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# Plastic and sustainability: a bibliometric analysis using VOSviewer and CiteSpace

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## Abstract

**Purpose** – This study aims to present a comprehensive knowledge mapping and an in-depth analysis of plastic and sustainability research to understand better global trends and directions in this field that emerged between 1995 and 2022.

**Design/methodology/approach** – This study presents a visual analysis of 1933 research articles listed in the Web of Science (WoS) databases between the years 1995 and 2022 related to plastic and sustainability. The knowledge mapping based on CiteSpace and VOSviewer presents the current research status, which contains the analysis of the collaboration network, co-citation network, references with citation bursts and keyword analysis.

**Findings** – The results reveal that China and the USA are the most prominent countries in exploring the notion of sustainability and plastic. The Chinese Academy of Science is the most prominent institution. Chai Qiang, Friedrich Daniel, Sahajwalla Veena and Ok Yong Sik are the most prolific authors in this field. Furthermore, circular economy, bioplastic, sustainable development, polyester and bioplastics are the highly discussed issues in recent years. Not surprisingly, COVID-19 is the latest topic of discussion started in 2021 due to its negative impact on plastic pollution and the challenges it posed to sustainability.

**Originality/value** – This study is among the pioneers to shed light on the current research status of plastic and sustainability using the bibliometric method and the newest data. This study also suggests that collaborations between scholars and institutions require to be enhanced for better management of plastic pollution and to contribute to sustainable development.

**Keywords** Sustainability, Plastic pollution, Bibliometric analysis, CiteSpace, VOSviewer

**Paper type** Literature review

## Introduction

Sustainability refers to maintaining a balance between society, environment and economy, commonly known as the triple bottom line (Quoquab & Mohammad, 2017). It suggests preserving the environment and maintaining individual behavior for the benefit of society and the economy in a given period (Gruen *et al.*, 2008). Indeed, environmental sustainability has become one of the most prioritized issues as the panacea for various environmental and social challenges, such as air and water pollution, deforestation, rising sea levels, waste disposal, loss of biodiversity, ozone layer depletion, etc (Quoquab & Mohammad, 2020). Environmental sustainability advocates take the responsibility to preserve natural resources and safeguard the world's ecosystems to promote health and well-being for the present and

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future generations (Khan, Zakari, Ahmad, Irfan, & Hou, 2022). It is a crucial strategy against the backdrop of the growth of the human population and the widespread exploitation of the environment by humans. Therefore, it is gaining significant research attention from academicians, scholars, governments and nongovernment organizations (Guidara, 2022; Quoquab & Mohammad, 2016).

Many factors affect the sustainability of the environment, among which plastic pollution has become one of the major threats in recent years (Burmeister & Eilks, 2012; Mallick, Pramanik, Maity, Das, & Sahana, 2021; Mir & Bhat, 2022; Kumagai, 2020; Pham, Nguyen, Le, Do, & Nguyen, 2022). With the growth of the economy and the development of chemical technology, a variety of plastic materials are made and used in all aspects of life (Harris, 1953). Since the commercial development of plastics in the 1930s and 1940s, plastics have become an indispensable part of the consumer market (Jambeck *et al.*, 2015). However, while humans have been enjoying the benefits of plastics, it led to many uncountable adverse effects, especially in terms of pollution (Rhodes, 2018; Saleh, Quoquab, & Mohammad, 2019). With the increasing use and production of plastic, the pollution caused by plastic has also increased tremendously, which has become a threat to biodiversity and human and societal well-being (Alpizar *et al.*, 2020). Usually, discarded and dumped plastics are burned in landfills, creating toxic materials polluting the air and soil (Khan, Ahmed, Najmi, & Younus, 2019). Therefore, plastic pollution is considered as a major environmental issue (Pandey, Surjan, & Kapshe, 2018).

In the Sustainable Development Goals (SDGs) of the United Nations (UN), at least 12 goals are related to plastic pollution (Walker, 2021). According to Jambeck *et al.* (2015), plastic pollution first appeared in the literature in the early 1970s. It was estimated that 19 to 23 million metric tons of plastic waste were generated in 2016, and the number will increase to 53 Mt annually by 2030 (Borrelle *et al.*, 2020). Similarly, the UN announced that plastic pollution has become a worldwide crisis (UNEP, 2017). Therefore, dealing with plastic pollution and realizing sustainable development has become a pressing need (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). To address sustainability issues, the circular economy has become an important strategy that governments have focused on (Geissdoerfer *et al.*, 2017). In 2018, to emphasize and achieve the circular economy, the European Union made a strategy for plastics to address the design, reuse, refurbishing and recycling of plastics (Matthews, Moran, & Jaiswal, 2021).

Besides, the outbreak of COVID-19 has increased humans' reliance on plastics (Vanapalli *et al.*, 2021). The increased demand for plastics has led to high pressure on the management system and aggravated the leakage of plastic waste into the environment (Vanapalli *et al.*, 2021). Indeed, the accumulation of plastic pollution is increasing at an unprecedented rate and has become a global concern that should be addressed with the utmost priority (Kumar *et al.*, 2021). However, no study systematically analyzed the current research status of sustainability and plastic. Therefore, this study intends to fill this gap in the literature by using bibliometric analysis via CiteSpace and VOSviewer.

This is a pioneer research to conduct a bibliometric study on "plastic and sustainability," which is expected to present a holistic image of this area by exploring the evolution of hot topics in the field. In addition, this study highlights the prominent scholars, institutions and important articles in this field. It helps researchers find collaboration partners, related and relevant journals and contributing research papers. The rest of the paper is organized as follows: first, the theoretical background is discussed, followed by the introduction of the bibliometric methods and a discussion of the data sources. Next, the results of the bibliometric analysis that consists of co-occurring and co-citation analysis are presented. Then, the emerging trends of "plastic and sustainability" are highlighted, and future research directions are provided. Finally, the implications and limitations of this study are discussed.

## Theoretical background

Sustainability is an elusive concept, and scholars debate on how to define this phenomenon (White, 2013). From a macro-point of view, sustainability means "all forms of life will flourish forever" (Ehrenfeld, 2005, p. 24). From a micro-perspective, scholars investigate it according to the elements of sustainability (Costanza & Patten, 1995; Robert, Parris, & Leiserowitz, 2005). Sustainability can be categorized into three main pillars: environmental sustainability, social sustainability and economic sustainability (White, 2013). White (2013) performed a tag clouds analysis on sustainability and found that environmental sustainability is the most concerning research topic by scholars in all tags related to sustainability.

Dealing with plastic pollution remains one of the major challenges for sustainalibity (Gilbert, 2017; Sudesh & Iwata, 2008). In the same manner, Blettler and Mitchell (2021) argued that plastic pollution is one of the most pressing environmental problems threatening the natural environment and human health. Needless to say, plastic pollution has deeply affected the global ecological system and human health (Sarkar, Dissanayake, *et al.*, 2022; Sarkar, Routroy, & Sultan, 2022). For example, marine creatures ingest plastic debris not only threaten their life and health but also hurts the human body when consumed by humans (Blettler & Mitchell, 2021). Some studies have shown that the smaller the particle size, the greater the risk factor from plastic (Pitt *et al.*, 2018). Microplastics and nanoplastics are ubiquitous in terrestrial and aquatic ecosystems (Sarkar, Dissanayake, *et al.*, 2022; Sarkar, Routroy *et al.*, 2022). One reason is the increase in plastic production, and the other is the plastic waste mismanagement of microplastics and nanoplastics, which results in tremendous adverse effects on environmental sustainability (Sarkar, Dissanayake, *et al.*, 2022; Sarkar, Routroy *et al.*, 2022).

