



Article

A Scientometric Analysis of Climate Change Adaptation Studies

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Abstract: In recent years, climate change has begun to put pressure on humanity and affect natural and human systems. The aim of this paper is to provide an improved understanding of the state of the literature on the impacts of climate change that can be addressed through measures related to disaster risk reduction, sustainable agricultural practices, and the circular economy. This review also represents a valuable and fundamental reference for both researchers and practitioners in these fields. A total of 74,703 articles (climate change adaptation, 45,030; disaster risk reduction, 5920; sustainable agricultural practices, 7940; circular economy, 15,813) published between 1990 and 2022 were extracted from the Web of Science Core Collection, and the links between these areas were mapped using VOSviewer. There has been an increase in the amount of published research on these four topics since 2007, indicating the increasing involvement of researchers to address these topics, influenced by the concerns of national and international bodies to address these changes.

Keywords: climate change; disaster risk; sustainable agricultural; circular economy



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1. Introduction

Researchers have detected significant changes in climate over 150 years, manifested mainly by a 0.8 °C increase in average temperature [1,2]. This has been driven by increasing greenhouse emissions, and by 2100, temperatures are expected to increase by between 1.8 and 4.0 °C [3,4]. CO₂, CH₄, and N₂O contents in the atmosphere have increased significantly since 1750 [5,6], driven by fossil fuel use, changes in land use, and increased agricultural activity [7–9].

Across the world, many natural systems are being affected by climate change, particularly due to rising temperatures [10–12]. The number of glacial lakes is increasing, river flows are being fed by melting snow, glacier melt is significantly increasing, and river and lake temperatures are rising [13–17]. With respect to birds, migrations start earlier and species are spreading toward the poles [18–20].

The effects of global warming are evidenced by countless observations of increased air and ocean temperatures and melting snow and glaciers [21,22], leading to an increase in global average sea levels [23,24]. Changes in ocean salinity, wind, and extreme weather events, such as droughts, heavy rain, and heat waves, have also been identified [25,26].

In terms of food production, temperature increases exceeding 1–3 °C could result in decreased yields, increasing the risk of famine [23,27].

The risk of coastal erosion will increase as a result of climate change and rising sea levels, with millions of people expected to be inundated each year, especially in low-lying, densely populated areas. The greater the effects of climate change, the greater the negative impacts on industries, settlements, and societies, especially poor communities, which are particularly vulnerable, and the greater the economic and social costs [6,7,28].

In Europe, wide-ranging impacts are expected, including glacial retreat, longer growing seasons, and changes in the geographical distribution of species, with implications for all regions of Europe. The risk of flooding will also increase, and many species in mountain areas will suffer [27–29]. In northern Europe, a reduction in heating needs due to increasing temperatures is expected, but this advantage will be outweighed by many disadvantages [30,31].

Some agricultural crops may be more productive if temperatures increase by 1–2 °C but will be negatively affected if temperature increased exceed this range. The latest economic data indicate that with a temperature increase of 4 °C, the average global loss would be between 1 and 5% of the global GDP [15,18,32].

Extreme climatic effects are expected to increase and become more frequent; the increased frequency and intensity of heat waves could lead to a decrease in agricultural production, affecting water availability and increasing heat-related deaths [33,34].

In some colder areas, an increase in temperature would lead to fewer cold nights, resulting in increased agricultural productivity, fewer deaths related to cold, and a reduction in energy required for heating. Furthermore, increased heavy rainfall would increase the risk of flooding and soil erosion and reduce surface water quality [13,14,18].

In developed and developing countries, the focus in recent decades has been on consumption of products in all sectors, leading to resource depletion and environmental impacts. Thus, practices that have been useful since the development of mankind are being revived with the aim of protecting the environment [14,35].

The effects of climate change are visible, so the most appropriate way forward is to adapt to climate change through measures aimed at reducing the risk of (natural) disasters, using sustainable agricultural practices, and implementing a circular economy (Figure 1).

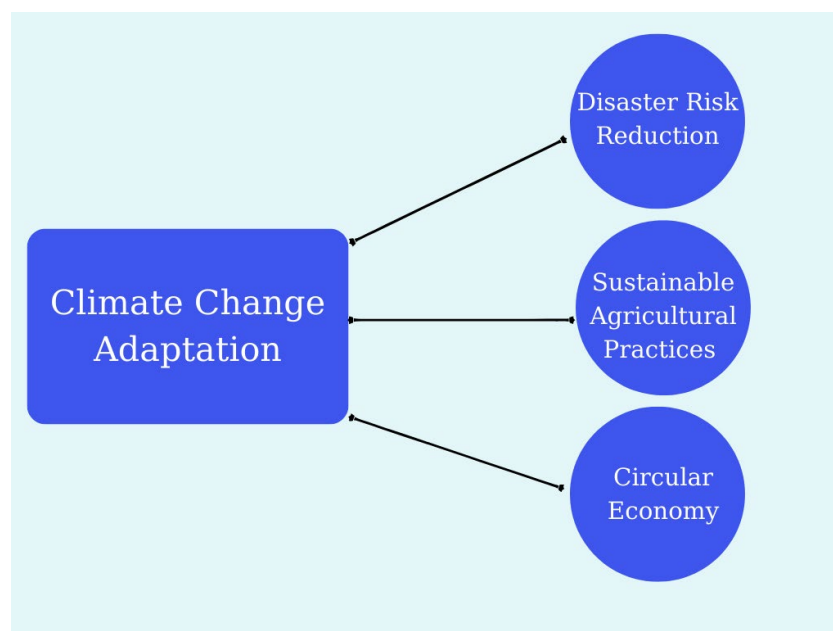


Figure 1. Measures that can target adaptation to climate change. Own processing via Canva.

According to the latest scenarios produced by researchers, global temperatures are projected to increase by 0.2 °C every decade [36–38]. Furthermore, warming tends to reduce the absorption of CO₂ from the atmosphere on land and in the oceans, leading to more man-made emissions remaining in the atmosphere [39–41].

Although there are some limitations to the effects of climate change, scientists report that over the last 30 years, global warming has had a measurable impact on physical and biological systems [42,43]. Furthermore, some regional effects are only now emerging and are difficult to disentangle because they depend on factors other than climate [44–47].

The impact of warming is viewed from several perspectives, namely the expected impact on natural systems, on human populations, and on specific regions. The effects of climate change affect all regions of the Earth, from the North Pole to the South Pole and from the Americas to Asia, with repercussions on natural systems and implications for water and ecosystems, as well as for people, affecting food production, industries, settlements, and societies. Therefore, action needs to be taken globally to mitigate these challenges associated with climate change (Figure 2).

