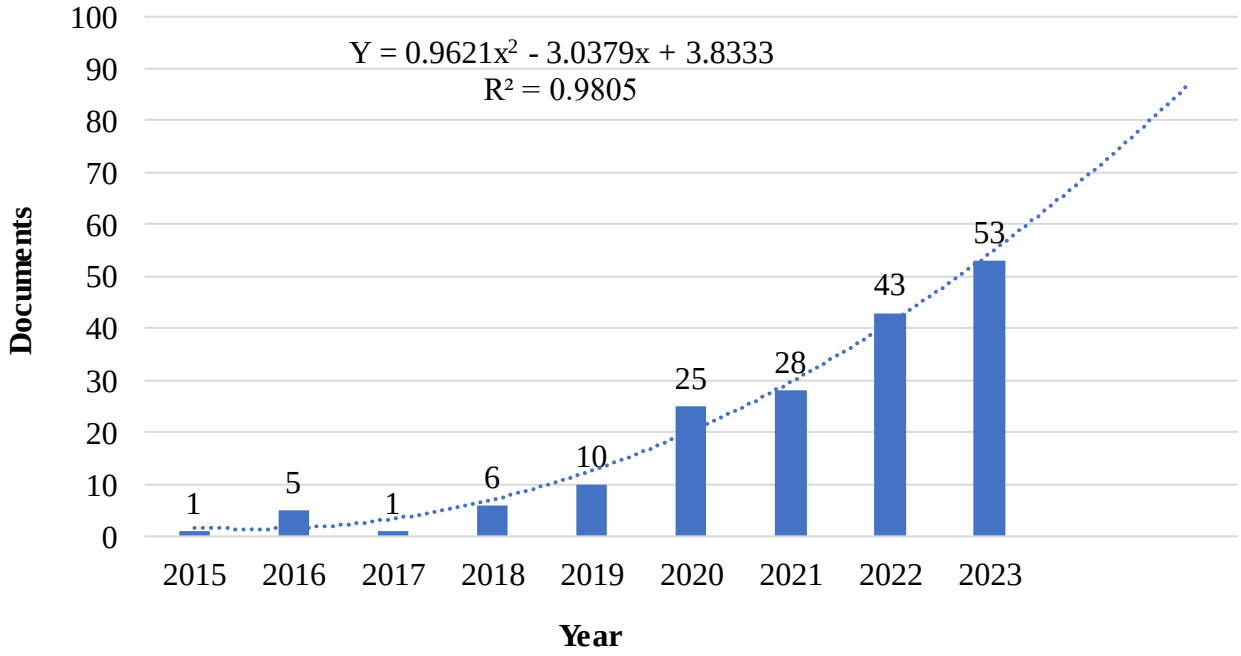

Figure 7. Dynamics of publications on the search query "financing circular economy" for the period 2015–2023 (172 documents)

Source: compiled by the authors based on the Scopus database.

The high reliability of the polynomial trend line at $R^2 = 0.9805$ indicates the maximum fit to the data and can be used to predict publication activity in the field in the near future. The trend is upward, which indicates future expectations for an increase in the number of publications on the subject.

Grouping scientific papers by the country of origin of the authors allows us to identify the scientific schools that deal with the above issues (Figure 8). It has been established that the leaders in terms of the number of such publications on financing circular economy are studies by Chinese (24), Italian (20), American (14), Spanish and French (14 each) scholars.

For example, according to the Scopus database, an analysis of the leading organisations involved in research in the field of financing circular economy shows that representatives of three universities published the most documents during the

period (Figure 9).

