



A bibliometric analysis of sustainable agriculture: based on the Web of Science (WOS) platform

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Abstract

The global trends of sustainable agriculture (SA) have expanded dramatically through many scholarly studies in this area. Many literary works have focused on several aspects of sustainable agriculture (SA), such as the effectiveness of pesticide management, impacts on cultivation and enhancement, quantifying with soil, water, and air, agro-ecological activities, ecological aspects, and other areas of focus. The review offers a structured bibliometric and network evaluation that will profoundly observe the recent trends of SA, which other studies in this field have not comprehensively analyzed before. The study's prime objectives are to investigate the progress, trends and themes, and provide a comprehensive mapping of the field of sustainable agriculture. The study utilizes the Web of Science core collection database to search, filter, and extract the published article from 1992–2020. The review commences by exploring over 3000 journal articles, those then filtered into some well-recognized matrix of impacts and published by impactful journals, institutions, and authors. The results indicate a stable growth in publications since 2006, with a sharp improvement from 2010. Thematic assessment of key concepts by exploring the abstract discovered a robust emphasis on quantitative resource associations within a strong subjective focus with farm capacities and inner-sectorial dominations. We reveal how the outcome may assist the sectors to facilitate better understandings and comprehend the challenging transitions based on brainstorming to action formulation.

Keywords Sustainable agriculture · Literature characteristics · Sustainability · Strategic coordination diagram · Bibliometric analysis

Introduction

Nowadays, sustainability has drawn significant interest among academics, researchers, scientists, general people, global communities, and political agendas. However, world agriculture sectors need to follow up on a dynamic and

complex set of issues to mitigate these challenges. The first and most important issue involves the current modern farming development situation, estimating the total production capacity of farming communities. The agricultural sector should be designed to foster economic growth, avail a viable society, and maintain a south ecological transition that can serve the present and future generations (Brundtland 1987; Elzen et al. 2012; James 2006). This situation has led to a new agricultural research paradigm popularly known as Sustainable Agriculture (SA). Globally, humanity can now make a more sustainable complement of food production and eventually go through one of the most significant technological, social, and ecological improvements after the industrial revolution (Shreck et al. 2006). The world is currently facing enormous pressure to maintain environmental sustainability, a healthy society, and economic competitiveness, which emerges developing a systematic way of cultivation, reducing the negative impact over the supply of food, water, and fiber for an ever-expanding population of the globe. In response to environmental, societal, and capital growth

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concerns posed by the introduction of modern technology-based agriculture, the concept of sustainable agriculture has evolved. The prime principles of sustainable agriculture (SA) could be specified as practicing environmental friendly farming mechanism that facilitates and foster with the help of technological advancement, which can quantify the production of nutritious foods without or fewer deteriorations of the soil, air, and water, and securing a better, safer, and healthy living for the farmers (Dunlap et al. 1993; Earles and Williams 2005; Gliessman 1990). The efficacious incorporation of economic, ecological, and social sustainability priorities has been at the foreground within the context of sustainable agriculture.

Additionally, there is a profound number of reviews on sustainable agriculture that have been traced recently. Some of these studies addressed the whole domain commonly and explicitly, while others have quantified the specific aspects such as challenges and improvement (Gimenez et al. 2018; Masclaux-Daubresse et al. 2010), agro-ecological prospects (Alexander 2017; DeFries et al. 2016; Leakey 2014; Pathak et al. 2018), farmer responses and perception, analytical models for the role of soils, water land efficiency (Lal 2008; Santoyo et al. 2017; Sharma et al. 2018; Velasco-Munoz et al. 2018), plant/crop protection (Datta et al. 2016; Dordas 2008; Zhang et al. 2018), smart, organic, and bio fertilizers (Calabi-Floody et al. 2018; Igiehon and Babalola 2017), conservation agriculture (Firbank 2012; Hobbs et al. 2008), fostering intensifications (Sharma et al. 2006; Struik and Kuyper 2017), scientific barriers to sustainable food production and potential solutions (MacRae et al. 1989), and evaluation of agronomy for sustainable agriculture (Villalobos and Fereres 2016).

This emergence area has developed for more than 25 years and has now entered its third generation of research. Instead of having a long history, the topic has not been quantified enough within the bibliometric analysis. Moreover, no study has been traced that can explore and quantify the evaluation of SA research's key trends and themes. This study intends to fill those gaps by critically exploring sustainable agriculture and portraying a clearer path for future research by combining bibliometric analysis and strategic coordination diagram. In line with the transnational pattern, in the recent progression, the idea of sustainable agriculture has been given more significant focus, and new and promising clusters have been compiled. The bibliometric approach enables research and provides a baseline for a systematic literature overview by establishing and advancing the type, design, and courses of published research work. We utilized the Web of Science (WoS) core collection database to gather scholarly information using some robust keywords, which lists up to 13,290 publications until 2020. Quantifying those scholarly values focuses solely on analyzing the article on sustainable agriculture, whereas we ignored the other forms

of publications like books, book chapters, preceding papers, and reviews. With some robust filtration process, finally, 3508 articles were selected for further processing. The background, research trends, ongoing issues, the author's keywords, and the historical aspect are explored systematically in this study.

Moreover, we carefully explored how the researcher, institutions, and countries are interconnected by employing citation and co-citation tendencies. The study illustrates the different phases by which the discipline can be reflected to understand the past of this research area, and the assessment of the studies cited most highlights the main concerns or discussions that can provide assessment for shaping this subject. Finally, the study offered rigorous and detailed investigations within the area of sustainable agriculture and provided an in-depth review in a way that any researcher can grasp the future research directions. The potential authors could use this study as a theoretical perspective for sustainable agriculture as this study compiles most of the recent and past articles, which might be helpful for potential studies. Most importantly, the current analysis can be acted as a starting point for new authors who want to become acquainted with the literature and patterns in this emerging research area called sustainable agriculture.

Additionally, we thoroughly reviewed the top 30 most globally cited SA publications to demonstrate how sustainability might evolve into agriculture dimensions. Finally, by examining the following questions for research, we paid full attention to comprise the evolving area of research:

RQ1: What are SA literature's globally studied key elements, trends, and themes?

RQ2: How did the key research directions by which the SA literature flourished over time?

RQ3: How several stakeholders (authors, institutions, and countries) are interconnected within this profound research domain?

RQ4: How the key themes are distributed within the level of centrality and density evaluations?

RQ5: How is SA literature triggered based on the centrality and density of key terms?

RQ6: What research gaps can guide future studies in terms of SA?

This study has analyzed past and present conditions, characteristics, hot spots, traced sustainable agriculture (SA) research trends, and presented a systematic path for future directions based upon the bibliometric analysis to feed the arguments of the research as mentioned above questions. For doing so, we used some scientific analytical tools such as Biblioshiny, VOSViewer, and CiteSpace. Moreover, we used a strategic coordinate diagram to carefully observe complex interactions between keywords and topics regarding sustainable agriculture research. The

current study's specific innovations were stated as (i) the study employed a bibliometric analysis to determine the core themes, drifts, and hotspots of sustainable agriculture literature. This approach will demonstrate the key component of SA-related scientific work more explicitly, especially compared to earlier analyses. (ii) The strategic coordinate diagram has explored the interconnections among the core aspects, key terms, and trends of existing literature on SA. (iii) The bibliometric analysis highlighted study gaps regarding the formulation, implementation, and assessing the field of sustainable agriculture and portrayed possible direction to fulfill the gaps based on the detailed review of top literature, current trends, and dynamic keyword analysis. The existing research has not explored those powerful tactics within the SA research domain.

The use of published studies to analyze the research trends through bibliometric approaches is receiving increasing attention (Aleixandre-Tudó et al. 2018). For identifying recognized and innovative conceptual domains, hierarchical clustering using bibliometric approaches might be quite useful (Fahimnia et al. 2015). This study could be used as a theoretical basement for SA research as this study compiles most of the recent and past articles, which might be useful for potential studies. This analysis might be a starting point for new authors who want to become acquainted with the literature and patterns in this innovative research area, namely SA. Finally, this review can offer in-depth insights in a particular way that any researcher can grasp the research gaps. The country's collaboration networks will help the legislations assess how the SA research field is closely connected globally, which further helps them finalize collaborative plans and actions. The three plot analyses will help future researchers and scientists explain how the topics are divided among the themes and help them form their research hotspots. Moreover, this study utilized some robust analytical framework to evaluate the key trends and areas and provide a comprehensive mapping of SA's field to deploy some vigorous directions for future researchers within this topic. The strategic coordinate diagram will help future researchers grasp the complex interactions between keywords and topics of ongoing research SA. Academicians and researchers will find the article crucial as the study outlines the insights and future research direction for understanding the concept and further exploration in SA. It will potentially assist in identifying clusters of different research themes and showing how the different clusters are interconnected and explored by various researchers and institutions. By collecting more current themes addressed by these scholars and highlighting the more significant academics within the groups, further emerging research areas may be identified.

Research methodology and initial data statistics

This study followed a three-step methodology for presenting the key findings: (i) bibliometric analysis, (ii) network analysis, and (iii) strategic coordination diagram analysis. The history of bibliometric analysis denotes that it was introduced by Garfield and Sher (1963). Although various researchers provide definitions for "bibliometric analysis," most of them comprised bibliometrics as an exploration methodology of scholarly documents such as journal articles and their subsequent reference reports to provide a scientific field map of a topic using statistics. The bibliometric tactics are widely used by policymakers, research managers and administrators, data analysts and librarians, and scholars to assess work quality, particularly in academics and research institutes. By providing a statistical summary of the published study, bibliometric approaches have become fundamental theoretical and practical scientific research assessment (Ellegaard and Wallin 2015). This methodology is widely used with statistical tools and mathematical software to identify a research area's principal determinants and trends (Freire and Nicol 2019) and enable performance assurance for publications (Raparelli and Bajocco 2019). Various bibliometric analytic techniques could trace these determinants, whereas co-authorship (authors, institutions, and country), co-citation, co-occurrence (keywords), and bibliographic coupling analysis are mostly used approaches (Li et al. 2019; Moral-Munoz et al. 2020).

