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Integrating explainable artificial intelligence and blockchain to smart agriculture: Research prospects for decision making and improved security

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ABSTRACT

Food safety hazards can be discovered and avoided using XAI and blockchain technology. The immutable and transparent ledger of blockchain technology can be used to maintain track of perishable food items, allowing for more rapid and precise detection of contamination and immediate removal from shelves. Using blockchain technology, smart agriculture can streamline the supply chain by connecting farmers directly with their customers. As a result, community members may be more confident in meeting their own dietary needs. Combining XAI, blockchain, and smart agriculture has far-reaching societal and economic implications. More efficiency, openness, and sustainability in the food chain might benefit farmers, consumers, and the world. This study provides a detailed bibliometric overview and visualization of integrating two prominent and promising technologies, explainable AI and Blockchain, into Smart Agriculture. In this study, the author implemented analysis in four phases, and for each phase, the author chose different strings, which provided different analysis results. 2479 articles are taken for “smart agriculture”, 103 articles for “Smart agriculture and blockchain”, 37 articles for “blockchain and explainable,” and finally, seven articles for “smart agriculture and explainable AI”. In this study, the mapping program VOSviewer is used for Network analysis. This study uses the co-occurrence, co-citation, and bibliographic coupling employed in VOSviewer to uncover significant focus areas and prominent authors and publications. By using a variety of publications, research was conducted on vital topics for this integration; as a consequence, influence and collaborations began to take place, ultimately leading to development.

1. Introduction

Agriculture is cultivating land, raising animals, and producing food, fiber, and other products for human use. It is a crucial industry for providing food and raw materials to support human life and economic development. Smart agriculture, or precision agriculture, applies advanced technologies and data analytics to optimize agricultural processes and increase productivity while reducing waste and environmental impact [1]. Smart agriculture utilizes various tools such as sensors, drones, artificial intelligence, and machine learning algorithms to monitor and manage crops, soil, and weather conditions. Farmers can make more informed decisions about crop management, irrigation, and pest control using real-time data, leading to higher yields, lower costs, and greater efficiency [2]. Smart agriculture incorporates various technologies, including Internet of Things (IoT) devices. These include sensors and drones that collect data on soil moisture, temperature, humidity, and other environmental factors [3]. Artificial intelligence (AI) and machine learning: These technologies are used to analyze the data collected by IoT devices and predict crop growth and yield [4]. Geographic Information Systems (GIS): These tools allow farmers to map their fields and identify areas requiring special attention or treatment. Robotics: Robotic devices, such as automated tractors and harvesters, can perform tasks more accurately and efficiently than human workers [5].

The goal of smart agriculture is to enable farmers to optimize their operations and increase their productivity while reducing their environmental impact. By leveraging data and technology, farmers can make better decisions about managing their crops, leading to higher yields, better-quality produce, and reduced waste. Smart agriculture is changing the way farming is done in several ways. For example, Increased

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efficiency: Smart agriculture allows farmers to use resources more efficiently, reducing waste and saving money [6]. Using sensors to monitor soil moisture levels, farmers can apply water only when needed, reducing water waste and saving on irrigation costs. Improved crop yields: By using data analytics to identify patterns in crop growth and environmental conditions, farmers can optimize growing conditions, leading to higher yields and better-quality crops [7]. Reduced environmental impact: Smart agriculture can help reduce the use of harmful chemicals and fertilizers, improving soil health and reducing pollution. Increased profitability: By reducing costs and increasing yields, smart agriculture can increase profits for farmers [8]. Overall, smart agriculture has the potential to revolutionize the way we produce food, making it more efficient, sustainable, and profitable.