During the COVID-19 pandemic, plastic medical waste posed a new challenge to environmental sustainability (Mazahir & Qamari, 2022). Besides the heavy use of plastic gloves and packaging, COVID-19 tests have also used many plastic products, such as plastic swabs, plastic pipettes, plastic tips and plastic tubes (Bansal & Sharma, 2021). It is estimated that each COVID-19 test generates 37g of plastic pollution (Celis *et al.*, 2021). Therefore, to ensure environmental sustainability and deal with plastic pollution, making straight environmental regulations and appropriate environmentally sustainable plastic waste management strategies are critical; they need efforts from all over the world (Sarkar, Dissanayake, *et al.*, 2022; Sarkar, Routroy *et al.*, 2022).

The recycling, reuse and reprocessing of plastics are regarded as the primary ways to align with sustainability (Klemeš, Fan, & Jiang, 2020). To decrease the negative effects of plastics, researchers from multi-disciplines have extended their cooperation in investigating issues such as business, materials science, chemistry and chemical engineering (Moshood *et al.*, 2022). Bio-based plastics are a promising alternative green material to decrease plastic pollution and enhance environmental sustainability (Ferreira-Filipe, Paço, Duarte, Rocha-Santos, & Patrício Silva, 2021).

In this study, we contribute to categorizing this subject by presenting a systematic bibliometric analysis. This bibliometric analysis of 1933 articles published over the last 28 years (1995–2022) is the first to present comprehensive and statistical insight into the research status and trends on "sustainability and plastics."

## Materials and methodology

### *Data sources*

Web of Science (WoS), which contains more than 13,600 journals database (Mongeon & Paul-Hus, 2016), is regarded as an ideal data source for bibliometric investigation (Fang, Yin, & Wu, 2018). It has been used in the bibliometric analysis in many social science studies (Cui, Mou, & Liu, 2018; Fang *et al.*, 2018; Li, Ma, & Qu, 2017; Sarkar, Dissanayake, *et al.*, 2022;

Sarkar, Routroy *et al.*, 2022). It is an up-to-date academic database and is also recommended as the preferred database when using CiteSpace software by Chen Chaomei, who is the creator of CiteSpace (Chen, 2006). Therefore, we chose the WoS as the data source in this study. Second, for acquiring high-quality articles and excluding interferential articles, the WoS Core Collection was chosen as the final data source, not all databases.

According to the information of WoS, the first article about plastic and sustainability was published in 1995. The data collection process for this study started on June 3, 2022; thus, the scope of this research is from 1995 to 2022. To avoid missing literature, synonyms such as "sustainable development and plastic" and "sustainability and plastic" are considered in the process of data collecting. The detailed search information is summarized in Table 1.

For acquiring high-quality data, we only use research articles as analysis data. After excluding proceedings papers (381), review articles (396), book chapters (83), editorial materials (31), letters (4), news items (13), meeting abstracts (4) and data papers (1), this study got 1933 literature available, which contains articles (396), early access (53) and books (2). In WoS, an article can have different document types at the same time. The available literature in this study contains 82739 related references.

*Knowledge mapping*

Knowledge mapping has been widely used in bibliometric analysis. Cui *et al.* (2018) called knowledge mapping "the quantitative analysis of publications in a given field" (Cui *et al.*, 2018, p. 842). It is a useful way to help researchers better understand the current research status and future research directions of a specified research field. Co-occurring analysis and co-citation analysis are the main analysis tools in bibliometric analysis. In the analysis of co-occurring, the prominent authors, journals, institutions and countries in a research field can be illustrated clearly. The results will be visualized as an image of a collaboration network, which can show the frequency of academic collaboration (scholar, country and institution). In the co-citation network analysis, the journals, articles and authors of a specified research field with the most citation frequency can be found. The higher the citation frequencies of an article, a journal and an author, the more important it is (Small, 2003).

In this study, we used CiteSpace 6.1 and VOSviewer software, which are often used by scholars (Chen, Lin, & Zhuang, 2022; Lin, Chen, & Chen, 2020; Luo & Lin, 2021; Zhang & Lin, 2022; Zhang & Quoquab, 2022). Many researchers use them simultaneously in a study (Ding & Yang, 2020; Meng, Wen, Brewin, & Wu, 2020; Ye, 2018). CiteSpace and VOSviewer have their advantages, respectively. Generally, VOSviewer has better clarity and user-friendliness than CiteSpace (Markscheffel & Schröter, 2021). The visualization network could be directly created by VOSviewer, and researchers can use it directly (Markscheffel & Schröter, 2021). However, CiteSpace has advantages in evaluative analysis over VOSviewer (Markscheffel & Schröter, 2021); for example, it can provide citation burst analysis and label clusters analysis.

| Criteria | Description |
|---|---|
| Source website | Web of Science Core Collection |
| Years | January 1995–June 2022 |
| Searching terms | "sustainable development and plastic" or "sustainability and plastic" |
| Inclusion criteria | Articles (1931), Early Access (53), Books (2) |
| Exclusion criteria | Proceedings papers (381), Review articles (396), Book chapters (83), Editorial materials (31), Letters (4), News items (13), Meeting abstracts (4), Data papers (1) |
| Sample size | 1933 |
| Reference size | 82739 |

**Table 1.**
Summary of searching details

In the graph of CiteSpace and VOSviewer, analytic objectives are represented by nodes. The bigger a node, the more important it is. The nodes that have high occur frequencies are presented in the center (Markscheffel & Schröter, 2021).

In this study, the co-occurring network and co-citation network were analyzed by VOSviewer and CiteSpace, respectively. Further, the emerging trends and future research directions will be shown by keyword analysis.

## Analysis and findings

### *Research outputs and their categories*

The number of publications about "Sustainability and Plastic" during 26 years period 1995–2021 is shown in Figure 1. There is an obvious inflection point in 2015. The number of publications is slowly increasing before 2015. However, there has been a sharp upward trend since 2015. The reason could be that the UN launched 17 SDGs in 2015 (Walker, 2021). Reducing the impact of plastic is one indicator under Goal 14, and at least, 12 SDGs are related to plastic pollution (Walker, 2021). Therefore, more and more researchers worldwide have started focusing on the relationship between sustainability and plastic. It could be forecasted that more articles will be published in the "sustainability and plastic" field. Based on the publication trend and the UN SDGs launch, two development stages can be concluded in this field.

### *Preparation phase (1995–2015)*

In this phase, the focus of researchers on sustainability and plastic gradually evolved from a preliminary stage to a wide range of discussion. According to the disciplines, the problem of environmental sustainability and plastic pollution has been the major concern in this subject. Table 2 shows the main disciplines in this stage: environmental sciences, engineering environmental and polymer science are the main disciplines that contribute to this field. In the natural sciences, bio-based plastics, regarded as the substitute for petroleum-based plastic, have a significant meaning to sustainability (Álvarez-Chávez, Edwards, Moure-Eraso, & Geiser, 2012). Table 3 presents the prominent authors of this phase. Some scholars have focused on this field, like Koeser, who has the most publications with five articles.