Along with accumulating the bibliographical information, Rowley and Slack (2004) recommend using structural coordination diagram approaches to provide a robust map of the research field, which allows the researchers to comprehensively screen the literature, portrait the visualization, and design future research directions. We follow up on a four-stage methodology for gathering the published bibliographic data and system design for the aimed field (Sustainable Agriculture), more specifically for quantifying the most relevant articles, identifying core extents of the studied field, and exploring the underlined aspects of the recent progression of existing research domains and thus portray a more straightforward pathway that can guide potential researchers within the studied area, which is suggested by Fahimnia et al. (2015). The pictorial representation of the methodology has portrayed in Fig. 1.

Select the searched keywords

Selecting search keywords are the prime stage in a bibliometric study. If we closely quantify the definition of Sustainable Agriculture (as evaluated in supporting document

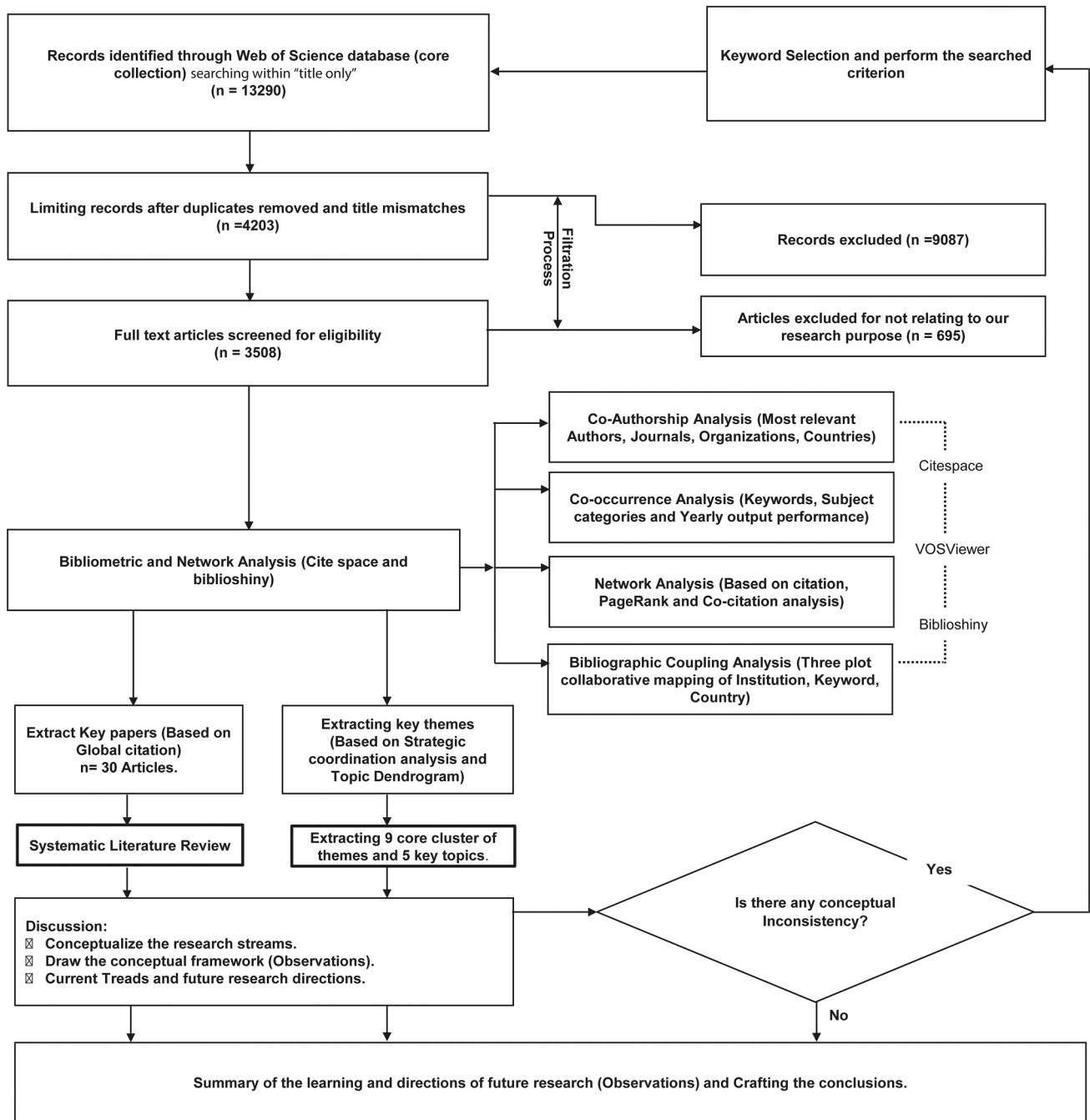


Fig. 1 Adopted methodology of the study. The key workflow of the study (adopted and modified from Sarkar et al. 2020)

1), we can find the following key perspectives, sustainable, sustainability, ecosystem, agriculture, agricultural, farm, farming, tillage, cultivation, and development. We used a structural combination of those keywords and searched within the WoS core collection database by selecting the title-only options:

“sustainable agriculture,” “sustainable and agriculture,” “agricultural sustainability,” “agricultural and sustainability,” “agriculture and sustainability,” “sustainable

agricultural,” “sustainable farming,” “farm sustainability,” “sustainable crop,” “sustainable and cultivation,” “sustainable agro,” “agro. Sustainability,” “Agri. Sustainable,” “sustainability and cultivation,” “sustainable agriculture and development,” “sustainable tillage,” “sustainable cultivation,” “agriculture sustainability,” “sustainable farm,” “sustainable development and agriculture,” “sustainable agroecology,” “sustainable cropping,” “sustainable agrarian,” “sustainable sowing,” and “sustainability and agricultural”

are used as keywords for data collection and feeding the research questions.

Select the database

The information was gathered from the webserver of ISI Web of Science (WoS), a platform that is extensively utilized by other scientific researchers in the field of bibliography, for example, Wang et al. (2014) and Gorraiz and Schloegl (2008). We used the “Web of Science Core Collection” database to cover more than 20,300 journals, books, and conferences with over 71 million research materials (AIRyalat et al. 2019). The academics also appreciated the WoS database for high-quality archiving sources and the collection of materials used by several previous research researchers as a robust and high-quality data source. As the most comprehensive scientific research website WoS by Clarivate Analytics, formerly known as ISI Web of Science, which is a mostly covered information regarding author/editor, title, source, conference information, abstract, cited references, document type, conference sponsors, addresses, times cited, keywords, publisher information, ISSN/ISBN, cited reference count, source abbrev., page count, IDS number, language, Web Of Science categories, research areas, funding information, accession number, author identifiers, usage count, PubMed ID, open access, hot paper, and highly cited paper.

Initial search results

We collected and explored only the journal articles, whereas conference papers, books, and book chapters have been excluded as journal article has held utmost scholarly value as suggested by Freire and Nicol (2019) and Wang et al. (2014). We selected the “all option” button of the WoS core collection for extracting the data for further analysis. We found 13,290 articles from the title search option covering all the searched keywords (see Table S2 of supporting file for the complete list).

Refinement of the search results

As the initial investigation was conducted, we found the oldest article addressing sustainable agriculture themes in 1989, but this sustainable agriculture first came within the title in the 1990s. We found some articles that appeared in more than one category within the initial stage. After removing those, it leaves unique 4203 articles. These include short documents, which are not related to scientific contributions like commercial magazines. We further conducted the refinement procedure (remove the commercial papers, without referred paper, paper those have no author information, those paper does not amplify our research questions) formulate 3508 published articles within 1992–2020. After

that, we used the Biblioshiny and Citespace software package to process these 3508 data further. All the important bibliographic data are downloaded into plain text format as it is a common format that Biblioshiny, VOSViewer, and Citespace can process.

Results and discussion

Before the final statistical analysis, we used an inductive reasoning tactic to fulfill the literature categorization part of this current study; see Fu et al. (2019) and Cornelissen and Clarke (2010) for more detailed inductive reasoning tactics. The analysis was carried out in three parts, “bibliometric study and network analysis,” which is portrayed in the “Bibliometric analysis” section and “Keyword statistics” sections. Biblioshiny and Citespace softwares give the bibliometric analysis robust touches for further data statistics, including details about keywords, authors, affiliations, hot themes, citation and co-citation reports, and many more. As Biblioshiny is a flexible, user-friendly, and easy use software, it is one of the best fits for the design of the bibliometric analysis, rather than other different computer-based software like BibExcel, Histcite, Pajek, and Gephi. Often, for comprehensive network analysis, Biblioshiny also helps to prepare sample data. We utilized two software packages, namely VOSViewer and CitespaceV, to analyze the citation counts and classify the existing literature on sustainable agriculture. VOSViewer (van Eck and Waltman 2014) and CitespaceV (Chen 2006) were chosen for their reliability with the large datasets, as well as offering a wide range of creative visualization analysis and investigative possibilities from existing network and visualization analytics software such as Pajek (Batagelj and Mrvar 2011) and Gephi (Contributors 2008).