1.1. Blockchain technology for smart agriculture

In Smart Agriculture, Blockchain technology significantly enables smart farming by providing a secure, transparent, decentralized platform for recording and sharing data [9]. The traditional agricultural supply chain involves multiple intermediaries, each handling different aspects of the supply chain, from production to processing, packaging, and distribution [10]. This can result in a lack of transparency and accountability, making it difficult to trace products back to their origin or verify their quality and safety. Blockchain technology provides a secure, decentralized, and tamper-proof platform for recording and sharing data across the supply chain [11]. By recording data on the blockchain, such as the date and location of planting, fertilizers, pesticides used, and the date and location of harvest, farmers and other participants in the supply chain can ensure that products are of high quality and safe consumption. In addition to traceability and security, blockchain technology can streamline agricultural transactions and reduce costs by automating payments, contracts, and insurance [12]. Smart contracts can automatically trigger payments or other actions based on predefined conditions, reducing the need for intermediaries and reducing transaction costs. Overall, blockchain technology has the potential to revolutionize the way we produce, distribute, and consume agricultural products, making the supply chain more transparent, efficient, and sustainable. In the context of smart farming, blockchain technology can be used in the following ways: Supply chain transparency: Blockchain can help improve transparency and traceability throughout the agricultural supply chain, from farm to fork [13]. Farmers can record information about their crops on the blockchain, such as planting dates, fertilizer and pesticide use, and harvesting times [9]. This information can then be accessed by other participants in the supply chain, such as processors, distributors, and retailers, to ensure the quality and safety of the food. Certification and verification: Blockchain can help farmers verify their compliance with regulatory standards and certifications, such as organic or fair-trade certifications. By recording this information on the blockchain, farmers can provide a transparent and verifiable record of their practices to consumers and other stakeholders. Smart contracts: Blockchain can automate agricultural transactions, such as buying and selling crops or leasing land. Smart contracts are self-executing contracts that automatically trigger a payment or other action when certain conditions are met. This can help reduce transaction costs and streamline agricultural transactions. Crop insurance: Blockchain can automate and streamline the crop insurance process, making it more efficient and transparent [14]. By recording information about crop yields, weather conditions, and other factors on the blockchain, insurers can more accurately assess risk and provide coverage to farmers. Overall, blockchain technology has the potential to enhance the transparency, efficiency, and security of agricultural transactions and data management, enabling more effective and sustainable smart farming practices [15].

1.2. Explainable AI for smart farming

In smart farming, Explainable AI (XAI) can be beneficial over traditional AI because it helps to build trust in the technology and ensures that farmers can understand the recommendations provided by AI systems [16]. In traditional AI models, such as deep neural networks, the decision-making process can be complex and challenging, even for experts. This lack of transparency and interpretability can make it difficult for farmers to trust the recommendations provided by AI systems and make informed decisions based on them. However, XAI techniques can help to address this issue by providing precise and interpretable explanations of how AI-based decisions are made [17]. For example, XAI can help farmers understand why certain crop management practices are recommended based on weather patterns, soil moisture, and pest presence. XAI can also help to improve the accuracy and effectiveness of AI-based recommendations by identifying biases and errors in the underlying data or algorithms. By explaining how these issues were identified and addressed, XAI can help farmers make more informed decisions and optimize their crop yields [18]. XAI has the potential to significantly improve the adoption and effectiveness of smart farming technologies by providing transparent and interpretable AI-based recommendations that farmers can trust and understand. Explainable AI can be used in smart agriculture to give farmers insights and explain how AI-based recommendations are generated [17]. Some ways that XAI can be used in smart agriculture: Crop health and disease management: XAI algorithms can analyze sensor data to detect early signs of crop disease and provide farmers with an explanation of the recommended course of action, such as applying specific pesticides or adjusting irrigation. Yield optimization: XAI can be used to analyze data on soil quality, weather conditions, and other factors to recommend when to plant, irrigate, and harvest crops for maximum yield. By providing clear explanations of the underlying models and data, farmers can make informed decisions about crop management [19]. Livestock management: XAI can be used to analyze data on livestock behavior, health, and feed intake to provide farmers with recommendations on how to optimize animal nutrition, detect early signs of disease, and improve animal welfare. Climate risk management: XAI can analyze weather data and other environmental factors to provide farmers with recommendations on adapting to changing climate conditions, such as adjusting planting schedules, switching to drought-resistant crops, or implementing more efficient irrigation practices. Overall, XAI can help farmers use the vast amounts of data generated by smart agriculture systems, leading to more efficient, sustainable, and profitable farming practices [20]. Bibliometric analysis is a research methodology that employs quantitative techniques to evaluate the influence, trends, and interconnections within a particular corpus of scholarly literature. This approach involves the measurement and assessment of numerous bibliographic components. The process encompasses various components, including the gathering and cleansing data, examination of bibliographic elements, analysis of citations, assessment of co-authorship patterns, examination of keywords, analysis of journals and sources, identification of publication trends, visualization techniques, and utilization of statistical analysis [21].