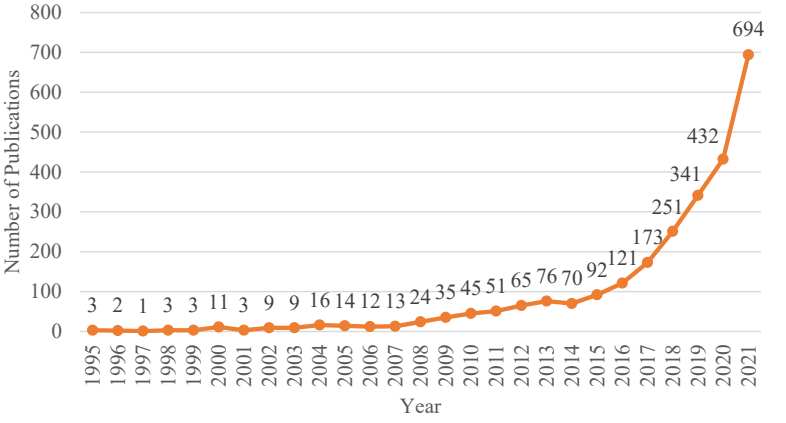


**Figure 1.**
The number of published papers on "sustainability and plastic"

| 1995–2015 | | 2015–2022 | |
|---|---|---|---|
| Disciplines | Number of publication | Disciplines | Number of publication |
| Environmental sciences | 118 | Environmental sciences | 722 |
| Engineering environmental | 78 | Green sustainable science technology | 514 |
| Polymer science | 51 | Engineering environmental | 343 |
| Materials science multidisciplinary | 49 | Materials science multidisciplinary | 226 |
| Horticulture | 45 | Environmental studies | 223 |
| Green sustainable science technology | 37 | Polymer science | 167 |
| Agronomy | 35 | Chemistry multidisciplinary | 143 |
| Energy fuels | 32 | Engineering chemical | 117 |
| Engineering chemical | 25 | Engineering civil | 117 |
| Engineering manufacturing | 23 | Energy fuels | 103 |

**Source(s):** Data Source: Web of Science (All document types)

**Table 2.** Main disciplines in two stages

| Two stages | | | | |
|---|---|---|---|---|
| | 1995–2015 | | 2016–2022 | |
| Rank | Authors | Number of publication | Authors | Number of publication |
| 1 | Koeser AK | 5 | Ok Yong Sik | 11 |
| 2 | Bi GH | 4 | Sahajwalla V | 10 |
| 3 | Bing XY | 4 | Friedrich D | 9 |
| 4 | Graves WR | 4 | Kumar R | 9 |
| 5 | Grewell D | 4 | Zhang Y | 8 |
| 6 | Mccabe KG | 4 | Zhao C | 8 |
| 7 | Niu GH | 4 | Alcala M | 7 |
| 8 | Schrader JA | 4 | Bonoli A | 7 |
| 9 | Stewart JR | 4 | Chai Q | 7 |
| 10 | Sun YP | 4 | Fini EH | 7 |

**Source(s):** Data Source: Web of Science (All document types)

**Table 3.** Main authors in two stages

*Rapid development phase (2016–2022)*

In this phase, the sustainability and plastic research field has a booming development. Since the announcement of 17 SDGs, the relationship between plastic and sustainability has got unprecedented attention. According to Figure 1, the number of publications has increased exponentially. In this phase, environmental sciences, green sustainable science technology, engineering environmental, materials science multidisciplinary and environmental studies are the main disciplines. It is noticeable that the publications on green sustainable science technology have an evident increase compared to the first phase, which means environmental sustainability is more focused on by scholars. Publications on environmental studies also significantly increased, which means scholars are more concerned with the environment. From Table 3, more scholars have deeply studied this field. Yong Sik, Sahajwalla and Friedrich *et al.* have contributed significantly to this field.

*The analysis of the collaboration network of plastic and sustainability*

*Prominent countries.* In the countries/regions collaboration network, at least 116 countries published one article. Sixty eight countries published at least five articles, and their density

visualization of the country network is shown in Figure 2 made by VOSviewer, in which the largest set of connected countries consists of 67 countries. Generally, there is a mature collaboration network between countries. In the figure of collaboration, the bigger circle and font are more important. China, the USA and Italy are the most prominent countries in the research field of "sustainability and plastic." China has the most publications with 351 documents, followed by the USA with 300 documents, with the most citations with 7662 citations. Table 4 shows the top 10 countries based on the number of publications. The next countries are Germany (140 publications), England (134 publications), India (113 publications), Australia (108 publications), Spain (104 publications), Brazil (102 publications) and the Netherlands (58 publications).

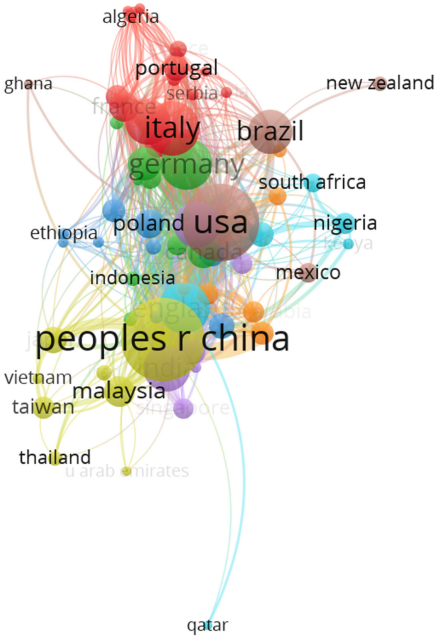


**Figure 2.**
Countries/regions collaboration network (minimum 5 documents) in the research field of "sustainability and plastic"

| Rank | Institutions | Documents | Citations |
|---|---|---|---|
| 1 | China | 351 | 5053 |
| 2 | USA | 300 | 7662 |
| 3 | Italy | 153 | 2594 |
| 4 | Germany | 140 | 2303 |
| 5 | England | 134 | 1969 |
| 6 | India | 113 | 1191 |
| 7 | Australia | 108 | 2163 |
| 8 | Spain | 104 | 1515 |
| 9 | Brazil | 102 | 896 |
| 10 | Netherlands | 58 | 1562 |

**Table 4.**
Top 10 countries based on the number of publications

*Prominent institution.* In the institution collaboration network, 2499 organizations have published one article at least. One hundred twenty seven institutions have published at least five articles. Their density visualization of the collaboration network is shown in Figure 3, made by VOSviewer, in which the largest set of connected institutions consists of 105 institutions. The Chinese Academy of Science is the most prominent institution in the field of "sustainability and plastic", with 70 documents and 1397 citations. The following are Northwest a&f University (35 publications), Lanzhou University (15 publications), China Agricultural University (15 publications), University Bologna (15 publications), Gansu Agricultural University (14 publications), Shanghai Jiao Tong University (14 publications), National University Singapore (13 publications), Iowa State University (13 publications) and University of Manchester (13 publications). It is noticeable that most institutions are from China, which is consistent with the result of the analysis of the countries/regions' collaboration network. One hundred five institutions have formed a close collaboration network. Moreover, other institutions also have their collaboration networks. Generally, the collaboration between institutions worldwide has a medium-scale collaboration network. However, the collaborations between institutions from different countries still need to strengthen (see Figure 3). The top 10 institutions that have the most publications are shown in Table 5.