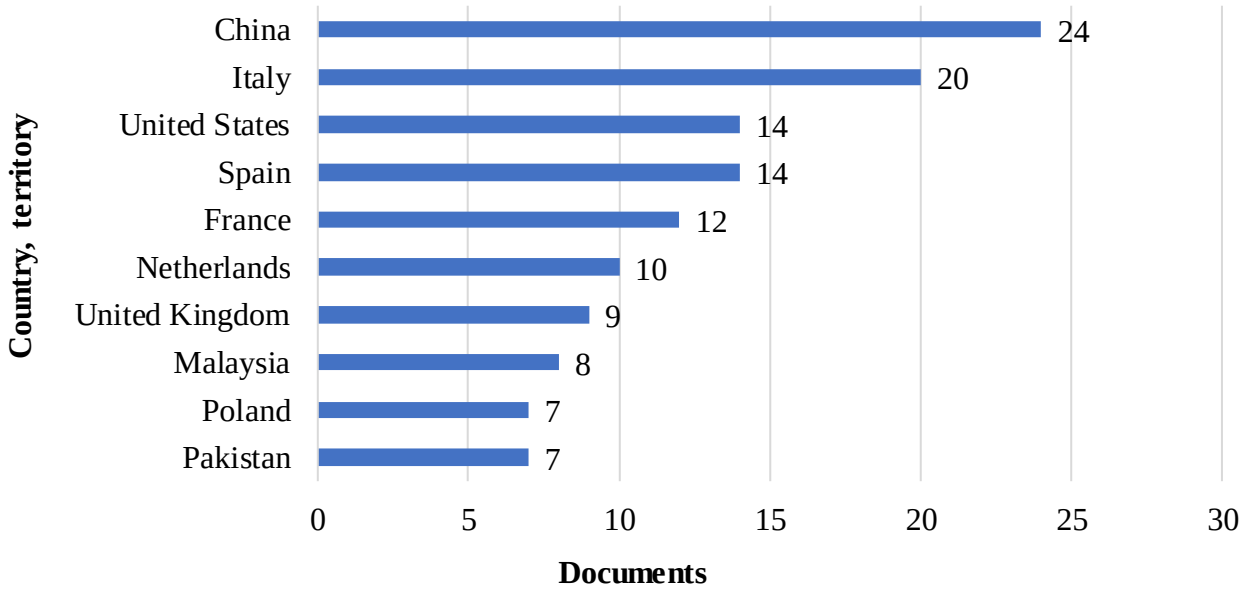

Figure 8. Ranking of countries by the number of publications by the search query "financing circular economy"

Source: compiled by the authors based on the Scopus database.

These include the University of Twente (Netherlands), Hamad Bin Khalifa University (Qatar) and Excelia Business School (France). The first two institutions are mainly represented in the Scopus database by works in the fields of computer science and engineering. The main research vector of the French scientific institution is economic and social sciences.