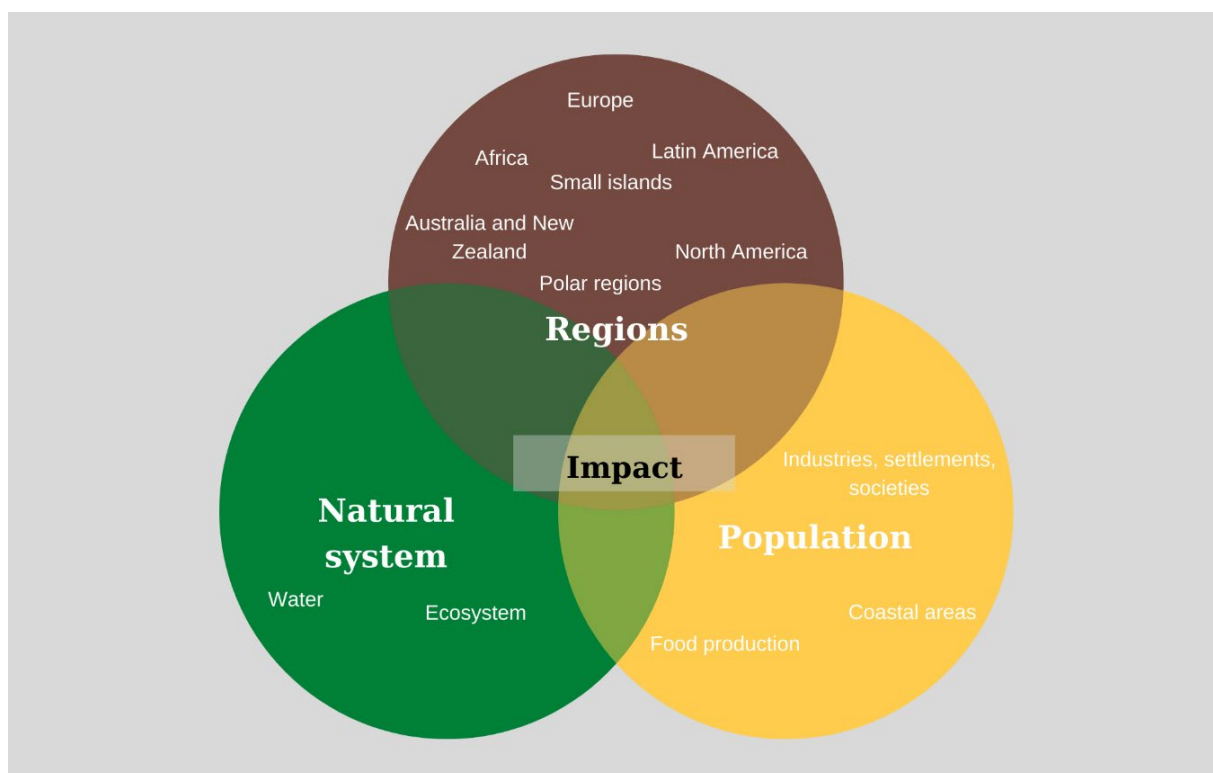


Figure 2. Perspectives on the impact of global warming. Own processing via Canva.

Research in the field reveals bleak predictions unless action is taken to combat global warming [17,19,36]. Natural systems will suffer in terms of water availability and river flows, which will increase in high-latitude areas and decrease in some mid-latitude areas and in the tropics [21,27,40]. Additionally, one-sixth of the world's population will be affected by water availability [26–28].

Between 20 and 30% of plant and animal species will be at increased risk of extinction, leading to major ecosystem changes, affecting biodiversity and the supply of water and food to the population [45–47].

In research, we visually present an overview of the literature in the fields of climate change adaptation, disaster risk reduction, sustainable agricultural practices, and the circular economy. Research collaboration between countries, organizations, and authors is also presented based on a series of cooperative analyses. In terms of bibliometric analysis of existing works, we aim to provide a valuable and fundamental reference for both researchers and practitioners in these areas.

2. Materials and Methods

Data collected from the Web of Science platform on the number of publications on the topics of climate change adaptation, disaster risk reduction, sustainable agriculture

practices, and circular economy were entered into SPSS statistical software (SPSS Statistics 20, IBM Software Group, Chicago, IL, USA). We performed descriptive statistics on studies published between 1990 and 2022. To this end, the minimum, maximum, range mean, and standard deviation were determined, as well as the Skewness and Kurtosis indices, which are important to characterize the distribution of the analysed series [48]. A total of 74,703 articles were analysed and classified into four domains over a period of 33 years (N) (1990–2022): climate change adaptation, 45,030; disaster risk reduction, 5920; sustainable agricultural practices, 7940; circular economy, 15,813. The data for 2022 are partial, as only studies published by mid-year were quantified.

Scientometrics is considered one of the most important disciplines of science, defined as an informational process performed through the quantitative study of science. For the purpose of our work, we use the term science in the epistemological sense, which implies a general development of the system under analysis, with emphasis on inter-relationships and disciplinary structure. As a structural entity of scientometrics, structural scientometrics was approached through bibliometric links, cocitation, and cognitive structure mapping of science perceptions [48,49].

The aim of this process is to provide an objective picture of how science develops over the years; how it evaluates timeliness by generating the main topics of interest used in academic work; and how it optimally organizes research systems and activities, management, and research productivity [50,51].

The term “bibliometrics” was first used by Alan Pritchard as early as 1969 and is considered a statistical and mathematical method, the scope of which is books and publications, and is also considered a branch of scientometrics. In this research, Web of Science database search results were exported into text format, including scientific articles on the topics of adaptation to climate change, reduction in disaster risk reduction, sustainable agricultural practices, and circular economy. We then uploaded these text data to VOSviewer software (Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands) to generate maps based on keywords of the included publications classified according to the main topic, research directions, and degree of cooperation between countries [51]. Through these keywords used to generate the database, we obtained unique results for publications studying these topics. Changing the search words generated completely different results (Table 1).

Table 1. Details of selected themes.

Criterion	Topics	Justification
1	climate change adaptation	Most scientists believe that even if efforts are made to reduce emissions, even with concrete results, some climate change is inevitable, a first necessary step is to adapt to its effects [1,2].
2	disaster risk reduction	One of the effects of climate change is the disasters caused by these effects, which have resulted in numerous losses of life and property [11,17].
3	sustainable agricultural practices	In 2019, agriculture accounted for a 10.55% share of EU greenhouse gas emissions among all economic sectors. Given this high share, researchers have deemed it necessary to identify environmentally friendly agricultural practices [49].
4	circular economy	As the world’s population tends to grow, the demand for raw materials and finished products is increasing, with a major impact on the environment [52].

Scientometric analysis was used to identify the performance of the articles and their results, as well as the journals, the mode of collaboration, and the research constructs [51].

Data were extracted from the Web of Science database, for which advanced search mode was used for the time period from 1990 to 2022, including various types of publications. Step 2 consisted of processing the extracted data and generating maps on the topics of interest for, about which conclusions were made in the third step (Figure 3).

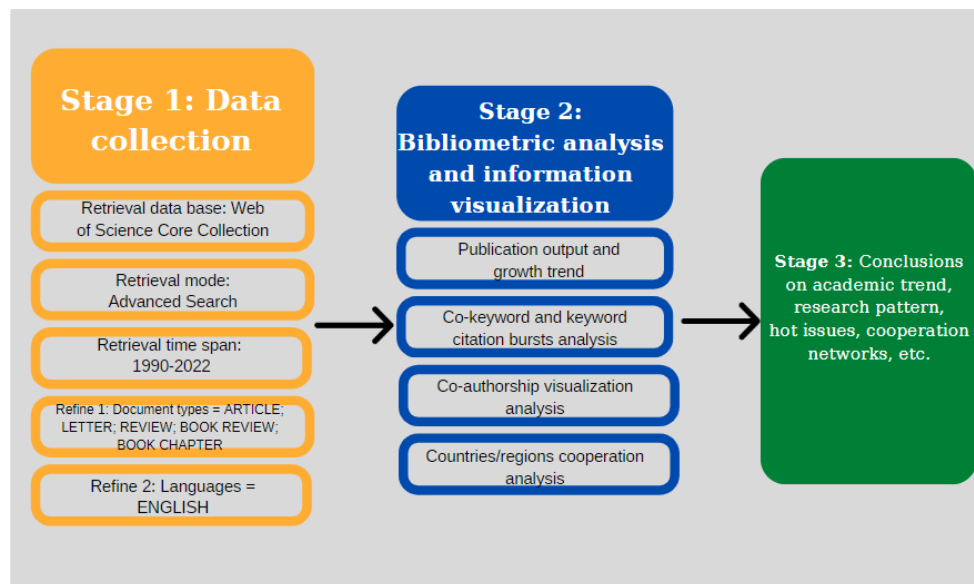


Figure 3. Steps in data collection and analysis using VOSviewer software. Own processing via Canva.

3. Results

In terms of the evolution of the number of WOS articles published according to the field analysed, there has been a considerable increase in the number of articles on the topic of “effects of climate change” (6008 publications in 2021). There has also been a marked increase in the number of articles on the “circular economy”, reaching 4730 in 2021 (Figure 4).