*Prominent authors.* In the author collaboration network, 7629 authors have published one article at least. One hundred eight authors have published at least three articles. Their density visualization of the collaboration network is shown in Figure 4, in which the largest set of connected scholars consists of 10. Figure 4 in the red cluster shows that the most leading

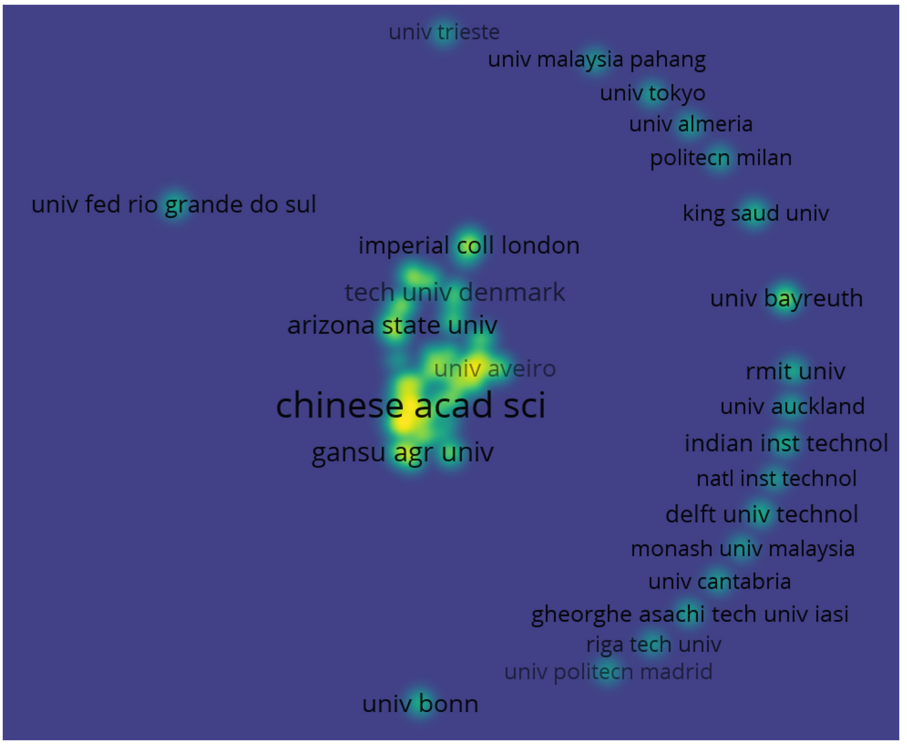


**Figure 3.**
Density visualization clusters of institutional cooperation (minimum 5 documents) in the research field of "sustainability and plastic"

authors are Chai Qiang (7 publications) and Fan Zhilong (5 publications) from China. They have formed a close collaboration network with their coworkers (Yu Aizhong, Zhao Cai, Guo Yao and Yin Wen) from the Gansu Provincial Key Laboratory of Arid Land Crop Science. Following them are two authors who have published eight documents, Friedrich Daniel from Baden Wurttemberg Cooperat State Univ Mosbach and Sahajwalla Veena from the University of New South Wales Sydney. They respectively have their own collaboration network. Yong Sik Ok, with seven documents from Korea University, is also a prominent

**Table 5.**
Top 10 institutions based on the number of publications

| Rank | Institutions | Documents | Citations | Country |
|---|---|---|---|---|
| 1 | Chinese Academy of science | 70 | 1397 | China |
| 2 | Northwest A&F University | 35 | 674 | China |
| 3 | Lanzhou University | 15 | 316 | China |
| 4 | China Agricultural university | 15 | 371 | China |
| 5 | University Bologna | 15 | 350 | Italy |
| 6 | Gansu Agricultural University | 14 | 207 | China |
| 7 | Shanghai Jiao Tong University | 14 | 322 | China |
| 8 | National University Singapore | 13 | 536 | Singapore |
| 9 | Iowa State University | 13 | 156 | The USA |
| 10 | University of Manchester | 13 | 225 | England |

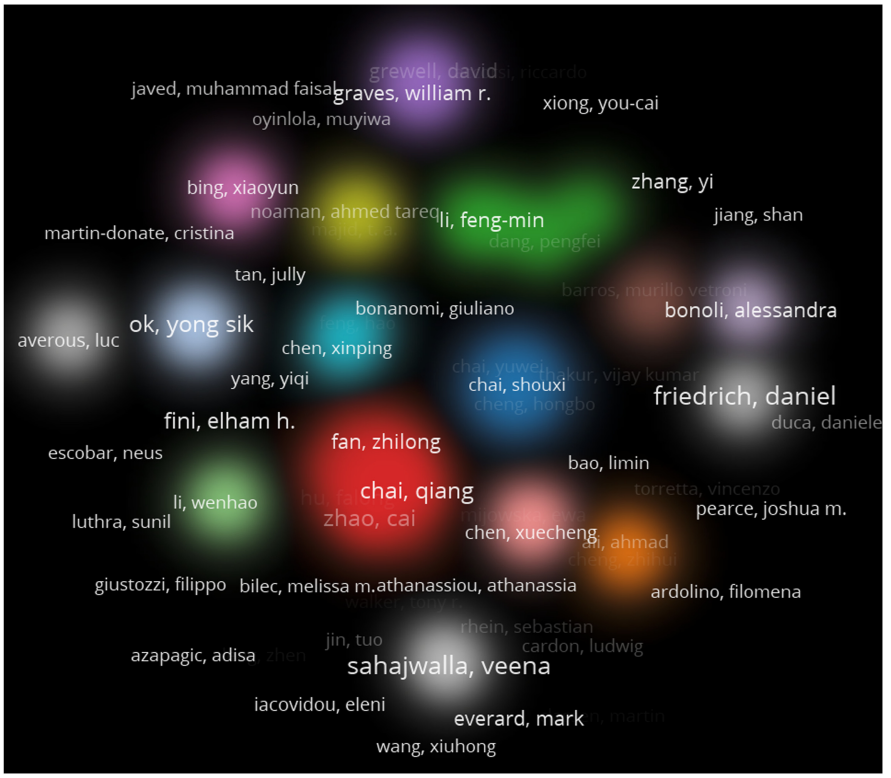


**Figure 4.**
Density visualization clusters of prominent authors (minimum 3 documents) in the research field of "sustainability and plastic"

author in this field. He is at the forefront of global efforts to develop sustainable waste management techniques and technology to address the growing crisis in electronic and plastic trash and particulate matter contamination of soil and air.

Generally, in the field of sustainability and plastic, researchers worldwide have formed a certain scale of a collaboration network. However, the collaborations between researchers from different countries and institutions still need to strengthen. Most collaboration between scholars from the same country and institution is especially prominent in the collaboration from Gansu Provincial Key Laboratory of Arid Land Crop Science. Table 6 shows the top 10 authors based on the number of publications with their institutions, countries, and citations.

*The co-citation network of plastic and sustainability*

*Document co-citation network.* Figure 5, generated by CiteSpace 6.1, shows the document co-citation network, which consisted of 924 references cited and 2713 co-citation links between 1995 and 2022, and the density of the research field network is 0.0064. We chose keyword terms and a log-likelihood rate (LLR) weighting algorithm to label the clusters. All the silhouette scores are above 0.8, which means the clusters have a reliable quality (Fang *et al.*, 2018). The largest 20 clusters are shown in Table 7.

Document co-citation networks can help future researchers quickly find mainstream research topics in this field and choose their appropriate research directions. The circular economy, with 93 member references, is the largest cluster. Based on the mean cite year, the circular economy is an emerging topic that scholars focused on in recent years. The following clusters are Bioplastic (63), COVID-19 (55), Sustainable development (52), Polyester (50), Bioplastics (46), Supply chain management (41), Ecological restructuring (22), Integrated management (20), Silk (16), Wheat-maize double-cropping System (16), Mechanical processing (15), Pots (13), Consumer principles (13), Poly (ethylene terephthalate) (12), Renewable feedstocks (10), Cracked and uncracked concrete (9), Environmental Technology (9), Eggs (8) and Bioethanol (8).