Bibliometric analysis

Various software programs with different capacities and weaknesses have been used during the modern era for bibliometric analysis. Biblioshiny, Citespace, HistCite, Publish or Perish, and BibExcel are the most used tools. Due to their superior flexibility in reconfiguring and integrating inputs from multiple databases, like Scopus and Web of science, Biblioshiny and Citespace have been adopted for this research. Both the software can provide a complete data assessment that could be used for a different proportion of network analysis tools, including Gephi, VOSViewer, and Pajek. However, Histcite is compatible only with Web of Science, and Publish or Perish is a kind of software that usually can process the data from Microsoft Academics and Google Scholars. Although Biblioshiny and Citespace is

are powerful tools to process bibliographic information or similarly structured content, one weakness of the softwares is that these need many hours of practice in fairly complex operating conditions.

Research output performance

According to prior literature investigation, the first sustainable agricultural-related study could be traced in 1940, whereas sustainable agriculture was formulated within the title of publications across the WoS core collection databases in 1992. The number of publications presented in Fig. 1 portrayed constant progression after 2007 due to the growing prominence of sustainability within contemporary agro-economic prospects. There were 3508 publications about sustainable agriculture indexed in the WoS core collection databases from 1992 to 2020 (after compiling after the filtration), denoting the swift development (Fig. 2). The amount of literature aligned SA is part of overall publishing within the WoS core collection database increased from 1.43% in 1992 to 2.57% in 2007 and reached the highest 12.12% in 2019, which seemed to be holding a significantly greater

from the overall articles published, particularly within 2007 to 2020. Figure 2 summarizes the key article’s production performance metrics patterns for 1992–2020. Our study also comprised the number of authors identified, and citations per article showed a shifting expansion with growing numbers of articles (from 50 in 1997 to 425 in 2019 and 347 citations till 2020), reflecting an expansion in the cooperation spectrum in SA research.

Subject categories representing Sustainable Agriculture research

Based on our research, we have found that the field of SA mostly covers both natural and social sciences. From 1992 to 2020, we traced 146 distinct subjective aspects that were triggered mainly by the domain of SA. Table 1 represents the top ten listed subjective categories associated with the domain of SA. Environmental science ranked first with 1113 articles within the top categories and possessed 31.727% out of 3508 articles. The following top subjects were Agriculture and multidisciplinary, which involved 720 publications holding 20.5% coverage and Green sustainable science

Fig. 2 Annual progression of articles produced in SA research. The first circle denotes the published year, the second one number of articles, the sum of time cited (this is the total number of citations all items within the year) are presented in the third circle, and the fourth circle highlights the percentage count out of 3508 articles

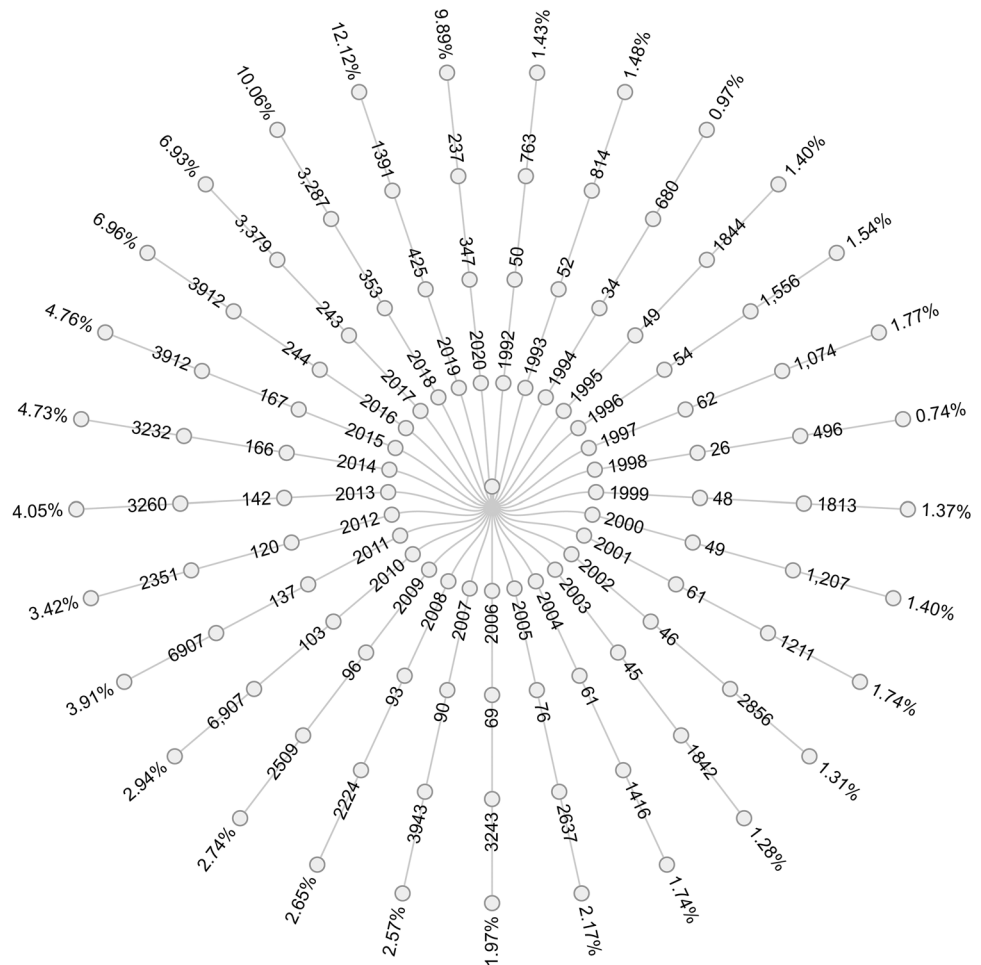


Table 1 Top ten active disciplines associated with SA research

Subjects Area	Records (%)	Total citation	H-Index
Environmental sciences	1113 (31.727)	18,042	61
Agriculture multidisciplinary	720 (20.525)	11,773	58
Green sustainable science technology	682 (19.441)	7302	36
Environmental studies	528 (15.051)	6480	37
Agronomy	332 (9.464)	5837	35
Ecology	274 (7.811)	8007	48
Engineering environmental	206 (5.872)	3248	29
Water resources	178 (5.074)	2402	27
Soil science	170 (4.846)	2402	32
Economics	152 (4.333)	3913	33

technology holds number three positions with 682 publications shared by 19.4% of the total publication count. Some other major subjective areas encompassed by Environmental studies (with 528 articles and 15.051%), Agronomy (332 publications and 15.051%), Ecology (274 publications and 15.051%), Engineering Environmental (206 publications and 15.051%), Water Resources (178 publications and 15.051%), Soil Science (170 publications and 15.051%), and the tenth position is Economics (152 publications and 15.051%). Thus, SA is a vastly multidisciplinary issue, mostly covering an adjacent interlinked with energy-oriental, environmental, economic, and technological aspects. Moreover, we found that this emerging agro-ecological domain represents the core issues of historical and contemporary environmental policies and strategies regarding sustainable advancement towards societal, ecological, economic transition.

The global contribution to publications

In the context of global research contributions, the USA is in the top position, with 1275 articles securing 36.35% of the total published article reaching the highest *h*-index 126, which indicates the USA's prolific scientific value global recognition. It is also recognized that China has a prominent position in this research field, with 745 articles (21.24%) and an *h*-index of 59, as shown in Fig. 3. Meanwhile, together, these top 2 countries are responsible for nearly 58% of the total publications. Like China and the USA, European countries (EU) are also very productive in this research field, as nine countries in the top 20 list are from the EU. Among these nine countries, the UK is the most productive with its contribution of 539 articles (15.36%) of total published articles reaching the highest *h*-index 90 on this continent, followed by Italy (461 articles). On the contrary, the contribution of the Asian continent is also mentionable, after China, India 563 (16.05%), Iran 124 (3.53), Malaysia 93 (2.65), and Japan 90 (2.57%) were also showed a good proportion of articles and reaching *h*-index 55, 25, and 17 respectively within top 20 productive country list. Besides,

the contribution of Brazil and South Africa with 197 articles (5.62% and *h*-index 23) and 107 articles (3.05% and *h*-index 14) respectively is also impactful from Latin America and Africa continent. With 315 (8.98%) articles and 201 (5.73), Australia and Canada hold a prolific position representing Oceania continents possessed with strong *h*-index of 34 and 32, respectively. By considering the evaluation of the last decade (2010–2020), however, 2334 articles were published, and here also, the USA secured the first global position with 37.9% of all articles, followed by China (14.7%) and India (6.76%).

Most productive institutions on Sustainable Agriculture

The comprehensive review of high-performance academic research organizations in the SA domain could be one of the best options to identify the most influential facilitators. We found that 1802 institutions shared 3508 articles altogether based on the evaluation. The top 50 productive institutions (at least 19 articles) were carefully extracted from the Biblioshiny app and were compiled according to their geographical locations (where we used the affiliation name disambiguation option of Biblioshiny). The geographical location portrayed in Fig. 4 is carefully crafted by using the web application of www.mapvisualizer.com. The navigation points correspond to every institution's participation rate and based on the proportional contributions, the color of these points has varied. Eventually, SA's field has drawn significant interest from organizations and institutions worldwide as per the global distribution of such organizations. The numerous regional territories of the USA, Europe, and Asia might also accomplish a broader territorial interruption of such inputs. The full version of the location map can be accessed from the link-https://www.mapcustomizer.com/map/Top%2050%20institution%20associated%20with%20SA?utm_source=share&utm_medium=email.