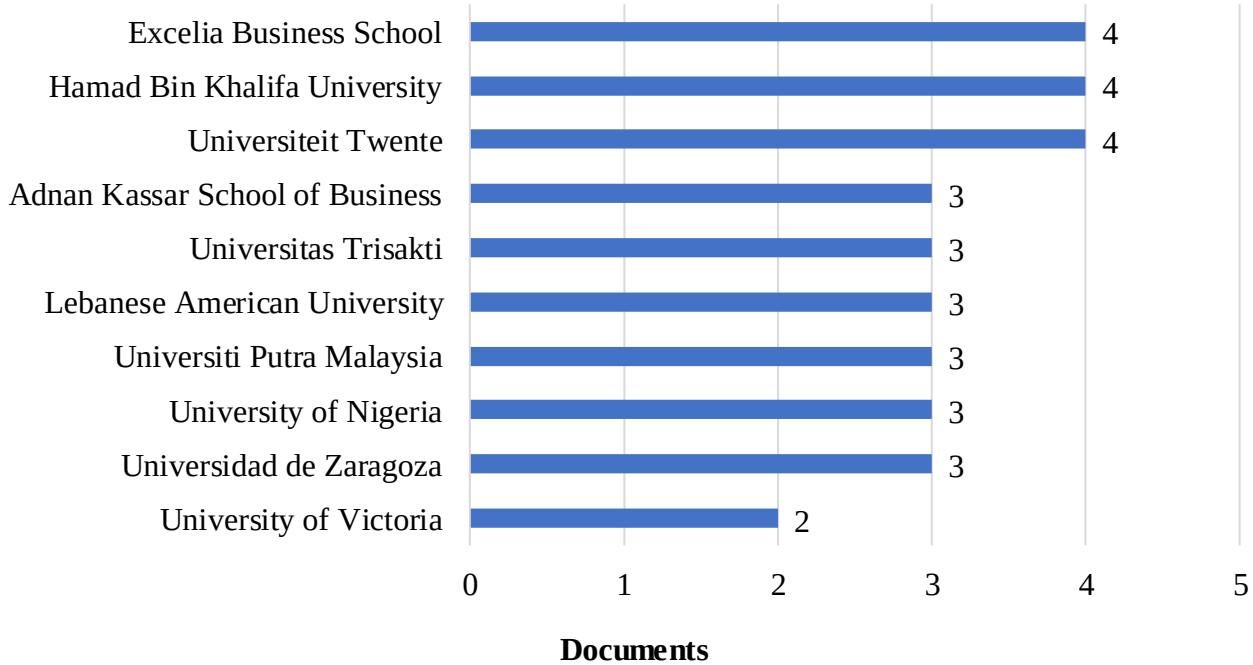

Figure 9. Ranking of research institutions, representatives of which have published the most papers on the topic of "financing circular economy"

Source: compiled by the authors based on the Scopus database.

The analysis by type of documents (Figure 10) shows that more than half of the works (65.2%) were published in the form of articles; 12.4% – conference materials; 10.4% – sections of books; 5.7% – reviews.

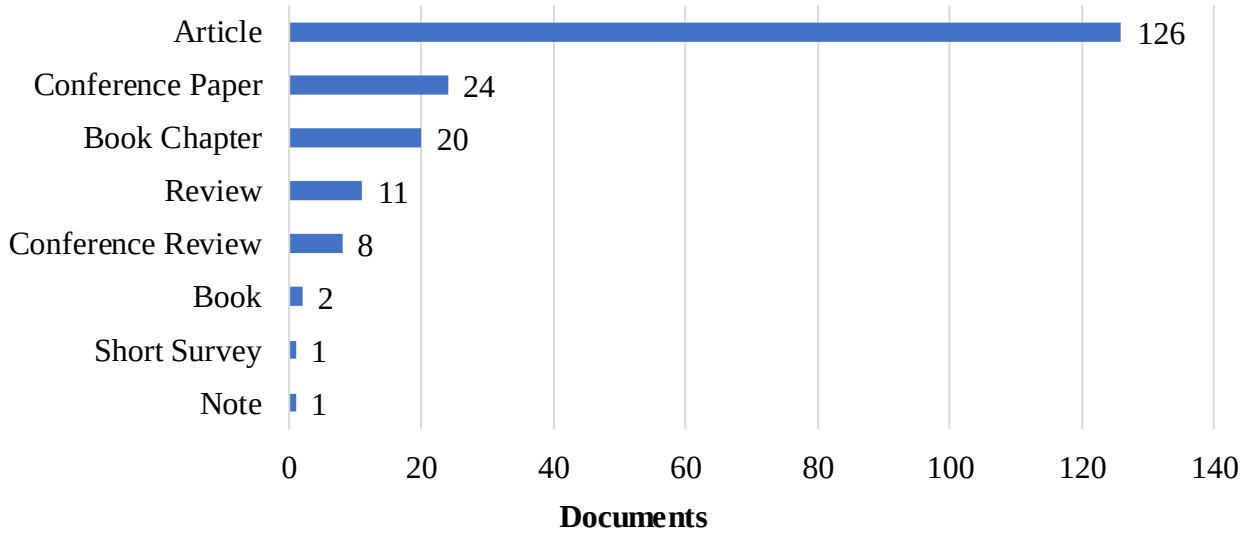

Figure 10. The number of publications by type for the search query "financing circular economy"

Source: compiled by the authors based on the Scopus database.

Figure 11 shows the rating of journals in the Scopus database, in which scientific works are found using the key words "financing circular economy".