Regarding descriptive statistics of the variables analysed, we observe that the most publications were recorded in the case of climate change adaptation, reaching a maximum of 6008 publications, as well as in the case of circular economy, with 4730 publications. In the last 10 years, the interest of researchers in climate change adaptation has accelerated, compared to the circular economy, which has seen a substantial increase in publications only in the last 5 years. This also explains the positive values of the Skewness and Kurtosis indices. Thus, the four variables with a value greater than 0 indicate that the distribution analysed is not symmetrical, tending more towards the lower part. Additionally, the Kurtosis index shows values higher than 0, which indicates a leptokurtic distribution of the analysed data (Table 2).

3.1. Climate Change Adaptation

According to the Web of Science database, the subject of “adaptation to climate change” is increasingly addressed, with 45,032 papers identified written between 1990 and 2022 in categories such as environmental sciences (14,302 papers), environmental studies (8701 papers), ecology (5656 papers), meteorology atmospheric science (5579 papers), water resources (3541 papers), green sustainable science technology (2948 papers), and multidisciplinary geosciences (2527 papers) (Figure 5).

The main interlinked keywords are impact of change, decision making, evolution, climate impact, government, policy, adaptation pathways, global environmental change, climate risk, integrated assessment, global warming, and global environmental change (Figure 6).

These are grouped into clusters. The first cluster (green) includes terms such as impact of change, system, responses, uncertainty, variability, climate resilience, evolution, model, water resources, decision making, evolution, model, scenarios, irrigation, energy, global warming, climate impact, adaptation measures, simulation, crop yield, wheat, maize, crop production, economic impact, land use, agriculture, food security, productivity, farmer perception, and temperature (Figure 6).

The second cluster (red) is associated with the following topics: resilience, policy, knowledge, sustainable adaptation, overcoming barriers, government, institutions, state, innovation, plans, public health, urban, cities, sustainability, urban planning, spatial planning, integration, zones, municipalities, adaptation pathways, adaptive governance, transformation, opportunities, global environmental change, climate risk, marine, land, integrated assessment, diversification, and impact assessment (Figure 6).

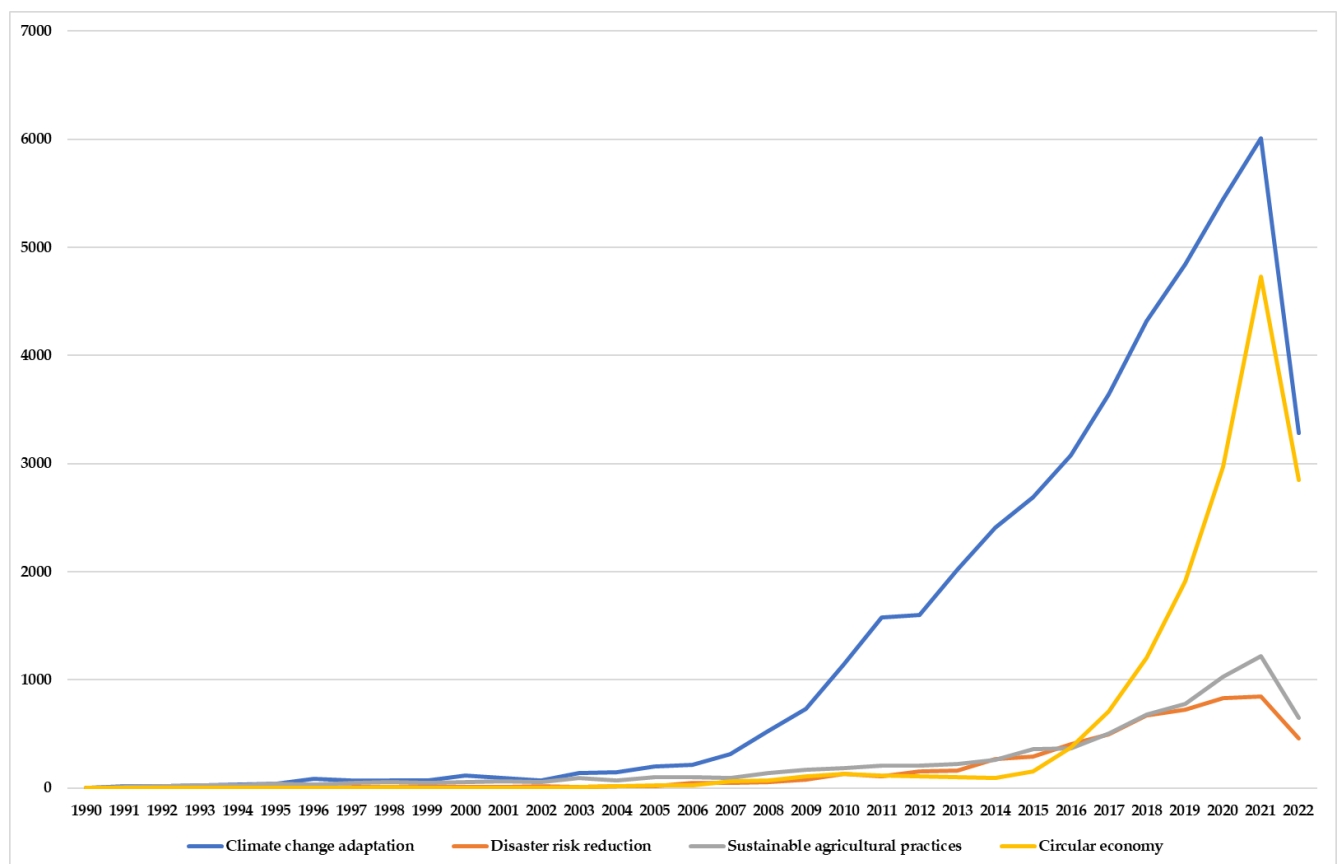


Figure 4. Evolution of the number of articles published in Web of Science Core Collection according to the fields analysed. Own processing.

Table 2. Descriptive statistics of variables. Source: Own calculations based on WoS data.

	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Climate change adaptation	33	2	6008	45,030	1364.55	1806.855	1.272	0.409	0.471	0.798
Disaster risk reduction	32	1	850	5920	185.00	264.795	1.509	0.414	1.053	0.809
Sustainable agricultural practices	33	4	1223	7940	240.61	306.928	1.892	0.409	3.084	0.798
Circular economy	33	1	4730	15,813	479.18	1084.104	2.785	0.409	7.672	0.798



Figure 5. Tree diagram of Web of Science publications on “climate change adaptation”. Source: Processed from Web of Science website.

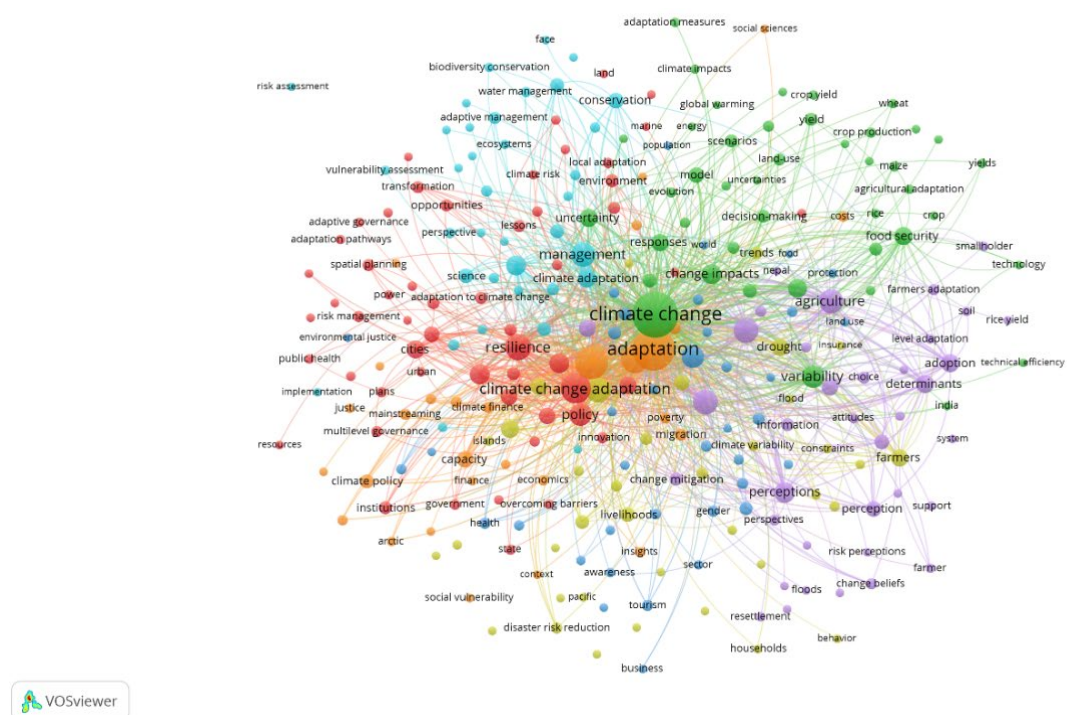


Figure 6. Connectivity of keywords used (adaptation to climate change). Source: Proprietary processing based on WoS results using VOSviewer.