After evaluating the top institutions based on the production number, a comprehensive list is given in the

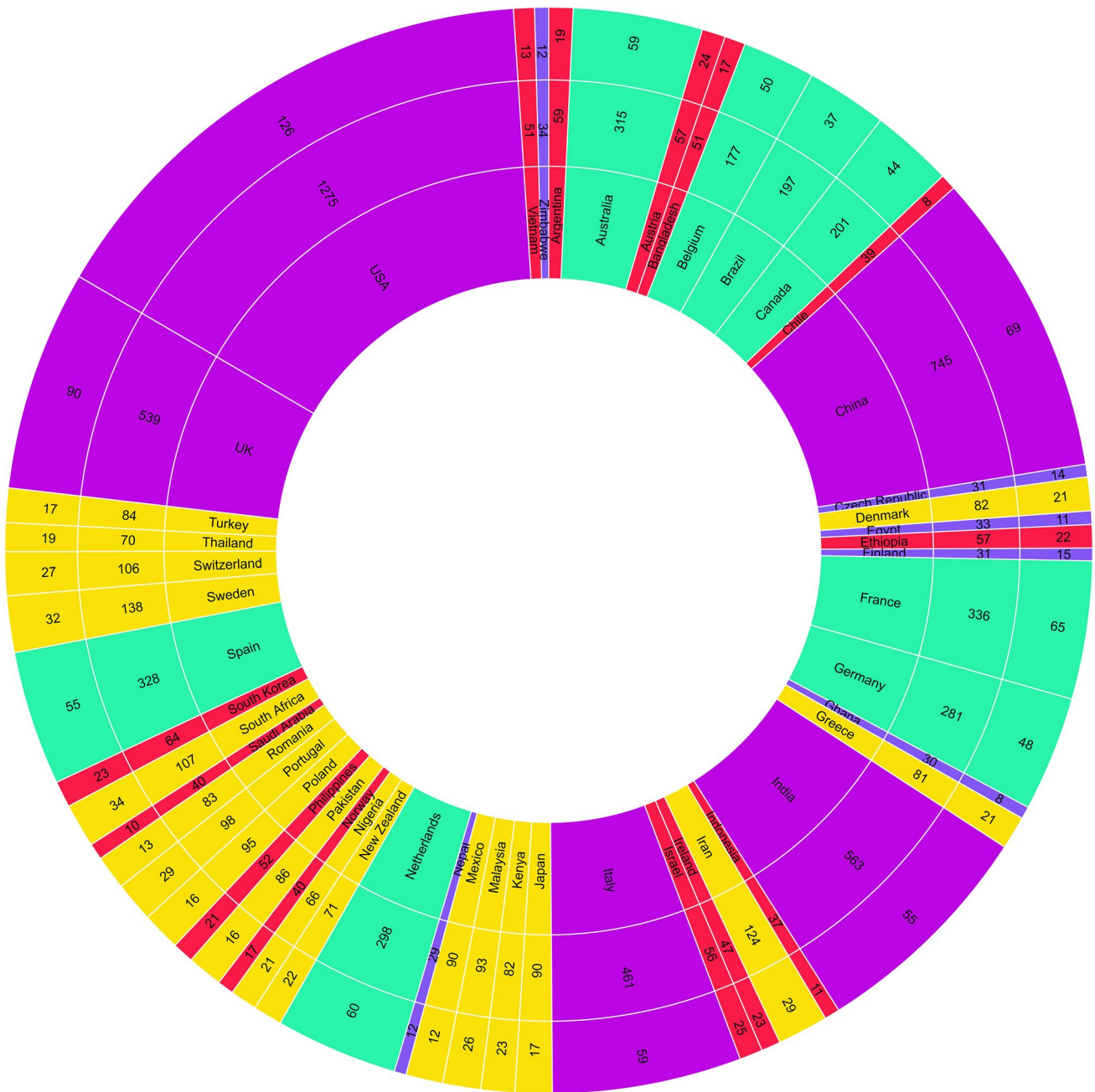


Fig. 3 Top 50 most productive countries on SA. The first circle denoted the country, whereas the second cluster highlighted the total number of publications, and the third circle comprised the associated h-index matrix within the particular country

supporting file (Table S4). We found that ten institutions have at least fourteen articles regarding SA. Table S4 portrayed that Wageningen University (85 articles), Cornell University (54), Michigan State University (52), University of California-Davis (51), Wageningen University & Research Center (48), Ghent University, China Agricultural University (41), Swedish University of Agricultural Sciences (39), University of Florida (35), International Crops Research Institute for the Semi-Arid Tropics (31),

and CIMMYT (31) have been found as impactful instructions in terms of SA research.

Most relevant Journals focusing on Sustainable Agriculture

In the list of top 20 journals, “Sustainability” is in the top position of all journals because it obtained 278 articles, followed by the “Agroecology and sustainable food systems”



Fig. 4 Geographical locations of the top 50 institutions. **A** Portrayed the global view of the institutions, and **B** covered the America region, **C** Europe region, **D** Asia region, and **E** Oceania region. The navigation points correspond to every institution's participation rate and

based on the proportional contributions, the color of these points has varied. Purple points (50–160), yellow points (30–50), red points (25–30), green points (20–25), and sky blues points (15–25) articles

(214) and “Journal of cleaner production” (111), as shown in Table 2. The journal *Agriculture Ecosystems & Environment* (82) and *Agricultural Systems* (74 articles) hoisted the maximum value of h -index (38 and 31 respectively), representing the core interest of researcher in these both journals as a hub of citation, bibliographic analysis, and the successive history of article publication which increases the number of citation per article (49.26% and 32.39% respectively).

The journal “Sustainability” is recognized for its broad topics and is a freely accessible publication based on the natural ecosystem, community, economics, and socially sustainable development. The journal “Agroecology and Sustainable Food Systems” formerly known as “Journal of Sustainable Agriculture,” emphasizes improvements, monitoring, and designing of global food production systems that can align the use of natural resources, maintain effective environmental conservation with the requirements

of the smooth development of economy, food safety, and social welfare. The “Journal of Cleaner Production” offers a forum to examine and explore ecological and biodiversity problems of industries, states, academic facilities, territories, and communities regarding both conceptual and implementation aspects. Finally, “Agriculture, Ecosystems and Environment” compiles research papers on the interaction among agroecosystems and the natural environment, particularly how farming affects the atmosphere and how environmental changes affect agroecosystems.

“Agricultural Systems” is a global platform that interacts with interrelationships involving agricultural systems and their environmental, socioeconomic, and political contexts. Moreover, it is concerned with agricultural systems, agriculture, or other landscape strategies and farming techniques. Similarly, IJAS aims to expand awareness about the practices and technology that contribute to agriculture's sustainability,

Table 2 Top 20 journals focusing on Sustainable Agriculture

Sources	Articles	<i>h</i> -index	Citation	Average citation
Sustainability	278	24	1770	9.94
Agroecology and Sustainable Food Systems/Journal of Sustainable Agriculture	214	22	1670	9.44
Journal of Cleaner Production	111	23	1651	14.87
Agriculture Ecosystems & Environment	82	38	4039	49.26
Agricultural Systems	74	31	2397	32.39
International Journal Of Agricultural Sustainability	66	16	1589	24.08
Land Use Policy	62	16	925	14.92
Ecological Economics	48	22	1930	40.21
Ecological Indicators	41	18	829	20.22
Outlook on Agriculture	41	10	327	7.98
International Journal of Sustainable Development and World Ecology	39	10	321	8.23
Agriculture and Human Values	29	13	779	26.86
Science of the Total Environment	29	13	496	17.1
Agricultural Water Management	28	14	677	24.8
Environment Development and Sustainability	27	6	99	3.67

how strategies, organizations, and socioeconomic mechanisms hinder or foster sustainable growth and reduce environmental detritions. As a global perspective-based journal, “Land Use Policy” profoundly accepted articles from various subjects that can trigger the socioeconomic dimensions and cultural, legislative, experimental, and formational-based research work of urban and rural land use. It offers a platform for exchanging views and knowledge that may be integrated to devise successful land use policies from a wide variety of backgrounds and community groups. The “Ecological Indicators” journal’s inclusive purpose is to incorporate and evaluate environmental and ecology indicators and provide a structured measurement of those within strategic endeavors. The journal offers a venue for analyzing conventional predictor implementations and analytical, computational, and quantitative methods such as indexes’ creation. It can be pointedly marked that eight above-discussed journals out of the top twenty lists publish solely associated with environmental, social, and economic dimensions, which comprise numerous knowledge and empirical analysis areas. The significant number of studies indicates that researchers prioritize the interaction of ecological, social, and economic dimensions studies concerning SA-related studies.

Keyword statistics

The keyword usually illustrates the fundamental objective of any article profoundly, and those can easily explain the core motive of any article in a detailed manner (Gong et al. 2019). The evaluations comprise 13,227 keywords of all

fields (authors keywords 8682 and keywords plus 5860). With the VOSViewer layout algorithm, the study comprises 50 most common keywords compiled by employing the “author’s keyword” (A) with at least 19 times occupancies and “all keywords option” (B) with at least 60 times of occupancies as portrayed in Fig. 5. There have been found some keywords that hold their position within both visualization patterns, whereas part “B” of Fig. 5 included some keywords from the mythological aspects apart from the core topics as it included all field options (the combination of author’s keywords, title, and abstract), whereas Table 3 lists the top 20 most used keywords comprised of keyword plus option in VOSViewer.

While interpreting keyword clustering diagrams, VOSViewer can examine the identifiers for various documents in detail and classify SA research hotspots. Moreover, we divided the top 50 keywords into 5 clusters according to the occurrence number. Cluster 1 consists of 19 items: adaptation, adoption, agriculture, China, climate change, climate change, environment, food, farmers, food security, future, impacts, innovation, land, policy, sustainability, sustainable agriculture, sustainable development, and system. Cluster 2 comprises thirteen items: biomass, conservation agriculture, growth, irrigation, maize, nitrogen, productivity, quality, soil, tillage, water, wheat, and yield. Cluster 3 comprises agricultural sustainability, efficiency, energy, framework, impact, indicators, life-cycle assessment, management, model, performance, and systems. Cluster 4 also consists of eight items: biodiversity, conservation, diversity, dynamics, ecosystem services, farming systems, intensification, and land use.