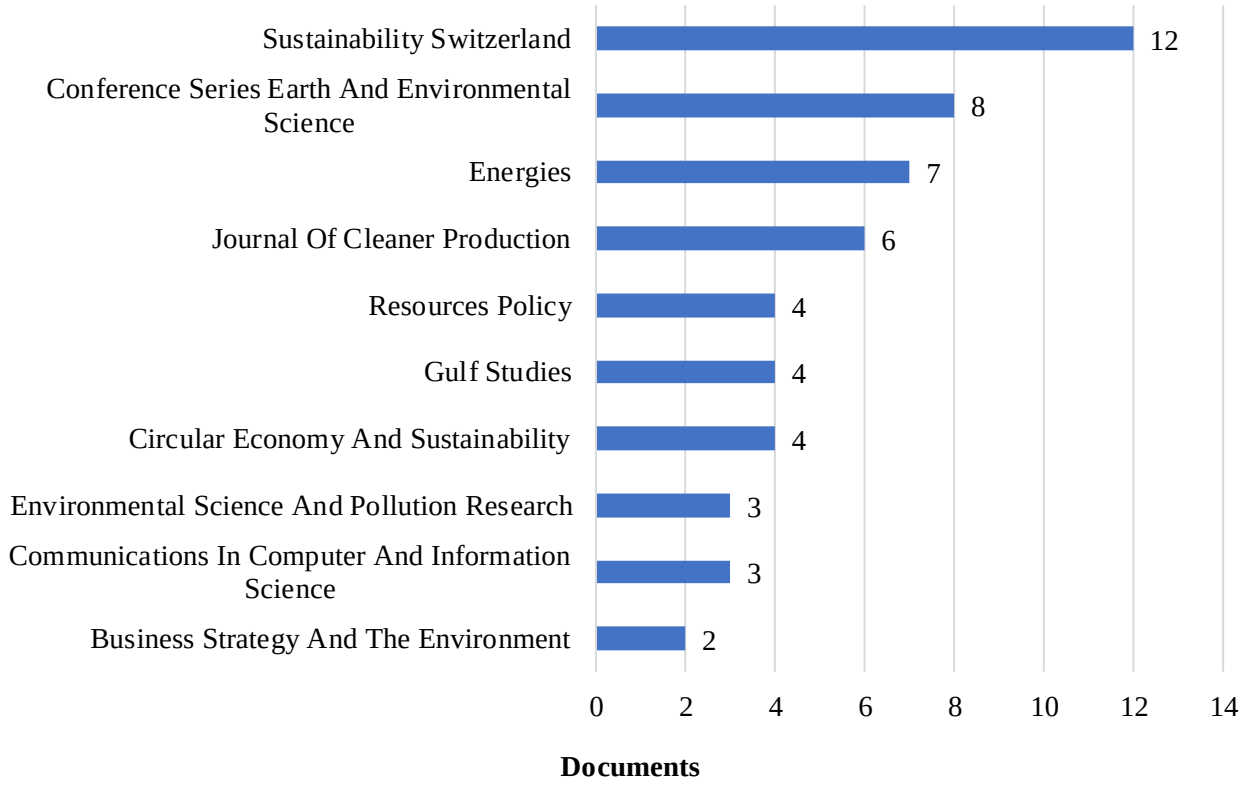

Figure 11. Ranking of scientific journals by the number of publications for the search query "financing of the circular economy"

Source: compiled by the authors based on the Scopus database.

Therefore, the most popular among scientists are the following journals Sustainability Switzerland (12), Iop Conference Series Earth and Environmental Science (8), Energies (7), Journal of Cleaner Production (6). Other journals contain less than five publications on the specified topic.

The results of the analysis of documents by fields of knowledge indicate that the financing of the circular economy is studied from the standpoint of various sciences (Figure 12).