The circular economy is a good alternative to the traditional economy, which has been focused on by the world (Shirvanimoghaddam, Motamed, Ramakrishna, & Naebe, 2020).

| Rank | Author | Documents | Citations | Institutions | Country |
|---|---|---|---|---|---|
| 1 | Friedrich Daniel | 8 | 23 | Baden-Wuerttemberg Cooperative State University Mosbach | Germany |
| 2 | Sahajwalla Veena | 8 | 72 | University of New South Wales Sydney | Australia |
| 3 | Ok Yong Sik | 7 | 37 | Korea University | South Korea |
| 4 | Chai Qiang | 7 | 108 | Gansu Provincial Key Laboratory of Arid Land Crop Science | China |
| 5 | Yu Aizhong | 7 | 108 | Gansu Provincial Key Laboratory of Arid Land Crop Science | China |
| 6 | Zhao Cai | 7 | 108 | Gansu Provincial Key Laboratory of Arid Land Crop Science | China |
| 7 | Fini Elham H | 6 | 29 | Arizona State University | The USA |
| 8 | Guo Yao | 6 | 85 | Gansu Provincial Key Laboratory of Arid Land Crop Science | China |
| 9 | Yin Wen | 6 | 85 | Gansu Provincial Key Laboratory of Arid Land Crop Science | China |
| 10 | Fan Zhilong | 5 | 39 | Gansu Provincial Key Laboratory of Arid Land Crop Science | China |

**Table 6.** Top 10 authors based on the number of publications

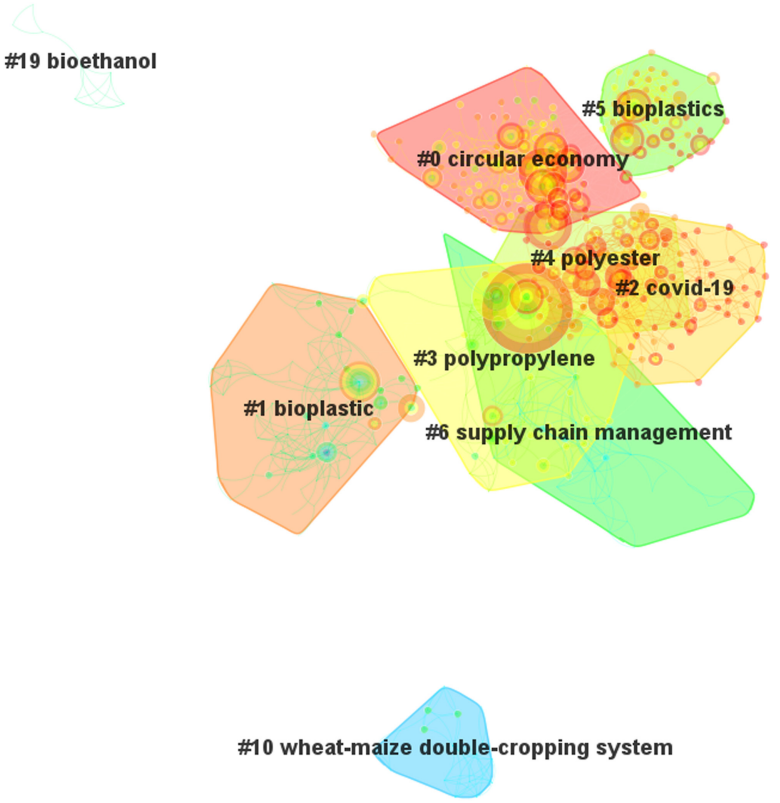


**Figure 5.**
A visualization of the document co-citation network

**Table 7.**
The largest 20 clusters in sustainability and plastic

| Cluster ID | Size | Silhouette score | Label (LLR) | Mean (cite year) |
|---|---|---|---|---|
| 0 | 93 | 0.833 | Circular economy | 2019 |
| 1 | 63 | 0.964 | Bioplastic | 2016 |
| 2 | 55 | 0.909 | COVID-19 | 2021 |
| 3 | 52 | 0.902 | Sustainable development | 2018 |
| 4 | 50 | 0.857 | Polyester | 2020 |
| 5 | 46 | 0.908 | Bioplastics | 2020 |
| 6 | 41 | 0.954 | Supply chain management (SCM) | 2016 |
| 7 | 22 | 1 | Ecological restructuring | 1999 |
| 8 | 20 | 1 | Integrated management | 1996 |
| 9 | 16 | 1 | Silk | 2003 |
| 10 | 16 | 0.996 | Wheat-maize double-cropping system | 2016 |
| 11 | 15 | 1 | Mechanical processing | 2000 |
| 12 | 13 | 1 | Pots | 2013 |
| 13 | 13 | 1 | Consumer principles | 2009 |
| 14 | 12 | 1 | Poly (ethylene terephthalate) | 2004 |
| 15 | 10 | 1 | Renewable feedstocks | 2007 |
| 16 | 9 | 1 | Cracked and uncracked concrete | 2014 |
| 17 | 9 | 1 | Environmental technology | 2004 |
| 18 | 8 | 1 | Eggs | 2010 |
| 19 | 8 | 0.996 | Bioethanol | 2017 |

Plastic pollution and the recycling and reuse of plastic are all closely related to the circular economy, which should be addressed with the utmost priority (Kumar *et al.*, 2021). Cluster #2 COVID-19 is the newest cluster with a mean cites the year 2021, which is a huge potential research topic for future researchers. The breakout of COVID-19 has led to an increase in plastic production, especially single-use plastics, which negatively influence environmental sustainability (Mallick *et al.*, 2021). Dealing with plastic waste during pandemics has become a huge challenge to some developing countries that have limited waste management facilities, which have been focused on by more and more scholars (You, Sonne, & Ok, 2020).

The article that provides data prediction got a lot of citations. The most cited articles are shown in Table 8. The article "Production, use and fate of all plastics ever made" by Geyer,

| Rank | Title and reference | Citation counts | Keywords | Cluster ID |
|---|---|---|---|---|
| 1 | "Production, use, and fate of all plastics ever made" (Geyer *et al.*, 2017) | 169 | Flow-analysis; Life-span; Microplastics; Environments; Ecosystems; Fibers; Steel; Land | 3 |
| 2 | "Plastic waste inputs from land into the ocean" (Jambeck *et al.*, 2015) | 48 | Subtropical gyre; Debris; Accumulation | 3 |
| 3 | "Mechanical and chemical recycling of solid plastic waste" (Ragaert, Delva, & Van Geem, 2017) | 40 | Mechanical recycling; Chemical recycling; Polymers; Solid plastic waste | 0 |
| 4 | "The Chinese import ban and its impact on global plastic waste trade" (Brooks, Wang, & Jambeck, 2018) | 38 | Circular economy; Economic Co-operation; Food packaging; Income levels; Plastic materials; Plastic wastes; Polymergroups; Solid waste management systems | 0 |
| 5 | "An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling" (Hahladakis, Velis, Weber, Iacovidou, & Purnell, 2018) | 26 | Plastics; Additives; Migration; Recycling; Toxicity; Environmental fate | 0 |
| 6 | "International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review" (Xanthos & Walker, 2017) | 23 | Single-use plastics; Microbeads; Plastic bags; Policies; Plastic marine pollution | 3 |
| 7 | "The Circular Economy e A new sustainability paradigm?" (Geissdoerfer *et al.*, 2017) | 23 | Circular economy; Sustainability; Sustainable development; Closed loop; Literature review; Circular business model | 0 |
| 8 | "Consumer response to packaging design: The role of packaging materials and graphics in sustainability perceptions and product evaluations" (Steenis, van Herpen, van der Lans, Ligthart, & van Trijp, 2017) | 21 | Sustainability; Green design; Cue utilization; Graphic appearance; Packaging materials; Consumer attitudes | 5 |
| 9 | "Strategies to reduce the global carbon footprint of plastics" (Zheng & Suh, 2019) | 21 | Life-cycle Assessment; Bio-based Plastics; Impact assessment; Sugarcane; Waste; Polymers; Polyethylene; Biopolymers; Assessments; Trends | 4 |
| 10 | "Conceptualizing the circular economy: An analysis of 114 definitions" (Kirchherr, Reike, & Hekkert, 2017) | 21 | Circular economy; 4R Framework; Sustainable development; Definitions; Content analysis | 0 |

**Source(s):** Compiled by authors from Scopus and WoS

**Table 8.** Top 10 most cited papers with co-citation frequency

Jambeck and Law (2017) has the most citation. It is systematically estimated that about 6300 Mt of plastic waste has been made as of 2015, and 12000 Mt of plastic waste will be made by 2050.