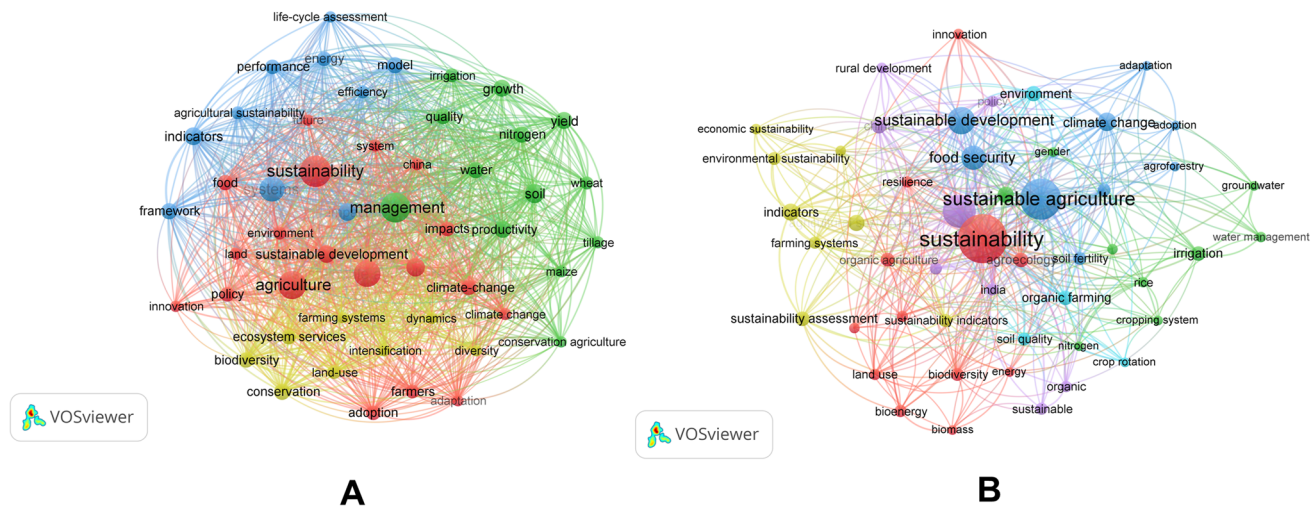


Fig. 5 Co-occurrence of the top 50 keywords associated with SA research. A Comprised of “Authors keywords” options. B Comprised by the “All Keywords” option, including “author’s keywords,” “Title of the articles,” and “Abstracts.” The size of nodes highlights the fre-

quency of listing. The co-occurrences within the same cluster derive the curves associated with the nodes. The less space among the pair of nodes highlights the higher proportion of the corresponding term’s co-occurrences

Table 3 Top 20 keywords of the SA research fields comprised of key-word plus tactics

Keywords	Occurrences	Total link strength
management	391	467
systems	292	348
agriculture	179	212
soil	162	170
impact	145	160
growth	134	117
yield	126	174
model	120	150
indicators	114	185
nitrogen	114	156
climate-change	113	114
framework	112	174
quality	112	134
conservation	108	143
productivity	107	132
water	105	110
impacts	102	137
food	93	85
performance	93	109
biodiversity	92	125

Network analysis of publications

From the initial stages of bibliometric studies, the concept of visualizing bibliometric networks, also called “science

mapping,” has gained significant persuasion as it profoundly shows the interconnection and how the core studies are connected within each other concentrated domains. Network visualization has emerged as an effective means of examining several bibliometric patterns, from networks of journals or articles to co-authorial networks between writers or institutions and within the countries or regions to occurrence networks of keywords. A bibliometric approach is typically evaluated within two-dimensional tactics, namely nodes and edges. The nodes usually quantify with publication names, authorship (authors, institutions, and journals), and keywords. On the other hand, the edge denotes the interconnection and pairing relationship among the identified nodes. The most commonly evaluated forms of interconnection are citation-based analysis of documents, the author’s keyword co-occurrence network, and the institution’s co-authorship network based on citation analysis. Furthermore, bibliometric networks are usually weighted as the density of the nodes. Therefore, the edges signify whether the network modules (nodes) are interconnected and quantify those interconnections’ significances.

A comprehensive network evaluation will be the following potential approach to fulfill the study’s analytical objectives. Various techniques are available for this intent, while Pajek, Biblioshiny, VOSViewer, HistCite Graph Maker, Gephi, and CitespaceV are the most popular (Freire and Nicol 2019). We used Biblioshiny and VOSViewer due to their versatile visual impairments and convenient settings, the comprehensive capability of sorting, the capacity to deal with multiple information types, and extensive build-in algorithmic tools for evaluating

and visualizing the network connections. These two software packages are more superior to the other potential software in many ways. For instance, HistCite is confined to web-of-science information output, and Pajek uses “.Net” data. CitespaceV could be one of the best alternatives. However, CitespaceV needs a very long time to master relatively complex user interfaces with a lack of flexibility (Fahimnia et al. 2015). Since VOSViewer has some drawbacks (precise network analytical approaches), along with VOSViewer, we utilized the powerful bibliometric analytical tools Biblioshiny.

Most cited articles on Sustainable Agriculture

The frequently cited publications are often evaluated to identify the core scientific articles and researchers with notable influences in that area or field. By carefully exploring the citation frequency and connected notes, the Biblioshiny application comprises the top 30 global cited papers (Table 4), with more than 175 times cited globally. Among them, about 30% of the article is cited only one time yet. Within the study, the term “Local citation” denotes the cited frequency of a paper within the network of the selected 3508 articles, and “global citation” represents the overall WoS citations count for the particular article. Our study found a noticeable gap between the cited frequency of local and global scale, which illustrates that sustainable agriculture research has drawn some substantial attention among other study fields (i.e., they gain citation by the study apart from the current search terms of SA). For example, it can be noticed in Table 5 Montgomery (2007) secured the second position in terms of global citation count (739 citations), but as per the local citation, it is far behind (8 citations). He formally evaluated well-structured principles for quantifying soil erosions’ effects, narrowed down by the subjective field, and broadened the interest for other topics as mainly the citation might arise due to any article’s content and its thematic values.

Meanwhile, the most cited articles needed ample time to draw up citations as a common principle. Table S3 represented the top 20 articles based on average global citations of the last five years. The “average citation per year” metrics are one of the well-known methods for measuring the direct influence of most other articles published recently (global citations distributed over the number of years since published). Table 4 and Table S3 (supporting document) showed that 18 out of 20 articles secure the position within both lists, which denotes that those articles comprised their values historically and held substantial popularity within the last five years.

Table 4 Top 30 global cited articles of SA

SL	Document	Local citations	Global citations
1	(Tilman et al. 2011)	74	2355
2	(Montgomery 2007)	8	739
3	(Tilman 1999)	12	652
4	(Asami et al. 2003)	1	582
5	(Pretty et al. 2011)	57	438
6	(Kennedy and Smith 1995)	1	431
7	(Kong et al. 2005)	2	399
8	(Brussaard et al. 2007)	7	396
9	(Wilson and Tisdell 2001)	6	365
10	(Kassam et al. 2009)	15	346
11	(Amon et al. 2007)	2	325
12	(Bouis and Welch 2010)	0	308
13	(Hobbs 2007)	6	292
14	(Welch and Graham 1999)	5	285
15	(Rigby and Cáceres 2001)	34	277
16	(Sanderson et al. 1996)	0	274
17	(Schroeder et al. 2013)	0	250
18	(Teasdale 1996)	2	235
19	(Rockström et al. 2017)	24	219
20	(Powlson et al. 2011)	4	216
21	(Glaser 2007)	4	204
22	(Van Cauwenbergh et al. 2007)	72	197
23	(Hansen 1996)	63	197
24	(Garrity et al. 2010)	4	196
25	(Pretty et al. 2003)	12	189
26	(Foyer et al. 2016)	0	188
27	(Busby et al. 2017)	2	180
28	(Marsden and Smith 2005)	7	175
29	(Meul et al. 2008)	5	173
30	(Pannell and Glenn 2000)	4	171

PageRank analysis

While the amount of citations explicitly evaluates the impacts of an article, several circumstances may also emerge where citations seem not to offer a clear overview of a publication’s scholarly legitimacy. PageRank would possibly provide a clearer view of any articles’ overall reputation as this domain progresses and maintains the metrics regarding continuous citations by other mostly cited articles (Fahimnia et al. 2015). Therefore, the current study is compelled to examine the set of articles with a broader context that would be mainly focused on who did specifically quotes the articles and what reputation they transmitted towards that particular issue, as suggested by Ma et al. (2008) and Fahimnia et al. (2015). In this regard, the PageRank evaluation was employed in the study to find out the most profound set of articles that would secure the significance of a particular

Table 5 Top 15 articles based on PageRank analysis

Node	PageRank
(Pretty 2008)	0.049679136
(Van Cauwenbergh et al. 2007)	0.049311216
(Tilman et al. 2002)	0.044636909
(Pickett 2013)	0.043112344
(Tilman et al. 2011)	0.041454112
(Rigby and Cáceres 2001)	0.041006446
(Hansen 1996)	0.037552083
(Montgomery 2007)	0.036223701
(Binder et al. 2010)	0.034748748
(Gomez-Limon and Sanchez-Fernandez 2010)	0.032683318
(Bouis and Welch 2010)	0.031394968
(von Wiren-Lehr 2001)	0.029517964
(Garnett et al. 2013)	0.028619845
(Pretty et al. 2011)	0.027311232
(Meul et al. 2008)	0.025140682

area. It includes the evaluations by simultaneously interacting with the prestige of citing and cited documents. Table 5 represents the top 15 articles based on PageRank evaluation. In Table 4 and Table 5, we can notice that only five articles secured the positions within these two tables, which denotes that these five articles are the powerhouse of citation and ample prestige. Those articles are Tilman et al. (2011), Rigby and Cáceres (2001), Montgomery (2007), Bouis and Welch (2010), and Pretty et al. (2011).