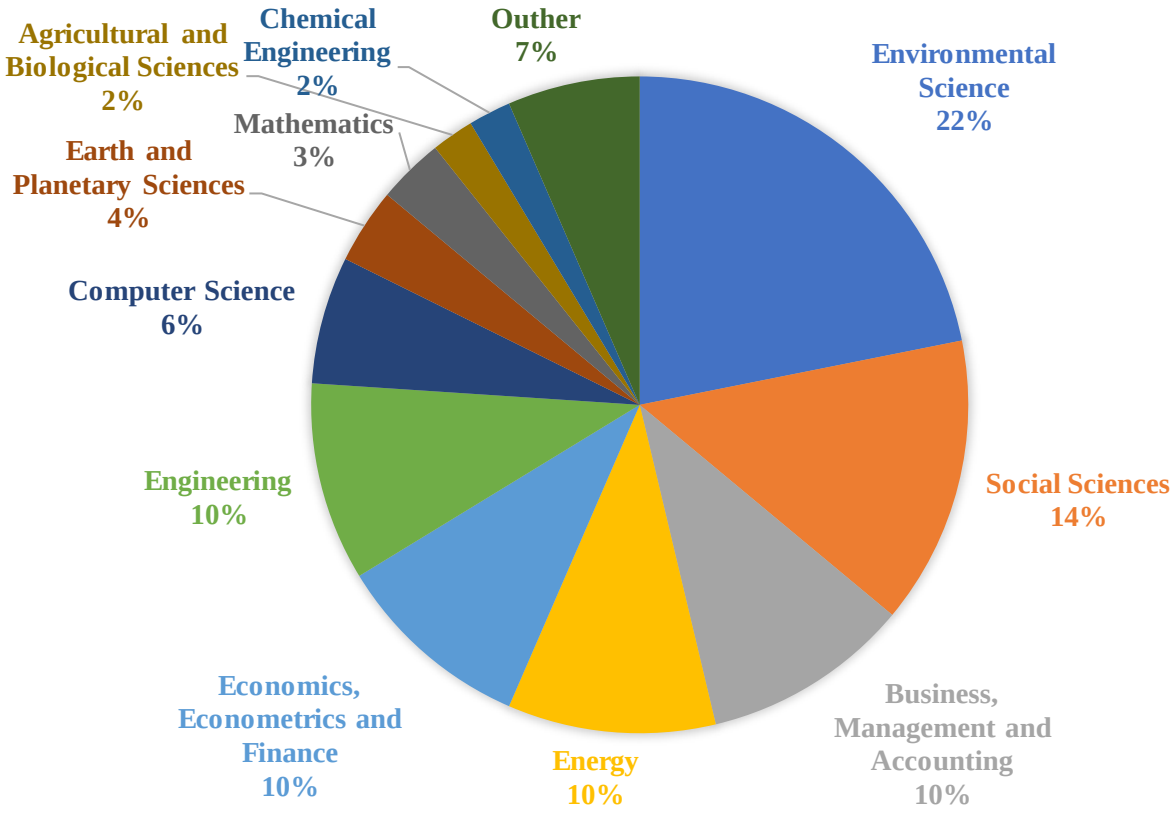

Figure 12. Publications by subject areas for the search query "financing circular economy" in the Scopus database (193 documents)

Source: compiled by the authors using VOSviewer based on the Scopus database.

The largest number of papers was published in the field of environmental sciences (22 %), social sciences (14 %), business, management and accounting (10 %), energy (10 %), economics and finance (10 %), engineering (10 %), and a slightly smaller number in computer sciences (6 %). In the field of agrarian and biological sciences, 9 papers were published (2 %). Thus, based on the analytical data of the Scopus database, in the world, the processes of financing the circular economy are studied mainly from the perspective of environmental sciences, social sciences, business, management, accounting, energy, economics and finance, engineering, and computer sciences (82 % in total). Overall, economic sciences accounted for 20 % of the world's publications. At the same time, 7 % of publications were in the "other sciences" category, which together indicates the interdisciplinary nature of research on circular economy financing in the world and the understanding of this phenomenon not only from an economic perspective, but also from the perspective of environmental sciences.