The third cluster (blue) includes terms such as future, risk, foresight, vulnerability assessment, communication, change, climate justice, framework, management, science, conservation, forest management, adaptive management, biodiversity, restoration, risk assessment, region, infrastructure, forest, and carbon (Figure 6).

The fourth cluster (orange) is interconnected with the following terms: social science, costs, vulnerability, capacity, economics, climate policy, public policy, development, insights, equality, indicators, migration, and poverty (Figure 6).

The fifth cluster (purple) includes keywords such as strategies, migration, perceptions, change mitigation, agriculture, perspectives, risk perceptions, trust, floods, resettlement, smallholder farmers, attitudes, choice, farmers, soil, smallholder, and information (Figure 6).

In 2015, the main topics addressed were management, climate impact, social science, environmental, risk management, capacity, migration, local government, finance, flood, food, crop, costs, global warning, forest, ecosystem, and trends (Figure 7).

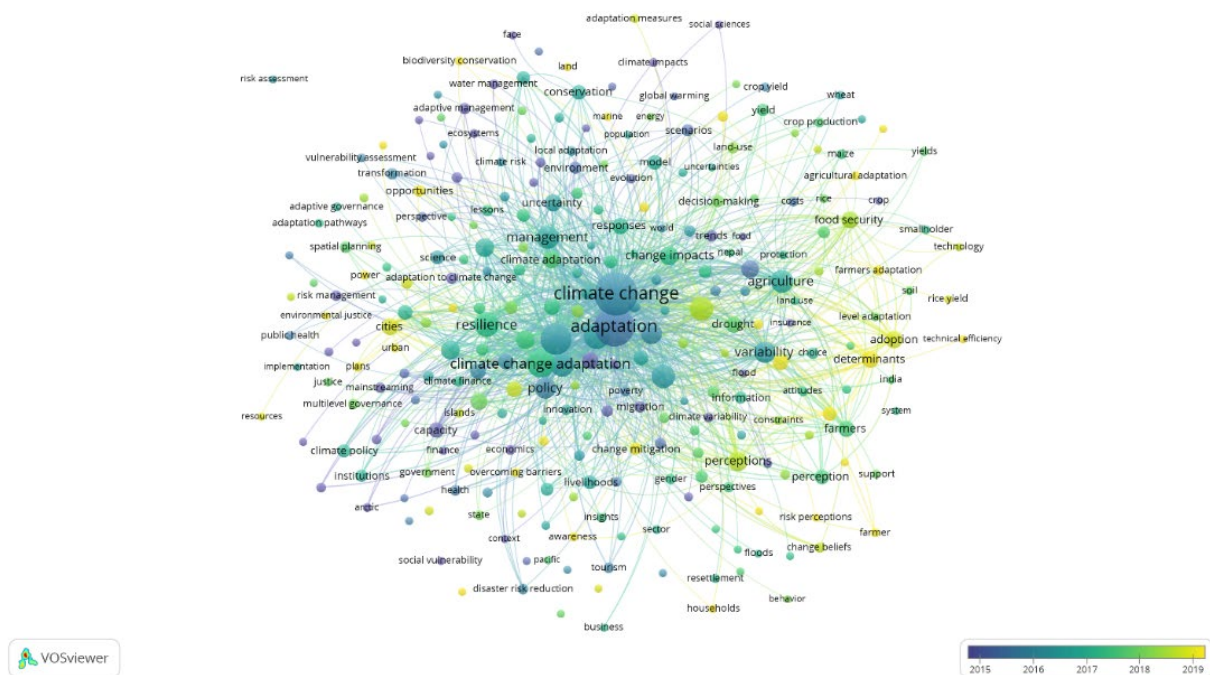


Figure 7. Connectivity of keywords used (climate change adaptation) by year. Proprietary processing based on WoS results using VOSviewer.

In 2016 and 2017 research focused on implementation, tourism, disaster risk reduction, science, transformation, conservation, biodiversity, model, agriculture, variability, choice, informational, perception, farmers, system, resettlement, governance, barriers, resilience, politics, adaptation planning, water, poverty, communities, and climate change policy (Figure 7).

In 2018, the following topics emerged: food security, yields, rice, land use, soil, productivity, climate adaptation, change adaptation, social-ecological systems, economic impact, climate justice, state, behaviour, decision-making, and level adaptation (Figure 7).

In 2019, researchers took a keen interest in the following topics: perceptions, mitigation of change, farmer, social capital, small farmers, determinants, adaptation, technical efficiency, rice yield, technology, strategies, climate resilience, agricultural adaptation, water-use efficiency, irrigation, land, biodiversity conservation, opportunities, city, urban, plans, area, awareness, resources, power. The evolution over time of the connectivity of the keywords analysed underwent a shift from climate change impacts, covering a more general set of topics, to the analysis of more specific topics, with a focus on solutions to adapt to climate change, particularly in relation to agriculture, with a focus on farmers, efficiency techniques, irrigation, and rational water use (Figure 7).

Austria, the United States, and the Netherlands are countries that attach particular importance to the specified topic, all of them addressing different research topics.

According to the map, there are six research directions, with Romania, Portugal, Poland, Finland, the Netherlands, Italy, Spain, Belgium, Sweden, Scotland, Italy, and Germany pursuing a similar research direction, with Romania in close collaboration with Portugal and Poland. The close association between authors from member countries of the European Union can be attributed to the various research programs funded by the European Union that foster partnerships between these countries. At the other end of the spectrum are authors from the USA, whose collaborations are mainly with researchers from India. In general, the interconnectivity between authors is global on the theme of “climate change adaptation”, as is to be expected, given that this is a global problem (Figure 8).

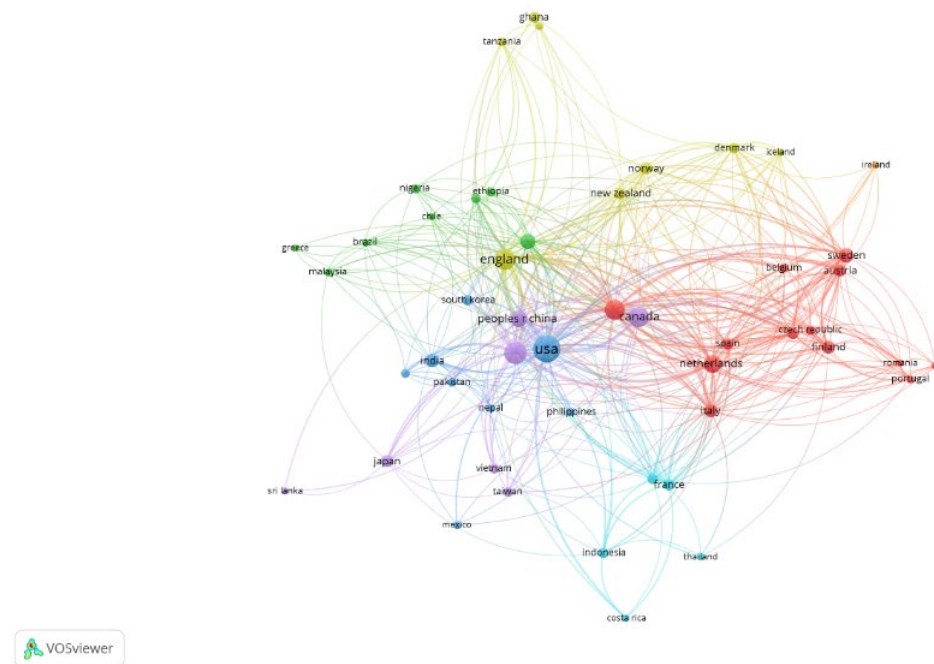


Figure 8. Graphical representation of coauthor countries (adaptation to climate change). Proprietary processing based on WoS results using VOSviewer.