On the contrary, Table 5 also comprised that Pretty (2008) and Van Cauwenbergh et al. (2007) hold the topmost portion according to PageRank but those are not highly cited. At the same time, most of the articles (12 out of 15) have been published after 2006 except Tilman et al. (2002), Hansen (1996), and Von Wiren-Lehr (2001). Since PageRank is largely inspired by prestige gained by its highly quoted articles, of course, there was a low probability for the latest articles to be cited by other high cited articles. Such finding is further confirmed by showing that the leading articles based on PageRank metrics (Table 5) have much fewer average periods since their publication than the top-cited articles (Table 4).

Co-citation network analysis

As the global research community became largely interconnected, the potentiality of exploring how researchers from diverse backgrounds correlates among themselves openly, so the citation tactics expanded gradually. These strategies closely assess current areas' competence and enable scholars to better interpret themes in a particular area (Chi and Young 2013). A co-citation analysis encompasses a series of nodes and edges, whereas nodes represent the articles and edge represent the article itself, and citations are listed within that

particular article. Usually, articles are considered as co-cited if the article is listed within the reference list. For example, publication X and Y will be considered as co-cited if articles both article X and Y have found within the references list of article Z. Articles cited most frequently by several other articles are being found to become much more associated and thus considered to be in the same field. Therefore, we adopted this methodology to find the most related article with the Biblioshiny application.

By utilizing the robust algorithmic framework (Louvain), we presented the co-citation network projection of articles (A), journals (B), and authors (C) in Fig. 6. Figure 6 A denotes that D. Tilman et al. (2002), Godfray et al. (2010), Foley et al. (2011), J. Pretty (2008), D. Tilman et al. (2011), and Van Cauwenbergh et al. (2007) were holding the most centralistic nodes, and those are also powerhouses of co-citation frequency. Figure 6 B comprised that “Agriculture, Ecosystems & Environment,” “Journal of Cleaner Production,” and “Agriculture System,” holding top positions within the co-cited sources. Figure 6 C crafted the top co-cited authors where FAO, Pretty J., and Tilman D. become repetitive within the top 50 authors based on co-citation occurrences. Gong et al. (2019) suggested that co-cited articles should be categorized or clustered as correlations found based on the nodes' strength and distances to provide comprehensive cartographical experiments. Thus, we portrayed robust categorizations of the network nodes with their betweenness and closeness in the next step. Closeness denotes the close connection within the same cluster, and betweenness denotes the differences and distances among the clusters. Such clusters are further interpreted by sorting and summarizing standardized clusters. The approach mainly emphasizes the connections within the components of co-citation groups and their citation pairs (Chen et al. 2010), which could be employed to identify a core co-cited collection of publications. Clustering has facilitated the scalar clustering method to recognize core thematic aspects, triggering interrelationships and cooperation forms. Segmentation became embraced by academics and became a crucial analytical approach in studying social networks (Shiau et al. 2017).

Evaluation of the core themes of Sustainable Agriculture by strategic coordinate diagram

In order to examine different dimensions of knowledge in any particular area, Law et al. (1988) developed a strategic analytical approach popularly known as strategic coordination mapping or diagram. The interconnection of the research frameworks in a specific field can be reflected in this criterion. These tactics are also crucial as it has certain flexibilities to profoundly evaluate the current trends and research streams and dynamic capabilities of assessing the

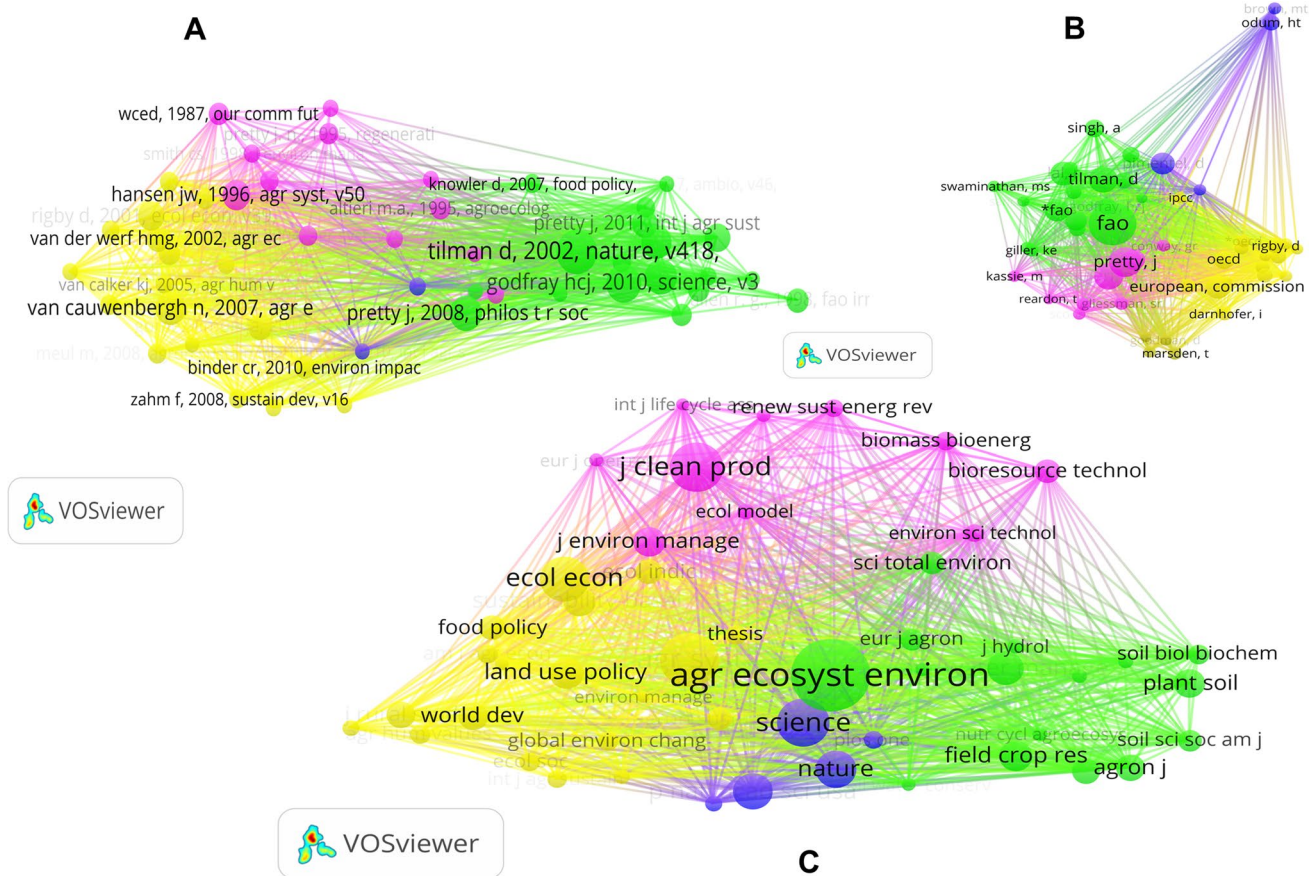


Fig. 6 Co-Citation networks. A Co-citation networking of references; B co-citation networking of authors; C co-citation networking of journals. Different colors indicate different research areas. The size of the circles represents the counts of co-citations. The distance between

the two circles indicates their correlations. The yellow clusters are comprised as the most prominent clusters, and the most representative clusters denote the green cluster

interconnection among several research themes. It is a two-dimensional framework comprising centrality and density-based evaluation tactics. The upside-down horizontal lines (X-axis) represent the correlational centrality, and left to right straight lines (Y-axis) are denoted with the particular research area’s density values or field. Density would be useful to evaluate the intensity of intersection points throughout the field and signify the individual category’s potential to withstand and improve. Principally centrality would be crucial to present the sections’ correlational levels and other subsections. The higher the centrality level denotes, the more significant interconnected groupings within the particular discipline.

Figure 7 produced the core themes, whereas the density represents the horizontal axis and centrality with the vertical axis. The diagram’s field is set with the author’s keywords, and the minimum cluster frequency and the number of labels (for each cluster) have been set as five. The coordination output produces 9 clusters. Figure 7 represents that clusters 2 and 8 hold the most significant centralistic

position than other clusters. It implies that those five clusters occupied a central role within SA analysis and possessed an intimate connection with the rest of the clusters. The centripetal values of clusters 7, 6, and 9 are gained greater values than the average values. It denotes that these three topics are highly interrelated with other themes. This could be possible because core researchers within the SA research domains had employed a wide range of case studies of various tactics and utilized sustainable practices within the core components of agriculture. Those are ample criteria to draw governmental, enterpriser’s, and farmer’s attention towards effective SA tactics. The centripetal degrees of the rest of the cluster is less than the threshold values, particularly clusters 1, 3, 4, and 5 possessed a lower central value indicates that the connection among these areas of research and other themes is minimal, and the contents of the study are not well focused.