It has been found that the following scientists have been engaged in research on

the financing circular economy: Franco-Garcia L., Mirza N., Muzamwese T.C. (four papers by each author) and Heldeweg M.A., Ibrahim A.J., Umar M. (three papers by each author). The researchers represent the universities of the Netherlands, France, Qatar and Beirut.

To conduct a bibliometric analysis, we searched for publications in the Scopus database using the keywords "financing circular economy" for all types of documents for the period 1994–2024. As a result, we selected 193 scientific papers that contain the specified search query in the title, abstract, and keywords. Using the VOSviewer software, a bibliometric map was built using the co-occurrence analysis type, which contains the 1354 most common keywords used at least five times and grouped into six thematically related clusters (Figure 13).

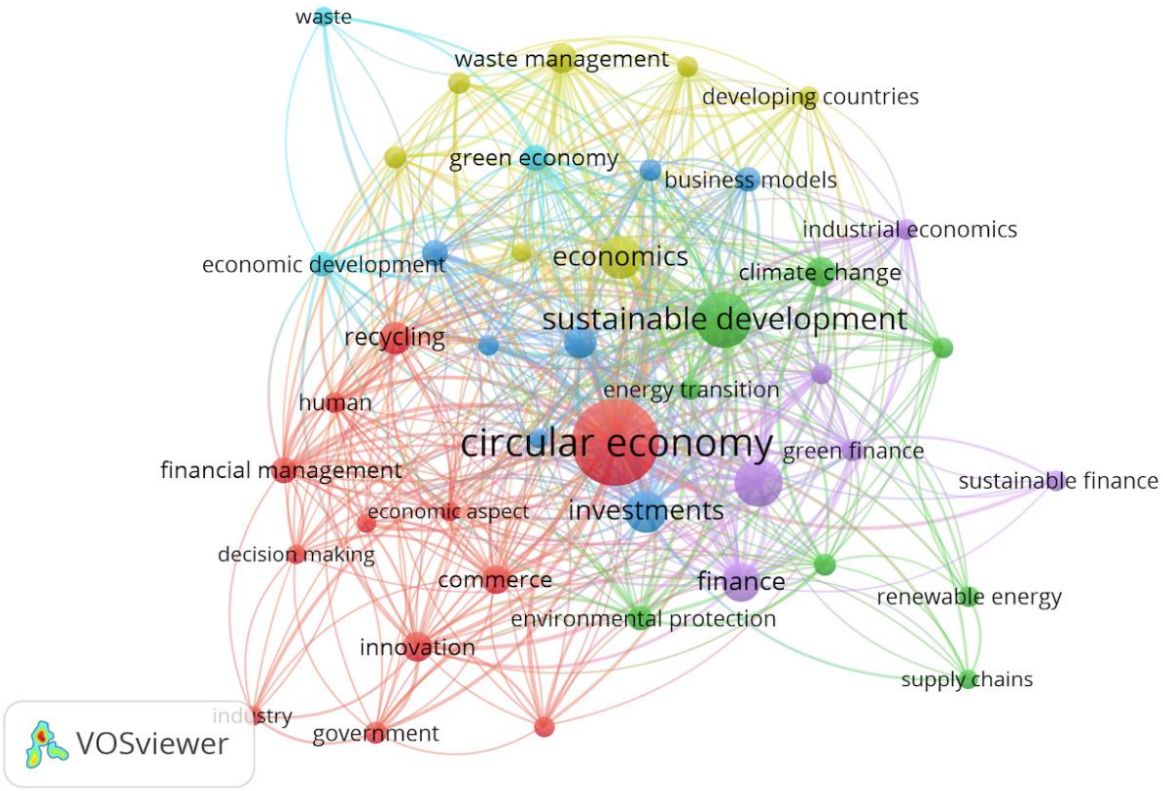

Figure 13. Bibliometric map of the most commonly used terms in Scopus publications on financing circular economy, 1994–2024 (193 documents)

Source: compiled by the authors using VOSviewer based on the Scopus database.

Cluster 1 (red) contains the largest number of terms (12), with the most commonly used keywords being "circular economy", "environmental economy", "sustainable development" and "investment". Cluster 2 (green) includes 8 terms, among which the most frequently used are "waste management", "finance" and "financing".