3.2. Disaster Risk Reduction

Between 1991 and 2022, 5920 scientific papers were published on the subject of disaster risk reduction, covering topics such as multidisciplinary geosciences (1729 papers), meteorology atmospheric science (1495 papers), water resources (1445 papers), environmental studies (1359 papers), environmental science (1259 papers), occupational environmental public health (636 papers), and civil engineering (350 papers) (Figure 9).

According to the bibliometric analysis, the main topics were climate change, policy, built environment, hazards, disaster risk management, social vulnerability, Hurricane Katrina, uncertainty, variability, community, education, people, and children. These keywords occurred at least five times in a survey and are grouped into clusters (Figure 10).

The first cluster (yellow) is linked to the following keywords: resilience, climate change adaptation challenges, governance, policy, sustainable development, built environment, disaster risk governance, sustainable development goals, disaster resilience, capacity, management, organisations, integration, community disaster risk, community participation, and future (Figure 10).

The second cluster (green) is about the consequences of disasters in different areas and countries, with the following keywords highlighted: disaster risk management, natural disaster, reduction, risk, hazards, hazards, insurance, losses, region, flood risk, flood risk, risk assessment, economics, developing countries, landside, and consequences (Figure 10).



Figure 9. Tree diagram of Web of Science publications on “disaster risk reduction”. Source: Processed from Web of Science website.

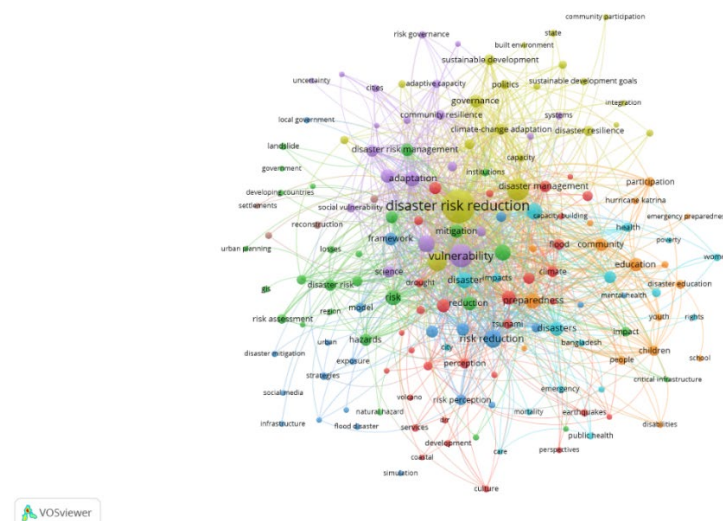


Figure 10. Connectivity of keywords used (disaster risk reduction). Proprietary processing based on WoS results using VOSviewer.

The third cluster (blue) includes main human issues, such as framework, city, disaster, disaster, determinants, mortality, public health, emergency, poverty, strategies, social media, decision making, infrastructure, risk perception, urban, urban, and model exposure (Figure 10).

The fourth cluster (purple) includes keywords such as vulnerability, climate change, social vulnerability, Hurricane Katrina, uncertainty, variability, cities, adaptive capacity, community resilience, systems, scientific knowledge, and sustainability (Figure 10).

The sixth cluster (orange) shows key community elements, such as community, education, people, people, children, youth, education, students, participation, children, people, school, disaster education, response, and preparedness (Figure 10).

In 2016, the focus of research was on disaster, hazards, losses, risk assessment, disaster mitigation, developing countries, variability, integration, globalization, mortality, culture, simulation, rights, gender, risk analysis, climate, institutions, and disaster reduction (Figure 10).

In 2017, researchers focused on disaster risk reduction, perception, risk perception, public health, recovery, flood, build environment, government, local government, and strategies (Figure 11).

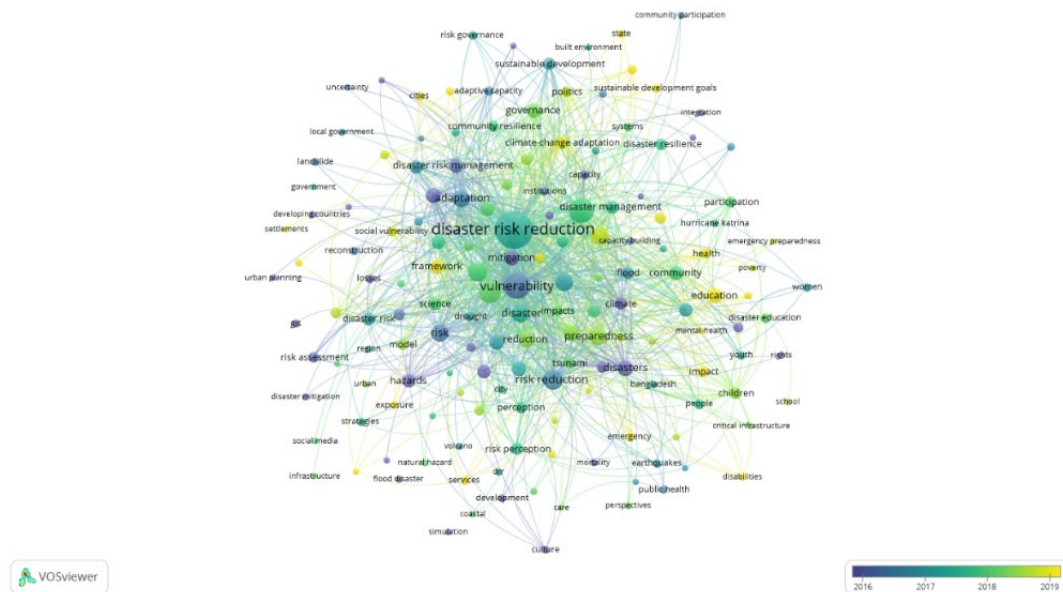


Figure 11. Connectivity of keywords used (disaster risk reduction) by year. Proprietary processing based on WoS results using VOSviewer.

In 2018 and 2019 researchers focused on politics, cities, future, state, health, education, impact, services, settlements, disaster governance, social vulnerability, communities, emergency, and climate change. The connectivity between the keywords used in relation to “disaster risk reduction” indicates a wide range of research spheres, with analysis performed from various perspectives, taking into account the multitude of disasters that can occur. (Figure 11).

Countries showing a particular interest in the topic of disaster risk reduction are Japan, Switzerland, the United States, and England. It is worth noting the considerable interest of authors in Japan on this topic, given that this country frequently faces such disasters (earthquakes). There are six research directions, with researchers from Japan, Malaysia, Indonesia, the Philippines, and Taiwan clustering in the same direction, whereas England, New Zealand, South Africa, Malawi, and Zimbabwe cluster in another direction. This topic is also investigated by researchers in the European Union from countries such as Belgium, Sweden, and Hungary, representing another research direction (Figure 12).