*Author co-citation network.* Author co-citation networks can find the most contributing authors in a specific field. Because CiteSpace only considers the first author in the analysis of author co-citation (Fang *et al.*, 2018), it defaults to using the abbreviation of the author's full name, which can cause the emergence of authors with the same name, especially in Chinese scholars. Therefore, this study adopts VOSviewer to analyze the network of author co-citation. The minimum number of citations of an author is set up at 20, and 213 authors of 58096 meet the threshold. Figure 6, generated by VOSviewer shows the author co-citation network, which consisted of 213 authors or institutions between 1995 and 2022. The top 10 most cited authors or institutions with co-citation frequency are shown in Table 9.

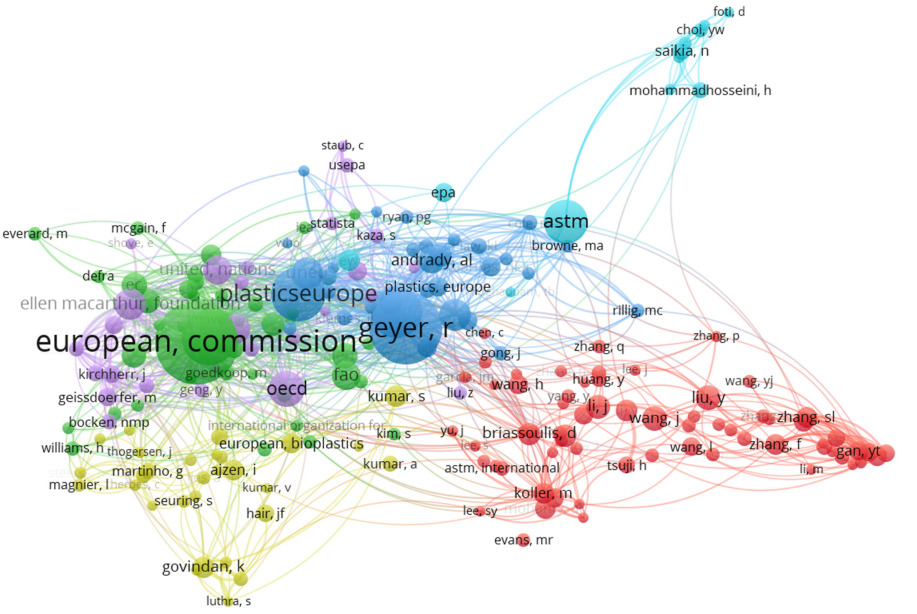


**Figure 6.**
A visualization of author co-citation network

| Rank | Author | Citations |
|---|---|---|
| 1 | European Commission | 229 |
| 2 | Geyer Roland | 194 |
| 3 | International Organization for Standardization (ISO) | 140 |
| 4 | Plastics Europe | 138 |
| 5 | Jambeck Jenna | 128 |
| 6 | American Society for Testing Material (Astm) | 106 |
| 7 | Organisation for Economic Co-operation and Development (OECD) | 84 |
| 8 | United Nations Environment Programme (UNEP) | 74 |
| 9 | Ellen Macarthur Foundation | 70 |
| 10 | Hahladakis Jn | 67 |
| 11 | Food and Agriculture Organization of the United Nations (FAO) | 65 |

**Table 9.**
Top 10 most cited authors with co-citation frequency

The author's co-citation network results show a good co-citation relationship in this research field. Institutions have essential roles in author co-citation networks, such as the European Commission, Organisation for Economic Co-operation and Development (OECD), United Nations Environment Programme (UNEP) and International Organization for Standardization (ISO). In addition, Geyer Roland is the second most cited author with 194 citations, which is consistent with the analysis of co-cited analysis. His article "Production, use and the fate of all plastics ever made" provides a scientific estimation of the total amount of plastics. Jambeck is another well noticeable scholar. In the article "Plastic waste inputs from land into the ocean," Jambeck *et al.* (2015) estimated approximately 275 million metric tons of plastic waste in 192 global countries in 2010.

*Journal co-citation network.* In order to outline the journals contributing to sustainability and plastic over the last 28 years, the journal co-citation network is shown in Figure 7. The results show a good co-citation relationship between journals. In total, 974 journals and 5999 co-citation links were found, and the density of the research field network is 0.0127. The top 10 most cited journals with co-citation frequency are shown in Table 10. The *Journal of Cleaner Production*, with 772 frequencies, is the most cited journal in the sustainability and plastic field. The following are Waste Management and Resources Conservation and Recycling. Generally, the higher the impact factor, the more citation frequencies a journal has (Fang *et al.*, 2018).

Table 11 concluded the most prolific journals. Compared with Table 10, many journals are the same, which means the more publications a journal has, the more likely it is to be cited.

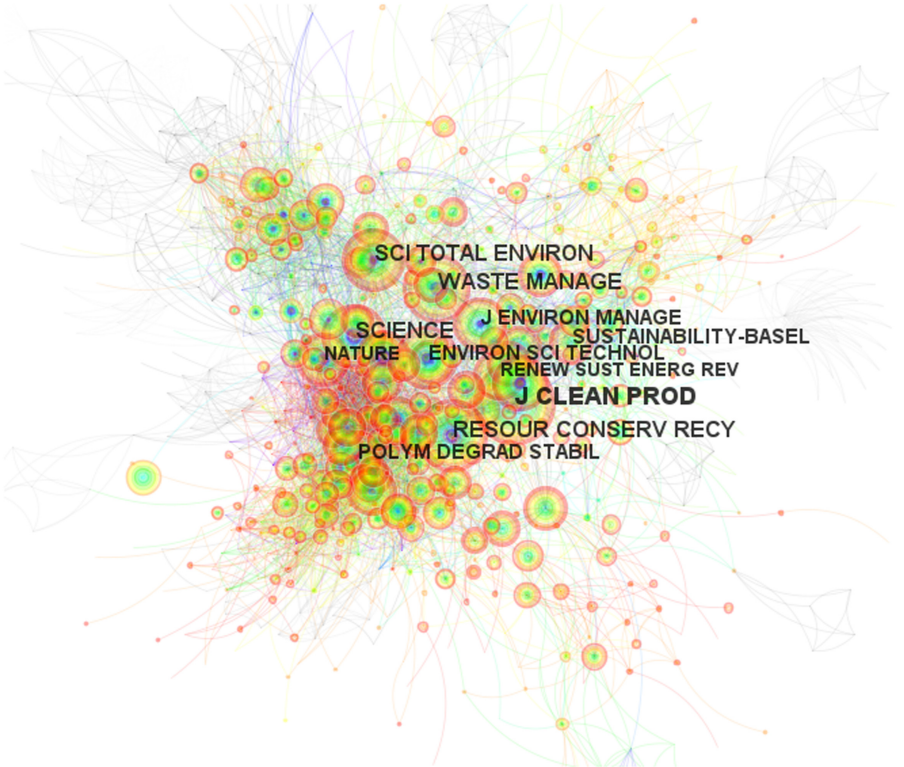


**Figure 7.**
A visualization of journal co-citation network

As observed, the *Journal of Cleaner Production* is the Top 1 in both tables, which certifies that the *Journal of Cleaner Production* is the leading specialist journal in the research field of sustainability and plastic.