Based on the density allocation representation, cluster 1 and cluster 3 have possessed greater popularity and become the most used themes to quantify SA practices,

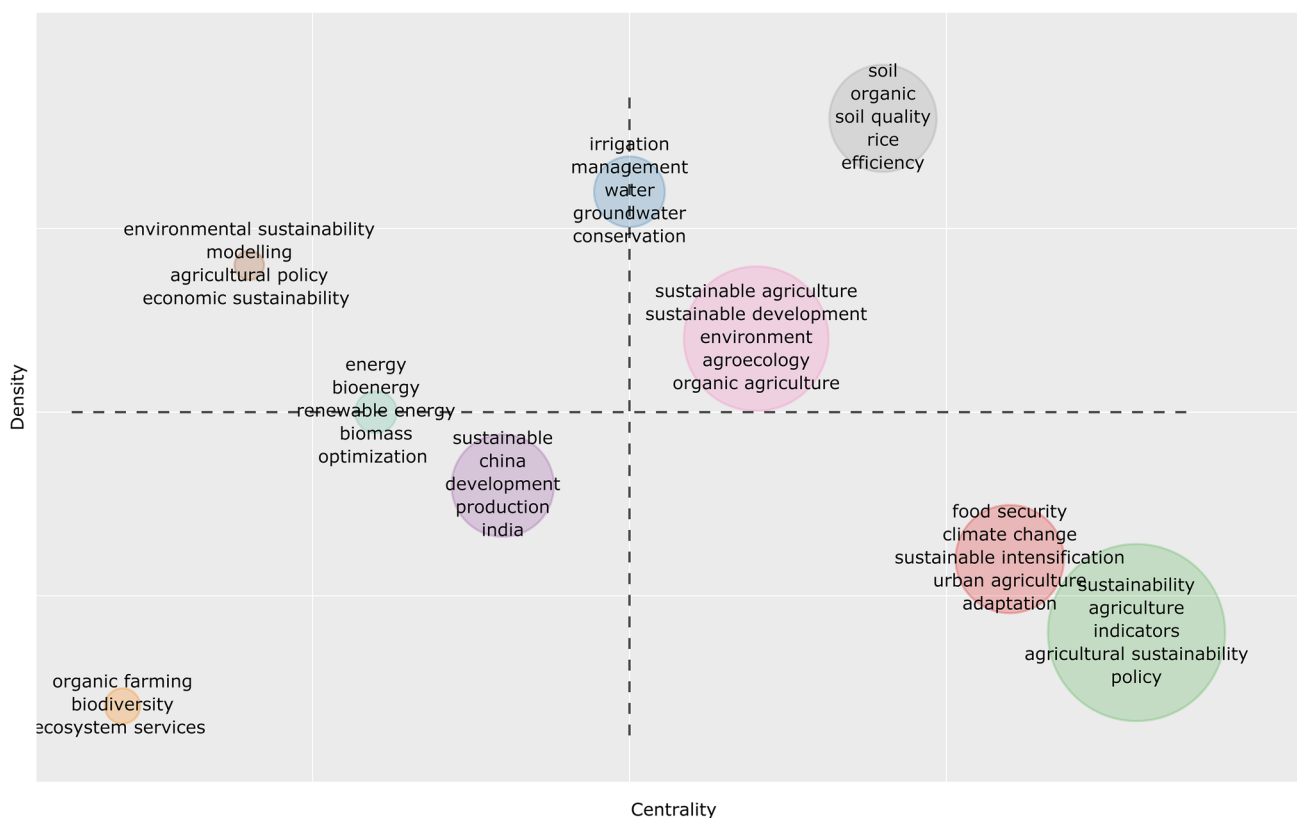


Fig. 7 Evaluation of the core themes by strategic coordination diagram. The horizontal axis denotes the density and the vertical axis with centrality level. The different cluster is represented by different colors and comprises five items each

demonstrating that these two clusters have developed an in-depth, consistent, and established conceptual background to gain and quantify the roadmap of SA. Cluster density of 8, 2, and 7 holds the position above from the average value line, which indicates that the theoretical structure is therefore formulated as certain shapes have been traced for such three themes, which further need a little bit more times to be highlighted and strengthened over the future prospective. The densities of the rest of the other units are secure the position under the mean point, which implies that such themes are still not adequately matured, and for this reason, the conceptual framework for those clusters is still not established. After carefully evaluating four dimensions (quadrant) produced by Fig. 7, we found quadrant “a” quantified with clusters 2, 7, and 8 secure the position within the most valuable quadrant. Quadrant “a” comprises greater centripetally and density values than the average scale, signifying that those two themes secure the position within the focal and foundational points of SA literature. With clusters 6 and 9 quadrants, “b” has been formulated. This quadrant represents the mostly higher centrality values but with lower density values than the average standards, signifying that those themes are well-positioned across SA’s central field. However, those themes are still not adequately mature enough

as the density level is relatively lower than the centrality value and is expected to profoundly grow within the scope of imminent research. The third quadrant (c) represents lower centrality and density values. Our analysis found that clusters 4 and 5 fit within this quadrant. This indicates that those clusters are not in the fundamental research themes of SA but could be suited among the study’s verges. This cluster might derive from the methodological section or other instrumental sections, with cluster 1 and cluster 3 quadrant “d” forms representing high-density and relatively low centrality. As per the themes’ centrality, the quadrant “d” implies that the literature focused on these themes within the SA study’s edge. On the other hand, the higher density denotes those firmly matured themes.

Discussion

The study’s prime objectives were to explore the major components of SA to put a profound spotlight on how various sustainable tactics were being transitioned within the agricultural domain and how past and current literature had been developed, which could act as a pathway for future studies. We used bibliometric and network

analytical tactics to determine the theoretical and practical aspects of SA within the study. Besides, the top 30 global cited articles have been extensively reviewed and provide an organized material analyzed to deal with current research questions. We discuss these areas in the following paragraphs, referring to each element of our conceptual framework, identifying gaps in the literature, and suggesting future research directions to fill these gaps.

Throughout the metadata searching, shorting, and collecting section, we have maintained a consistent combination of selected keywords for this study that must cover all the key aspects and themes of sustainable agriculture, such as sustainable practices throughout the production, operation, purchasing, sourcing, and performance measurement, and production methods. In addition, since sustainable agriculture has evolved from sustainable development concepts, we also choose some keywords to cover the SD concepts, such as environment, ecological balance, and climate change. Various authors have also highlighted these tactics within a similar research design (Gong et al. 2019; Wang et al. 2014).

Figure 8 portrayed a more precise overview of how institutions from various parts of the world had possessed scientific collaboration within specific keywords. Table S5 comprised the USA, UK, and China’s collaborative network, which indicates that these countries possessed overall impacts for facilitating the global issues of SA. Since SA is a well-established field of research for the agricultural domain, a substantial progression of research has been identified. The field of sustainable agriculture did not develop due to its immense importance, but the allocation of SA mainly covers broad area themes, as stated in Table 6. It eventually boosted this emerging area of modern agricultural approaches and portrayed an excellent niche of research scope. Multiple players and institutions of the agricultural sectors always paid a deep concern to effectively manage sustainability issues within the agricultural domain to facilitate the social, environmental, and economic transition to enjoy the core betterment of SA. This acknowledges this topic’s significance and encourages preliminary working performance within the multiple players, as Lal’s (2008) study confirmed. The environmental strengthening aspects

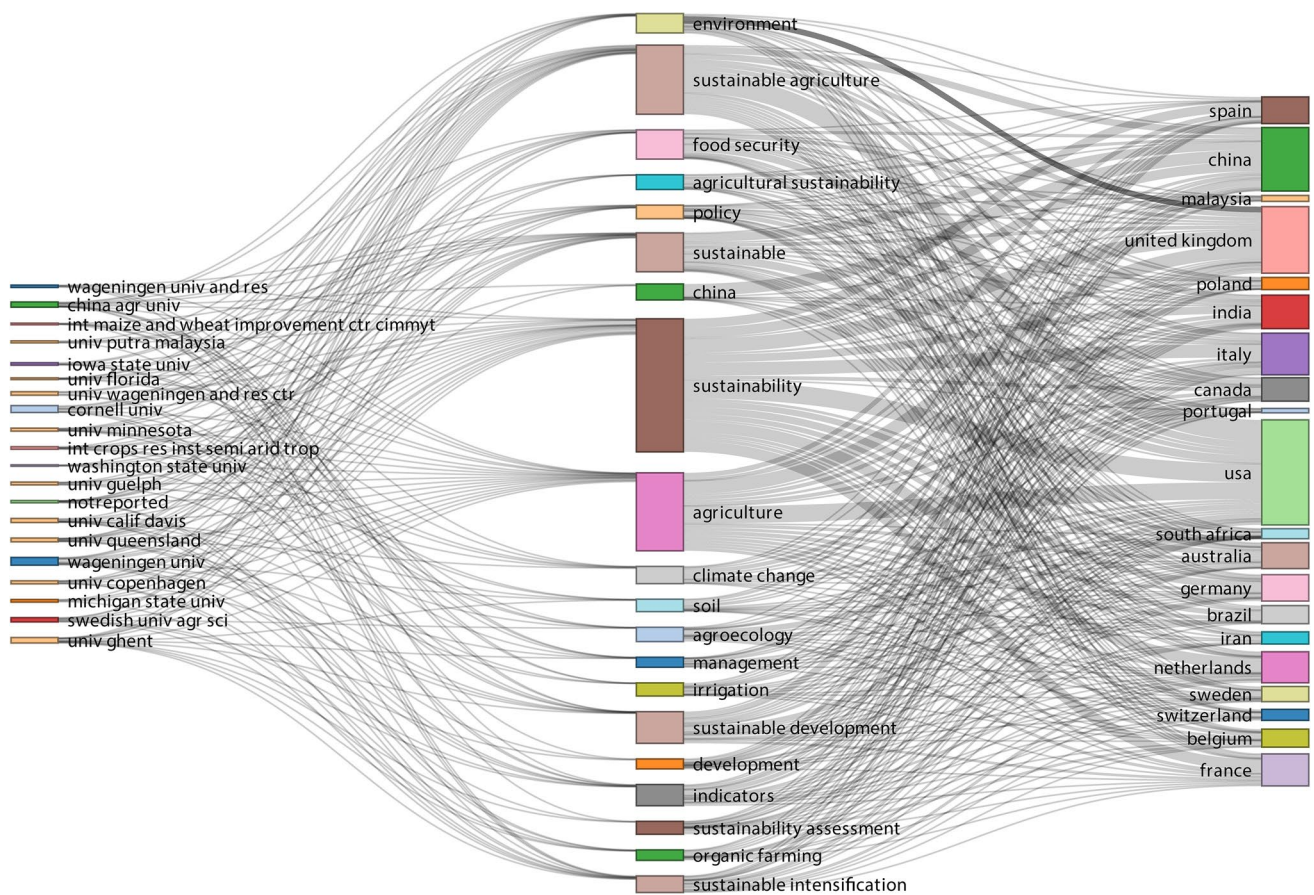


Fig. 8 Three plots a collaborative map of institution, keyword, and country associated with SA. The first plot represented the institution, the second plot denoted the associated keywords, and the third plot

highlighted the countries working on those keywords. The curve line stated the connections and the size of the plots comprised by the density of appearances