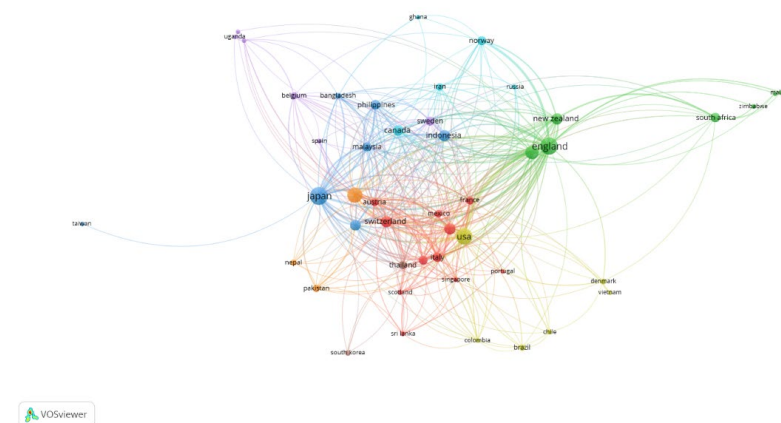


Figure 12. Graphical representation of coauthor countries (disaster risk reduction). Proprietary processing based on WoS results using VOSviewer.

3.3. Sustainable Agricultural Practices

The subject of “sustainable agricultural practices” registered 7941 papers in the Web of Science database between 1990 and 2022, included in categories such as environmental sciences (2327 papers), agronomy (979 papers), green sustainable science technology (977 papers), multidisciplinary agriculture (963 papers), environmental studies (888 papers), and ecology (643 papers) (Figure 13).



Figure 13. Tree diagram of Web of Science publications on “sustainable agricultural practices”. Source: Processed from Web of Science website.

According to the map generated by VOSviewer software, keywords are grouped into clusters. The first cluster (blue) contains terms related to environment and agriculture, such as biodiversity, ecological intensification, agroecological practices, common agricultural policy, soil health, farming, intercropping, organic carbon soil, microbial community, agri-environment schemes, and rural development (Figure 14).

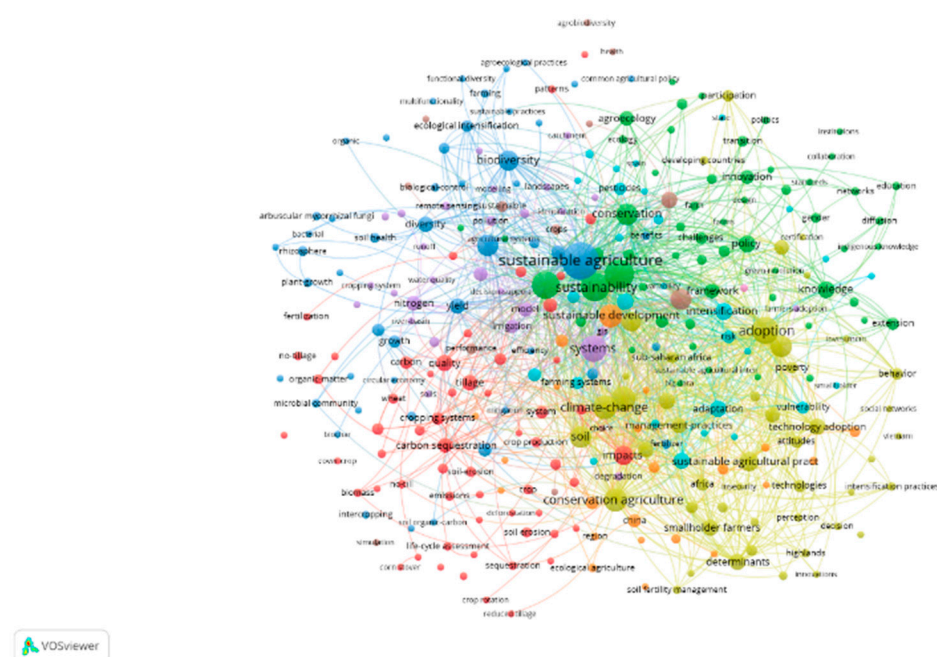


Figure 14. Connectivity of keywords used (sustainable agricultural practices). Proprietary processing based on WoS results using VOSviewer.

The second cluster (green) covers diverse topics, including policy, extension, sustainability, conservation, agroecology, ecology, barriers, rural development, transition, design, farm, security, challenges, governance, perspectives, management, and agriculture (Figure 14).

The third cluster (yellow) includes keywords such as poverty, soil, climate change, adoption, farmers, behaviour, technology adoption, attitudes, insecurity, decision, perception, smallholder farmers, determination, multivariate probit, and water conservation (Figure 14).

The fifth cluster (red) is associated with carbon, quality, soil quality, climate, no-till, corn stover, crop rotation, reduced-tillage, crop, deforestation, wheat, fertilization, system, impact, and soil organic carbon (Figure 14).

The sixth cluster (brown) includes the following terms: agrobiodiversity, food, sustainable intensification, protection, crops, health, and performance (Figure 14).

In terms of the year in which researchers wrote about certain topics, since 2014 and 2015 the focus has been on transition, policy, agriculture extension, soil erosion, biomass, cover crop, ecological agriculture, nitrogen, soil quality, simulation, and water quality (Figure 15).

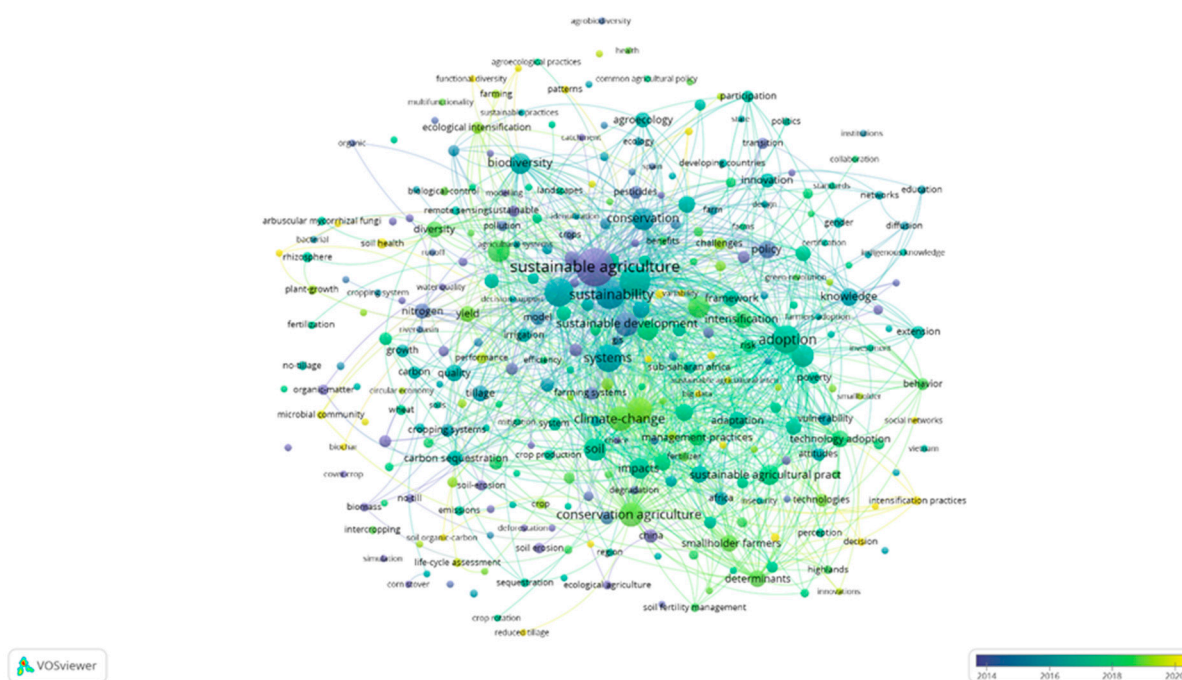


Figure 15. Connectivity of keywords used (sustainable agricultural practices) by year. Proprietary processing based on WoS results using VOSviewer.

In 2016 and 2017, researchers were concerned with keywords including cropping system, carbon, growth, knowledge, biodiversity, agriculture, agroecology, participation, bioenergy, diffusion, education, networks, and farm (Figure 15).