*Emerging trends of plastic and sustainability and future research directions*

*References with citation bursts.* A citation burst means an article is cited closely in the short term, which can partly show the research hotspots in a research field (Fang *et al.*, 2018). As illustrated in Table 12 thirteen articles on sustainability and plastic have citation bursts. Two articles have citation bursts starting in 2020. Haider, Völker, Kramm, Landfester and Wurm (2019) contributed to evaluating the potential of biodegradable polymers, which are regarded as alternative materials to commodity plastics. Zheng and Suh (2019) first estimated the effect of the strategies to mitigate the global anthropogenic greenhouse gas (GHG), and they estimated the GHG emissions of conventional plastics were 1.7 Gt $CO_2$-equivalent in 2015, which is projected to reach 6.5 Gt $CO_2$-equivalent by 2050. Therefore, humans need to integrate energy and materials and make efficient strategies to control the increased GHG from plastics (Zheng & Suh, 2019).

*Keywords analysis.* The analysis of keywords could show the research hotspots in a specified field, help scholars systematically understand the evolution track of the field and provide future research directions for related scholars (Meng *et al.*, 2020). Figure 8, made by CiteSpace 6.1 R2, shows the co-occurring network of the keyword. Keywords with the same meaning, sustainability and sustainable development, are merged into one. Table 13 presents the main keywords by year, in which the keywords selected appeared more than 50 times. Generally, most keywords are related to environmental sustainability and plastic pollution.

**Table 10.**
Top 10 most cited journals with co-citation frequency

| Rank | Journal | Frequency | Impact factor |
|---|---|---|---|
| 1 | *Journal of Cleaner Production* | 772 | 9.297 |
| 2 | *Waste Management* | 512 | 7.145 |
| 3 | *Resources Conservation and Recycling* | 487 | 10.204 |
| 4 | *Science of the Total Environment* | 424 | 7.963 |
| 5 | *Science* | 396 | 47.728 |
| 6 | *Environmental Science and Technology* | 340 | 9.028 |
| 7 | *Sustainability* | 337 | 3.251 |
| 8 | *Journal of Environmental Management* | 264 | 6.789 |
| 9 | *Polymer Degradation and Stability* | 251 | 5.03 |
| 10 | *Nature* | 238 | 49.962 |

**Table 11.**
Top 10 most prolific journals

| Rank | Journal | Publication number | Impact factor |
|---|---|---|---|
| 1 | *Journal of Cleaner Production* | 136 | 9.297 |
| 2 | *Sustainability* | 132 | 3.251 |
| 3 | *Resources Conservation and Recycling* | 51 | 10.204 |
| 4 | *Science of the Total Environment* | 41 | 7.963 |
| 5 | *Waste Management* | 33 | 7.145 |
| 6 | Polymers | 31 | 4.329 |
| 7 | *ACS Sustainable Chemistry Engineering* | 30 | 8.198 |
| 8 | *Construction and Building Materials* | 29 | 6.141 |
| 9 | *Agricultural Water Management* | 24 | 4.516 |
| 10 | *Environmental Science and Pollution Research* | 23 | 4.223 |

**Source(s):** Data source: Web of Science

| References | Strength | Begin | End | 1995-2022 |
|---|---|---|---|---|
| Evans *et al.* (2010) | 4.44 | 2011 | 2014 | |
| Álvarez-Chávez *et al.* (2012) | 7.42 | 2013 | 2017 | |
| Rossi *et al.* (2015) | 4.26 | 2015 | 2017 | |
| Hottle *et al.* (2013) | 4.26 | 2015 | 2017 | |
| Jambeck *et al.* (2015) | 17.5 | 2017 | 2020 | |
| Liu *et al.* (2014) | 4.16 | 2017 | 2019 | |
| Tsiropoulos *et al.* (2015) | 3.61 | 2017 | 2018 | |
| Eriksen *et al.* (2014) | 6.71 | 2018 | 2019 | |
| Steffen *et al.* (2015) | 6.15 | 2018 | 2019 | |
| Ghisellini *et al.* (2016) | 3.73 | 2019 | 2020 | |
| Zheng and Suh (2019) | 5.1 | 2020 | 2022 | |
| Haider *et al.* (2019) | 3.63 | 2020 | 2022 | |

**Table 12.**
Main articles with citation bursts

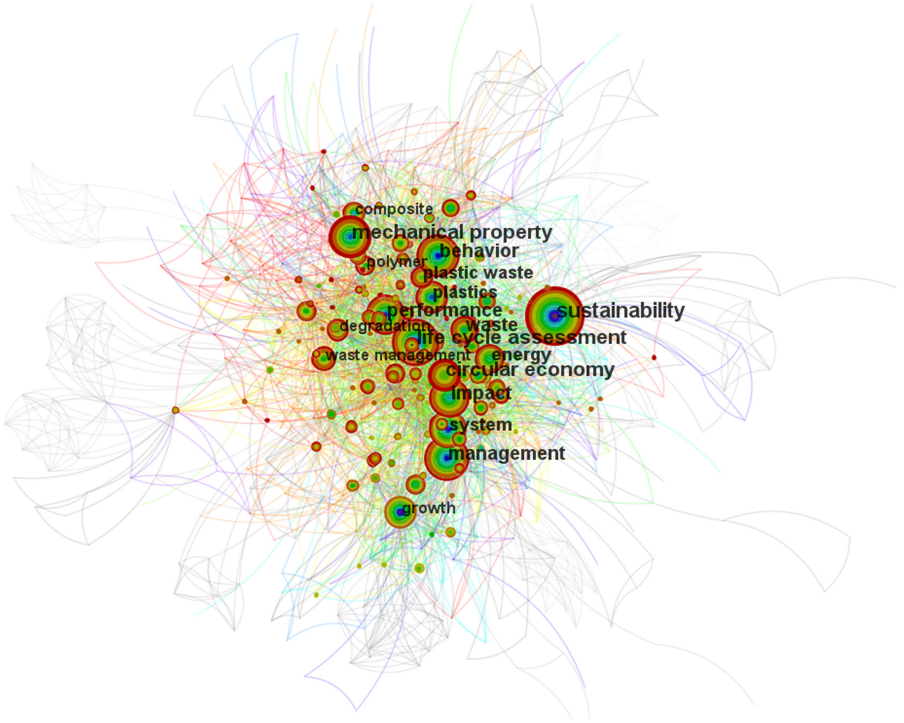


**Figure 8.**
Network visualization map of keywords

The most frequent keywords are sustainability, with 221 frequencies. The following keywords are life cycle assessment (145), mechanical property (127), circular economy (126), performance (122), management (120), behavior (117), impact (112), waste (92) and system (89).

| Year | Keywords | Frequencies | Centrality |
|---|---|---|---|
| 1998 | Waste | 92 | 0.05 |
| 2000 | Management | 120 | 0.10 |
| 2002 | Performance | 122 | 0.06 |
| 2004 | Sustainability | 239 | 0.20 |
| 2005 | Growth | 58 | 0.07 |
| 2005 | Behavior | 117 | 0.08 |
| 2006 | Energy | 75 | 0.03 |
| 2006 | Model | 54 | 0.02 |
| 2006 | Polymer | 52 | 0.03 |
| 2008 | Composite | 53 | 0.03 |
| 2009 | System | 89 | 0.04 |
| 2009 | Design | 63 | 0.02 |
| 2009 | Degradation | 52 | 0.02 |
| 2010 | Life cycle assessment | 145 | 0.08 |
| 2012 | Plastics | 76 | 0.07 |
| 2013 | Mechanical property | 127 | 0.06 |
| 2013 | Impact | 112 | 0.04 |
| 2014 | Plastic waste | 66 | 0.03 |
| 2016 | Waste management | 59 | 0.01 |
| 2017 | Circular economy | 126 | 0.01 |