Table 6 Core themes based on co-citation clustering analysis

Cluster level	Keywords collection
Food security	Climate change, livelihoods, sustainable intensification, gender, livestock, adaptation, food security, agroforestry, urban agriculture, rice, and adoption
Irrigation	Management, irrigation, water, groundwater, contaminations, conservation, farming, innovation, conservation, and water management
Sustainability	Agriculture resilience, governance, sustainability, indicators, rural development, environmental assessment, agricultural sustainability, life cycle assessment, food, land use, policy, model, sustainability assessment, productivity, economic, social, and ecology
Sustainable	Sustainable growth, viability, accountability, development, production, soil fertility, rotations, integrated management, and intensification
Organic farming	Ecosystem services, biodiversity, organic farming, tillage, pesticides, subsidies, health, and organic agriculture
Environmental sustainability	Environmental sustainability, agricultural policy, modeling, economic sustainability, social viability, government, and laws
Sustainable agriculture	Sustainable agriculture, agroecology, sustainability indicators, farming systems, analysis, sustainable development, farmers, environment, agricultural system, and sustainable farming
Soil	Soil, conservation agriculture, maize, cropping system, efficiency, soil quality, systems, organic, wheat, sustainable production, crop, nitrogen, yield, economics, and erosion
Energy	Optimization, energy, bioenergy, renewable energy, energy, saving, and biofuel

of sustainable agriculture hold most of the research's attention as it holds a significant concern to effectively allocate the environmental transitions that can lead to fewer detritions and more productivity. A clear viewpoint in research activities on current agro-ecological systems will be recommended for ecological enhancement, although SA practices the strengthen the social viability and economic solvency, which is supported by Adegbeye et al. (2020), El Chami et al. (2020), Semida et al. (2019) and Rose et al. (2019). To minimize or prevent adverse effects of chemical controlling indicates an increasing value for sustainable growth metrics, the formation of strict legislation and credential schemes for availing long-term effects, and increases the awareness level of general farmers. The increasing trends show that the field is still emerging. The SA is an emerging field that primarily deals with a wide range of subfields, as shown by the key subject area (Table 1). We also observed that the growth of SA-related studies is relatively steady. The findings demonstrate a wide-spread collaboration between the authors, institutions, countries, or regions, indicating that SA is nearly identical and well established. Since the general dynamic in SA publication is not linear, this is strong evidence that SA combines agriculture, economics, social, and environmental themes dominant area that quantifies sovereign and vibrant attention towards the researcher from a wide range of backgrounds.

The comprehensive bibliometric-based critical review essentially assesses a wide range of readership as it provides comprehend and structured specification of the particular research field. According to the results on the author's affiliation and the top journal's aims and scope, the focus of SA research is not only based on core agricultural domains but also a broad aspect of social, economic, and environment.

It has also been schematized in that predominantly those three major fields play a leading role in connection with SA and publish their findings in mostly those specific scope-oriented journals. So the structure and distribution of the SA study are primarily concerned with those themes. Journals, institutions, and authors with a background in biotechnology, engineering, ecology, and economics are signified widespread within the field of SA. The research directions also demonstrated that the social sciences field is also profoundly addressed along with the technical aspects, which indicates a comprehensive connection between the methods formation and adoption process (Kassie et al. 2009). By careful evaluation of the topic hotspot, it can be traced that the SA is a multi-dimensional research field with various wings like adoption, theory formation, ecological behaviors and transitional practice, and biodiversity (Asami et al. 2003). According to the World Wildlife Fund (WWF), if agricultural activities can handle sustainably and responsibly, crucial ecosystems can be preserved or revived, water resources can be retained, and soil fertility and groundwater also would have been enhanced (Constance and Bonanno 2000). A linkage within SA could extend these emergent research areas and further enhance the particular topic (Rodriguez et al. 2009). The publication's conceptual heterogeneity, journal aims, and scope portraits in the study endorse these assumptions.

The current study utilized the quantitative approaches to collect the data from the WoS data platform and provide a clear assassination of the SA research field with some robust tactics. However, the SA principle is perceived in numerous forms. However, it frequently implies synchronously or asynchronously with the implementation of sustainable land use, water, fertilizers, power, and eco-friendly pesticide

control strategies, emphasizing community monitoring and decision making based on socio, economic, and ecological perspectives. We noticed the remarkable progression of SA and agrarian sustainability, indicating that the research themes address current global hurdles via maintaining farm performance within a socially desirable level. A wide range of studies was also found that profoundly triggered the socio-economic aspects within a certain extent that can meet the current environmental demands and patterns.

Conclusion

This study's main goal is thus using the bibliometric approach for mapping the whole field of SA to examine and define the crucial literary works on this subject based on previous, ongoing, and future trends within this emerging field of research. This study employs bibliometric methodologies to analyze the journal articles on SA critically and comprehensively summarize how SA theories develop over-time. The analysis's foundation mainly comprises a visual overview of the SA study's growth patterns, core research institutions, key researchers, key themes, and focus points. Moreover, the evidence about the use of metadata diagrams and critical review based on the research network framework in such literature was unique, quantifying the current study's exceptional novelty. The main research content and core themes of SA were further furnished with a coordinated strategic diagram that reflected the paper's core innovation. The study analyzed the bibliometric data and systematically reviewed the published article indexed in the WoS database regarding SA from 1992 to 2020. A total of 3508 publications were obtained from particular manual filtration, illustrating 11,550 authors, 860 journals, and 113 countries. Over the last 30 years, publications in this area of interest have risen in an elucidative way.

The annual scientific production rate of 12.3% shows a promising future for this research topic. We concluded that the knowledge for understanding the trends and themes, potential remediation and management of the resources detritions within the ecological context, and sustaining the overall societal domains and applying it as a new SA research concept. The study comprises the changing climate dynamics, and global warming is the prominent hacks for exploring by the researchers in this area of knowledge. Identifying the most productive countries, institutions, and top articles will assist future researchers in a similar direction with a profound knowledge to identify their interest's field. This study explores the most prominent bibliographic data with visual analysis to help the prospective researcher choose the holistic research field. Our observations demonstrate that the most impactful publications are concentrated among a small number of researchers. As the topic

has matured, several more scholars have embraced the innovative discipline of sustainable agriculture, advancing the contribution in multiple sub-domains. The study found that 2019 is the most fruitful year with the highest publication count. Both natural and social sciences are the most crucial subject areas, and with 32% and 21% coverage, environmental sciences and agriculture multidisciplinary become the most covered active disciplines. The USA and China secured the topmost position among the highly productive countries. Moreover, we found that 1802 institutions are sharing 3508 articles altogether, and Wageningen University (85 articles), Cornell University (54), and Michigan State University (52) are the best institutions for producing SA-related articles. The study revealed that "Sustainability" and "Agroecology and sustainable food systems" are the hotspot journal with 278 and 214 articles, respectively. The co-keyword analysis indicates that sustainable management, systems, agriculture, soil, and impact of sustainable agriculture were the hottest fields comprised of keyword plus tactics. Likewise, Food security, irrigations, and sustainability have become the most dominant themes covered by SA-related publications. According to the results on the author's affiliation and the top journal's aims and scope, the focus of SA research is not only based on core agricultural domains but also a broad aspect of social, economic, and environment.

Overall, this study portrayed a deep background and profound boon of data that will help academia, scientist, and governments understand how the SA-centered studies are crafting impacts towards the environments and its potential impacts in the long run towards the world's biodiversity. We believe that this study will benefit from the associated literature as it stands among the only few studies that are profoundly designed to capture the holistic gap for SA research. The study illustrates the different phases by which the discipline can be reflected to understand the history of this research area, and the assessment of the studies cited most highlights the main concerns or discussions that can provide a more detailed assessment for shaping the future of this emerging area. As the prime aims of the study evaluated the SA research field based on the data only from the WoS core collection database, where we limited our search options only within the title and selected only the article which contains some specific phrases, those could be lead to miss some data. Moreover, the web of sciences only contains the data published after 1950, which are the study's main drawbacks. Our review was designed to explore only the research article published in journals (the review, conference, books, and book chapter are intentional excludes), which might have limited the full mapping capacity of our analysis.

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Author contribution All authors contributed to the study’s conception and design. Material preparation, data collection, and analysis were performed by AS & HW. The first draft of the manuscript was written by AS & WM, and AR & LQ further extended and finalized it. AKH and AS carefully reviewed and adjusted the revision suggested by the anonymous reviewers. All authors read and approved the final manuscript. All the authors read and approve the submission into the current form.

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Data availability Data and material are available upon request.

Code availability Not applicable to the study.

Declarations

Ethics approval As the study has not included any human participants, therefore no ethical approval is required.

Conflict of interest The authors declare no competing interests.

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