In 2018 and 2019, the focus of researchers was on the following topics: farmers, poverty, adaptation, impact, soil, migration, innovation, food, strategies, conservation agriculture, smallholder farmers, determination, diversity, healthy, agroecological practices, and determinants (Figure 15).

In 2020, the main topics were functional diversity, organic carbon, intensification practices, barriers, patterns, bacteria, soil health, decisions, and crop productivity. The year 2014 was the new programming period for the European Union's Community agricultural policy (2014–2020), especially considering that seven of the top 10 countries ranked by origin are part of the European Union. Thus, the topics covered focused predominantly on

transition and policies, whereas at the end of this programming period, studies focused more on the results of the directions set by the European Union (Figure 15).

The countries with the most papers indexed in the Web of Science on the topic of “sustainable agricultural practices” were the USA, with 1605 papers; China, with 861 papers; India, with 656 papers; and Italy, with 567 papers. The top authors were from countries with highly industrialised agricultural industries where the practice of sustainable agriculture is a necessity and is also linked to the need for food in the context of population growth (i.e., China and India) (Figure 16).

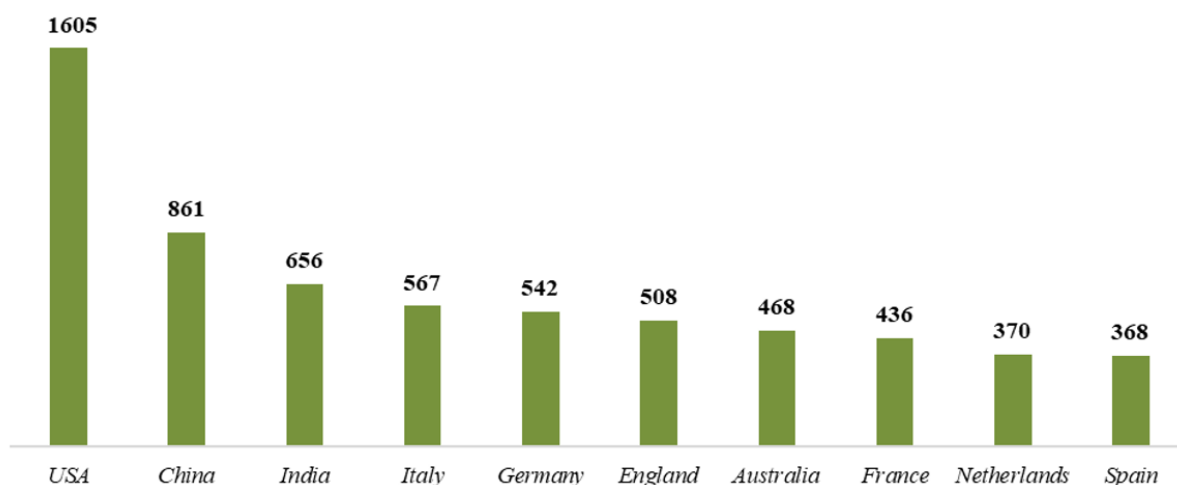


Figure 16. Top author countries on the topic of sustainable agricultural practices. Own Processing.

3.4. Circular Economy

The interest in the topic of “circular economy” is illustrated by the multitude of 15,813 research papers published between 1989 and 2022 according to the Web of Science database. Most of the papers were included in the following categories: environmental science (6039 papers), green sustainable science technology (4373 papers), environmental engineering (3287 papers), environmental studies (2244 papers), energy fuels (1287 papers), and multidisciplinary materials science (1010 papers) (Figure 17).



Figure 17. Tree diagram of Web of Science publications on “circular economy”. Source: Processed from Web of Science website.

The interest in the topic of “circular economy” is illustrated by the multitude of 14,453 research papers written between 1989 and 2022 according to the Web of Science database. Most of the papers were included in the following categories: environmental science (5523 papers), green sustainable science technology (3972 papers), environmental engineering (3037 papers), environmental studies (2027 papers), energy fuels (1164 papers), and multidisciplinary materials science (925 papers) (Figure 18).

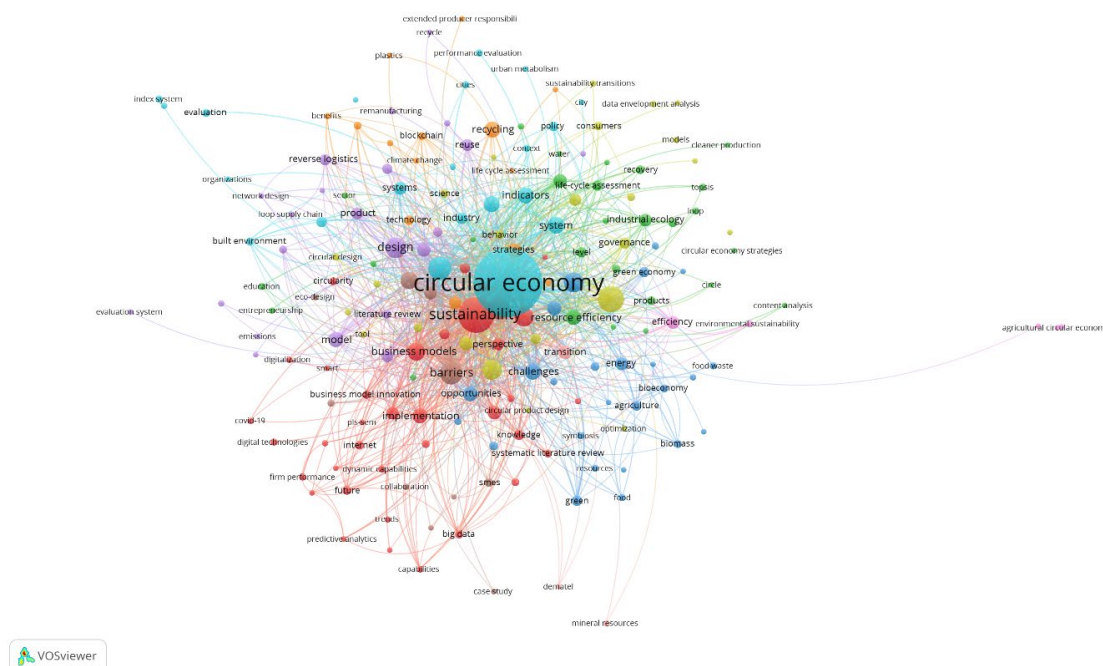


Figure 18. Connectivity of keywords used (circular economy). Proprietary processing based on WoS results using VOSviewer.

Cluster one (blue) contains terms related to our topic, such as indicators, industry, system, construction, build environment, evolution, index system, policy, context, energy, opportunities, green, food, bioeconomy, agriculture, food waste, biomass, history, and ecology (Figure 18).

The second cluster (red) includes the following keywords: implementation, internet, business models, COVID-19, future, trends, big data, capabilities, knowledge, digital technologies, supply chain management, and circularity (Figure 18).

The third cluster (purple) focuses on logistics and includes the following keywords: product, reverse logistics, design, reuse, remanufacturing, model, emissions, information, evolution system, network design, efficiency, environmental sustainability, sharing economy, recourse, life cycle, and integration (Figure 18).

The fourth cluster (green) includes keywords such as cleaner production, TOPSIS, loop, industrial ecology, industrial symbiosis, level, resource efficiency, sector, and content analysis (Figure 18).

Terms related to the subject matter by year show research topics since 2017 such as: index system, reverse logistics, evolution, performance evolution, data development, resource, agriculture, optimization, and awareness (Figure 19).

In 2018 and 2019, researchers addressed the following topics: efficiency, environment, recycling, model, energy, implementation, product design, loop, eco-efficiency, organizations, and recovery (Figure 19).

In 2020 and 2021, researchers addressed the most numerous topics: indicators, level, governance, strategies, barriers, opportunities, big data, firm performance, digitalization, food waste, smart, tool, benefits, supply chain, blockchain, business, and transition (Figure 19).