Cluster 3 in dark blue includes 7 terms containing "climate change", "agriculture" and "biodiversity". Cluster 4 contains 7 terms. Cluster 5 includes 6 terms. Cluster 6 is the smallest in blue in terms of the number of terms included, which includes "recycling", "economic aspects" and "sustainable environment".

For a detailed presentation of the systematised information based on the results of the clustering, we constructed Table 2.

Journal of Innovations and Sustainability
ISSN 2367-8151
2024, Vol. 8, No. 3
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Table 2

Thematically related clusters for the search query "financing circular economy"

Cluster	Conventional name	Number of words	The most frequently used words in alphabetical order
Cluster 1 (red)	Circular solutions at the micro level	12	circular economy (42), commerce (28), decision making (15), economic aspect (20), financial management (26), government (15), human (26), industry (9), innovation (25), profitability (15), recycling (30), small and medium-size enterprise (16)
Cluster 2 (green)	Environmental protection in the context of sustainable development	8	climate change (27), energy transition (15), environmental impact (21), environmental management (22), environmental protect (22), renewable energy (7), supply chains (8), sustainable development (39)
Cluster 3 (dark blue)	Sustainable business models and their investment	7	business models (19), economic and social effects (21), environmental economics (28), financial markets (20), financial system (19), investment (s) (61)
Cluster 4 (yellow)	Economic rationale for waste management	7	biogas (18), carbon (25), developing countries (21), economic analysis (26), economics (35), municipal solid waste (21), waste management (26)
Cluster 5 (purple)	Green financing	6	environmental sustainability, (24) finance (92), green finance (26), industrial economics, (22) sustainability (34), sustainable finance (6)
Cluster 6 (blue)	Green economy	3	economic development (22), green economy (27), waste (12)

Source: compiled by the authors using VOSviewer based on the Scopus database.

The chronological study confirmed that most of the terms used when searching for the phrase "circular economy financing" are new, as they have appeared in recent years, and their usage is significant (Figure 14).

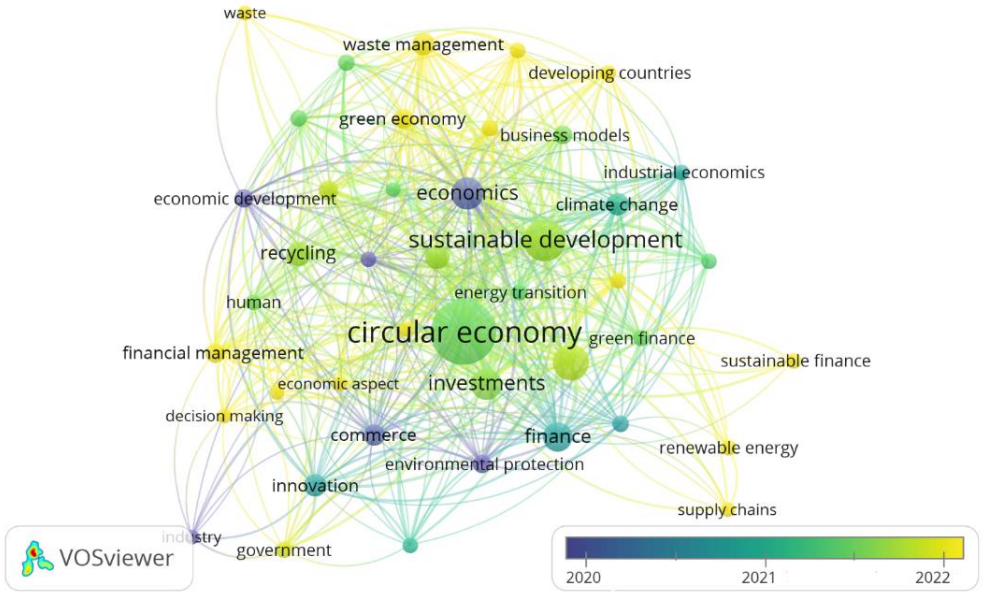

Figure 14. Bibliometric map of the chronology of the use of terms in publications in the Scopus database on financing circular economy, 1994–2024 (193 documents)

Source: built by the authors using VOSviewer based on the Scopus database.