**Table 13.**
Main keywords by year

To further explore research trends, Figure 9 illustrates the time zone view of keywords. The keywords are ordered according to their first coming-up time. Since 2015, the circular economy and waste management have been noticeable research topics. To better explore future research directions, this study concluded the new coming keywords in the recent three years. The detailed keywords are shown in Table 14, in which selected keywords appeared more than ten times. Material scientists in recent years have focused on thermal properties and bioplastics. Plastic pollution is also a research hotspot in recent years, and bioplastics are

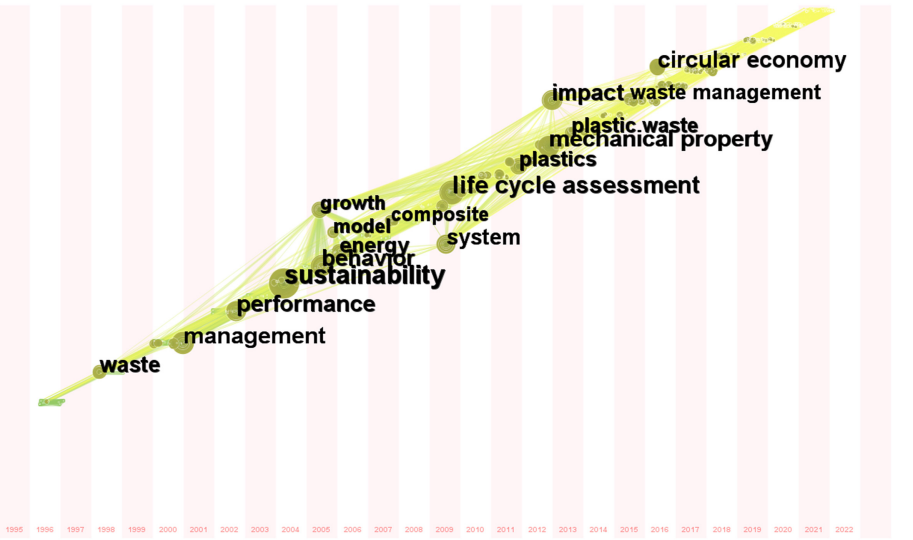


**Figure 9.**
Time zone view of keywords

| Year | Keywords | Frequencies |
|---|---|---|
| 2019 | Thermal property | 10 |
| 2019 | Supply chain | 13 |
| 2019 | Education | 14 |
| 2019 | Conversion | 12 |
| 2019 | Barrier | 18 |
| 2020 | Mixture | 12 |
| 2020 | Purchase | 12 |
| 2020 | Food waste | 14 |
| 2020 | Plastic pollution | 20 |
| 2020 | Pollution | 30 |
| 2021 | Bioplastics | 10 |

**Table 14.**
New coming keywords in recent years

biodegradable materials that come from renewable sources. They can be used to reduce the problem of plastic pollution, both of which are highly focused on by scholars. In education, the relationship between sustainability and plastic is also concerned not only in the university (Waard, Prins, & van Joolingen, 2020; Yeung, So, Cheng, Cheung, & Chow, 2017) but also in secondary school (Burmeister & Eilks, 2012) and primary school (Zorpas, Voukkali, & Loizia, 2017).

## Discussion

The relationship between sustainability and plastics is close, and this topic has been the focus of governments, policymakers, practitioners and academicians. In this study, the analysis based on VOSviewer and CiteSpace provides the knowledge mapping of sustainability and plastics. The problem of plastic pollution towards environmental sustainability is a highly pointed issue by scholars. The publications about this topic have exponential growth. Based on the analysis, there is a mature collaboration network between countries where China and the USA are the most prominent. The Chinese Academy of Science is the most prominent institution to work on this topic. However, the collaboration between institutions still needs to be enhanced. In terms of authors, Chai Qiang, Friedrich Daniel, Sahajwalla Veena and Ok Yong Sik are the most prolific authors in this field, and the collaboration between scholars still needs to be advanced.

Using cluster analysis of CiteSpace, this study found that circular economy, bioplastic, COVID-19, sustainable development, polyester and bioplastics are the main research topics focused on by scholars in recent years. COVID-19 is the newest topic in 2021 since it led to the increased use of plastics and brought new challenges to sustainability. Geyer *et al.* (2017) research entitled "Production, use, and the fate of all plastics ever made" is the most cited article. It has provided a systematic estimation of the amount of plastic waste globally. Geyer Roland is also the most cited scholar in the co-citation network. It is noticeable that institutions are the central part of the co-citation network, the European Commission, OECD, UNEP, and the ISO, which significantly contribute to this field.

In the journal co-citation network, the *Journal of Cleaner Production* is the most contributing and has the most publications in this field, which makes a significant impact. Scholars from various disciplines have focused on the relationship between sustainability and plastics. The circular economy and plastic pollution have been hotspot research topics in recent years. Nature scientists focus on thermal properties and bioplastics. The field of education also raised concerns about the problem of sustainability and plastic. This study also illustrates the emerging trends of plastic and sustainability and future research directions.

## Implications

This study utilizing CiteSpace and VOSviewer, respectively, fills the research gap by providing a holistic and comprehensive understanding of the research status about "sustainability and plastic." The implications of this study can be understood from two perspectives, history and the future.

From the historical perspective, based on the curve of publication number, this study divides the development of this research field into two phases, the preparation phase (1995–2015) and the rapid development phase (2016–2022), which can help scholars understand the current research status and the development trends. Besides, this study holistically illustrates the current collaboration networks of countries, institutions and scholars, which shows that scholars need to further enhance their collaboration, especially in transnational.

It can also help to serve as a guide for future researchers. The knowledge mapping of "sustainability and plastic" presented in this study can improve research efficiency and save learning time for scholars (academicians and practitioners) who are interested in this field. The most contributing scholars and most cited articles are found in this study, which can help scholars improve their reading efficiency and find authoritative scholars to track their studies. The most contributing journal in this field (particularly the *Journal of Cleaner Production*) can serve as the most relevant and related source of the literature and a suitable publication platform for scholars. The recent hot topics and/or the keywords can help scholars to find valuable future research directions.

## Limitations and future research directions

Although this study filled the research gap in bibliometric studies of sustainability and plastics research, it only considers English literature. For a better and more comprehensive analysis, future researchers can consider the literature written in other languages, such as Spanish, Chinese, Japanese, etc. In addition, bibliometric analysis cannot analyze the research logic and the relationship between variables. Therefore, future studies can utilize narrative or systematic literature reviews to accomplish these objectives. Furthermore, bibliometrics analysis depends on the database used, and the WoS may lead to biases that favor Natural Sciences and Engineering to the detriment of social sciences (Mongeon & Paul-Hus, 2016). Therefore, future researchers can expand their search to other data sources, such as Scopus and Google Scholar.

According to the current research trend, on the one hand, this paper calls on scholars to strengthen cooperation between different disciplines and countries; on the other hand, for future researchers in this field, this study provides some potential topics for future researchers from different disciplines. For scholars focused on economics and management, lifecycle assessment, circular economy, behavior research, plastic pollution and COVID-19 have been hotspot research topics in recent years. For scholars focused on engineering, thermal property and bioplastics have huge research potential.

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