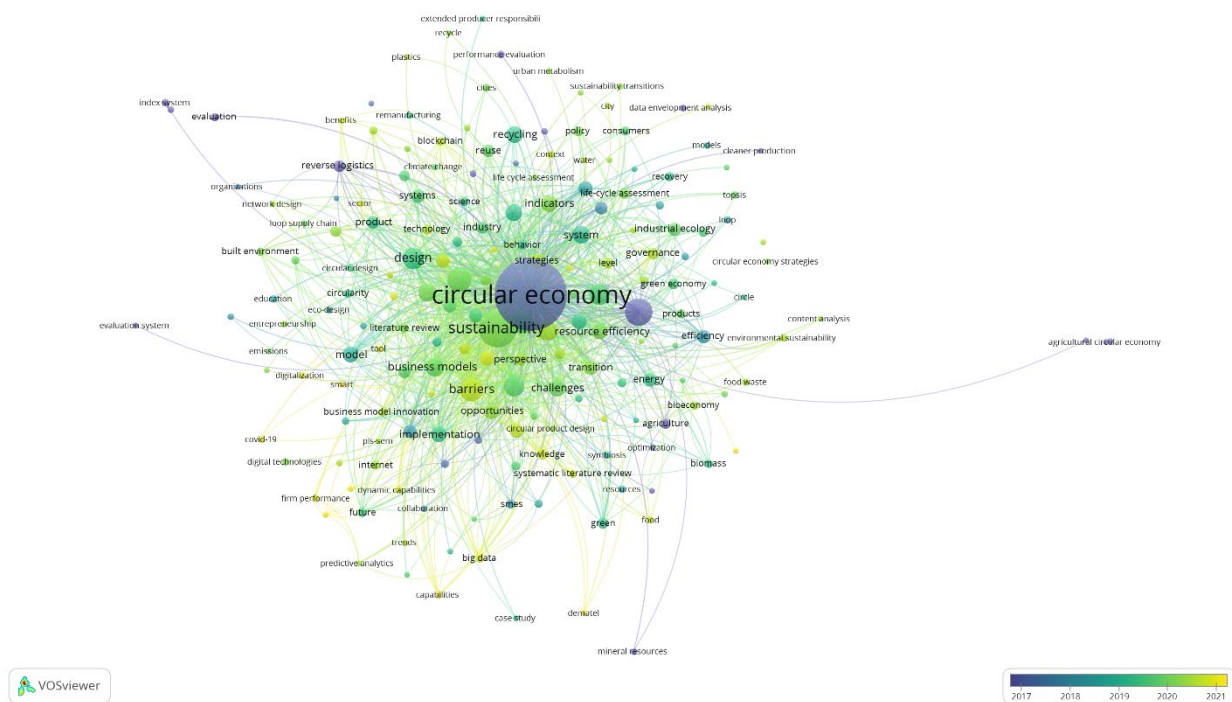


Figure 19. Connectivity of keywords used (circular economy) by year. Proprietary processing based on WoS results using VOSviewer.

According to the Web of Science database, the top countries with the most papers published between 1989 and 2022 on the circular economy are China, with 2101 papers; followed by Italy, with 1850 papers; Spain, with 1468 papers; England, with 1367 papers; and the USA, with 1017 papers. The great interest of Chinese authors in the field of “circular economy” is relevant in the context of finding solutions to meet the needs of the population and correlated with increasing living standards. The directions taken by the European Union in this area also influenced the direction of research in EU countries (Figure 20).

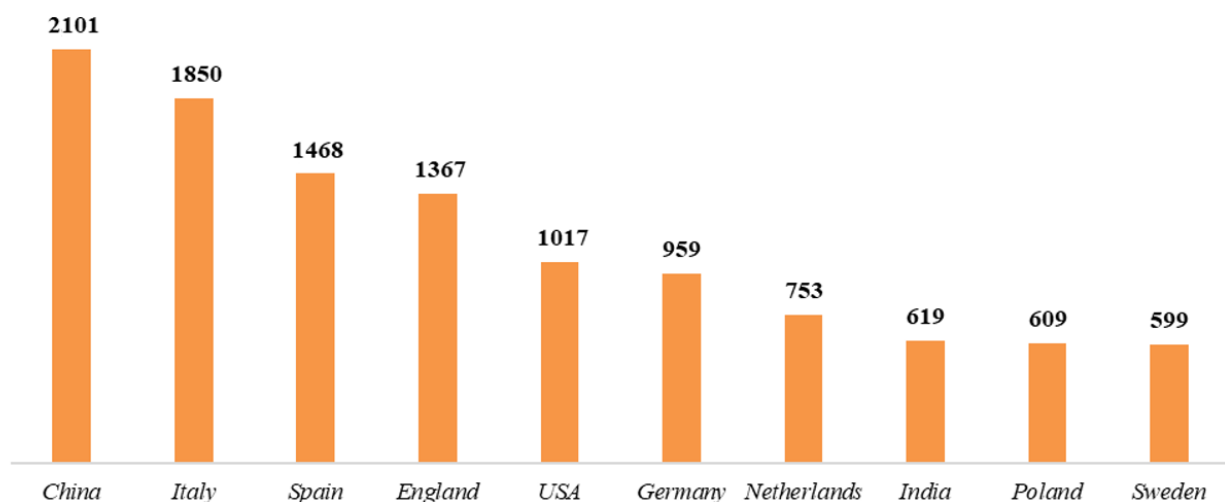


Figure 20. Top author countries for the topic “circular economy”. Own processing.

4. Discussion

Although emissions are expected to cause unavoidable warming, even if the volume of greenhouse gas concentrations remains at 2000 levels; therefore, adaptation is the only solution. Many of the incipient effects of climate change can be addressed through adaptation, although associated costs will tend to increase [53,54]. Adaptation solutions include

technological, behavioural (changing consumption habits), policy, and management solutions [53–55]. Policies established by the European Union as a whole, in conjunction with the funding of research activities, have succeeded in creating synergies between Member States, finding and developing solutions to help adapt to climate change.

The effects of climate change can be seen by all and are visible in the increasing frequency and intensity of natural disasters, especially in developed countries, where economic losses slow their development and, in poor countries, contribute to the loss of human life. The links between ‘disaster risk reduction’ and other keywords are based, in particular, on the occurrence of phenomena that cause significant economic and social losses, thus justifying the number of publications in countries vulnerable to such events, such as Japan and the USA [55–57].

Sustainable agricultural practices can contribute to reduced vulnerability to climate change and can also lead to increased resilience [58,59]. However, climate change tends to slow down this process, both by exposing negative impacts and by eroding adaptive capacity [60–62]. The top countries to report on this topic (sustainable agricultural practices) are predominantly European Union member countries, which, although not experiencing significant population growth as in other continents, are concerned about the use of sustainable agricultural practices to ensure continuity for future generations [63–65].

Although the ‘circular economy’ is a relatively new field, research interest has grown in recent years as a result of the inability to meet the needs for goods and food in the context of a growing population, as well as in countries where increases in living standards have been identified. More than 30 years ago, in communist-ruled countries, this process was commonplace, even if it was not known by that name; “everything was used and nothing was wasted” with a desire to save money [64–69].

5. Conclusions

Climate change is already having a measurable impact on natural and human systems, which has encouraged researchers around the world to focus on solutions for climate change adaptation, disaster risk reduction, natural resource management, sustainable agricultural practices, and, more recently, the circular economy, with a particular focus on society [70–72].

Many policy instruments can be applied to stimulate mitigation actions, both nationally and internationally, with advantages and disadvantages of each action [73,74]. Regulation and standardisation can create certainty about the level of emissions but discourage innovation [73–75].

By imposing carbon taxes, policy makers can create an effective mitigation incentive but cannot ensure a predetermined decrease. Subsidies and credits in this area are a possible solution for the development and diffusion of new technologies, which are often costly but essential [70–73].

Clearly, policies set at the local or regional level may make it more difficult for companies to develop or may jeopardise people’s living standards, but they are the only way to adapt to climate change. Funding for research is a key component, and this is also reflected in the many collaborations at the European level as a result of policies adopted by the European Commission [64–66].

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