The phrases that appeared in 2022 are marked in yellow, while those that appeared earlier are marked in dark green and blue, respectively, as indicated by the legend in Figure 14. The concepts that have been used intensively in recent years in research include “waste management”, “green economy”, “green finance”, “sustainable finance”, “renewable energy”, etc.

Discussion. The study demonstrates a steady growing interest in the topic of financing sustainable development and the circular economy, based on the Scopus scientific metric base. At the same time, leading scientists focus their attention on ecological changes in the efficiency of the circular economy [15–18]. Instead, representatives of the ecological approach used in sustainable development emphasise climate change, ecological degradation, and financial needs [19; 20].

Regulatory authorities create funds to encourage environmental protection and energy-efficient solutions by companies, encourage financial institutions to offer green loans, optimise energy savings and generate green strategies that shape the system of capital inflows. Research [15] demonstrates the processes that link funding to environmental innovation. Instead, the process of capital withdrawal limits the growth of the enterprise, which intensively uses resources and creates accumulation in significant volumes. It is much more difficult to attract capital for a small firm [21]. This requires state regulation and tax policy for small and medium-sized businesses interested in implementing circular processes and principles of sustainable development [2].

The existing problems create the conditions for combining the efforts of producers and consumers to cooperate in the fight against the climate change, to cooperate in solving issues of scarcity of resources for producers, and stimulate financial institutions to promote the transition of companies to the low-carbon market, which is a commercial potential for them [22].

Conclusions. The bibliometric analysis reveals a dynamic picture of research in the field of sustainability finance and circular economy, offering in-depth insights into trends, actors, connections and thematic clusters. In line with global environmental concerns and sustainable development goals, the issue of financing sustainability initiatives is gaining momentum. The analysis provides a critical view of the trajectory of research on sustainable development and circular economy financing, emphasising its importance in addressing social and environmental issues, stimulating innovation and promoting sustainable economic growth. The existing growing trends in publication activity for both search queries have been determined, which indicates the growing popularity of the topic in scientific circles. The scientific papers containing the search queries form an idea of sustainable development and the circular economy in close combination with effective resource management, cooperation with stakeholders, fundraising and innovative development technologies.

The interdisciplinary nature of sustainability and circular economy finance is evident in its diverse subject areas, covering environmental sciences, social sciences, energy, engineering, economics and business management. Leading journals,

including Sustainability Switzerland, Journal of Cleaner Production, Sustainable Production and Consumption, Journal of Environmental Management, Business Strategy and the Environment, are an important platform for sharing ideas and shaping discourse in this area.

Geographically, China, the United States and Italy are the leaders in research on sustainable development finance and the circular economy, with active contributions from the United Kingdom, India, France and Germany. These countries align their research with their unique challenges, economies and environmental imperatives.

Well-known institutions, including Chinese, British, American, Italian and German universities, play a crucial role in advancing research in the field of sustainable development finance and the circular economy. These institutions embody their countries' commitments to sustainable development, innovation and environmental protection.

The clusters of topics on financing for sustainable development and the circular economy illustrate the multidimensional nature of the research environment. These clusters are correlated and intertwined, highlighting the need for comprehensive frameworks, impact assessments of financial instruments and a deeper understanding of the regulatory framework to promote sustainable development.

The obtained results are the terminological landscape of the modern paradigm of financing sustainable development and circular economy of agricultural enterprises. Further research involves a transition from the issue under consideration to the coverage of the European experience of financing sustainable development on the basis of the circular economy in the works of domestic and foreign scholars and their regulatory and legal regulation.

Acknowledgment. The publication contains the results of the research within the framework of the scientific project "Strategy and innovative technologies for the processing of organic animal waste in the context of ensuring land degradation neutrality: from linear to circular economy" (state registration number 0122U001484).

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