Integrating Explainable Artificial Intelligence (XAI) and Blockchain into Smart Agriculture can significantly benefit from applying bibliometric analysis. This tool facilitates the identification of research trends, the mapping of research networks, the assessment of research impact on Smart Agriculture, the identification of new technologies, the benchmarking of research outputs, the provision of information for strategic planning, and the creation of a systematic literature review [22].

The initial stage of the process involves collecting data, which may be sourced via academic databases or research libraries. Data cleaning is an essential process that involves eliminating duplicate entries and enhancing data quality. Using bibliometric analysis facilitates the comprehension of the scholarly environment, patterns, and study influence in these domains, thereby guiding the advancement and execution of inventive remedies within the agricultural sector [23].

The bibliometric analysis serves as a robust methodology for acquiring valuable insights into the current state of research and facilitating informed decision-making processes about integrating Explainable Artificial Intelligence (XAI) and Blockchain technologies within the domain of Smart Agriculture. This aids in comprehending the topography, patterns, and consequences of study in various domains, hence directing the advancement and execution of inventive resolutions for the agriculture industry [6].

2. Literature review

In a recent research, authors discussed the potential of smart irrigation systems to improve water efficiency and increase crop yields. The authors argue that IoT-based irrigation systems can help farmers better monitor and manage water usage and improve crop quality and quantity [24]. In another research, researchers examined the potential of smart pest management to improve crop health and reduce the use of pesticides. The authors argue that AI-based pest management systems can help farmers more accurately detect and diagnose pest infestations and reduce harmful pesticides [25]. Notably, the research explored the potential of smart crop monitoring to improve yield prediction and optimize crop management. The authors argued that big data analytics and AI could analyze crop data in real-time and provide farmers with actionable insights for optimizing crop management [26]. Previous research shows smart livestock management can improve animal welfare and increase productivity. The authors argued that IoT-based monitoring systems can help farmers better monitor animal health and behavior and improve overall productivity and profitability [27]. The literature indicated that the potential of smart supply chain management to improve traceability and transparency in agriculture is another area of research that needs to be explored. The authors argued that blockchain-based supply chain management systems can help reduce food waste, improve product quality and safety, and increase stakeholder trust [28]. A comprehensive literature review discussed the potential of blockchain technology to improve food safety by enabling more efficient tracking of food products throughout the supply chain. The authors argue that blockchain technology can help prevent foodborne illness outbreaks and improve consumer trust in food products [29]. The authors examine the potential of blockchain technology to improve payment processing in agriculture by enabling more efficient and secure transactions between farmers, distributors, and other stakeholders. The authors argue that blockchain technology can help to reduce transaction costs and improve payment security [30]. Researchers explored the potential of blockchain technology to improve crop insurance by enabling more efficient and transparent claims processing. The authors argue that blockchain technology can help to reduce fraud and increase trust between farmers and insurance companies [31]. Building upon the gaps identified in the literature, another research seeks to examine the potential of blockchain technology to improve traceability in agriculture by enabling more efficient tracking of product origin and processing history. The authors argue that blockchain technology can help to improve supply chain transparency and reduce the incidence of food fraud [32]. Researchers explored the potential of blockchain technology to improve sustainability in agriculture by enabling more efficient tracking of environmental impact and resource usage. The authors argue that blockchain technology can help promote sustainable farming practices and increase consumer trust in sustainably produced food products [33].

Authors explored the potential of XAI to improve decision-making in precision agriculture by enabling more transparent and interpretable machine learning models. The authors argue that XAI can help farmers understand better the reasoning behind machine learning models used in precision agriculture and increase trust in these models [34]. Previous studies have defined XAI's potential to improve crop yield prediction by enabling more transparent and interpretable machine learning models. The authors argue that XAI can help farmers better understand the factors contributing to crop yield and make more informed decisions about crop management [35]. Another study explored the potential of XAI to improve pest detection in agriculture by enabling more transparent and interpretable machine learning models. The authors argue that XAI can help improve the accuracy and reliability of pest detection models and increase trust among farmers and other stakeholders [36]. The authors also discussed the various aspects of XAI to improve soil mapping in agriculture by enabling more transparent and interpretable machine learning models. The authors argue that XAI can help improve the accuracy and reliability of soil mapping models and provide more detailed and valuable information to farmers and other stakeholders [37]. Despite extensive research on XAI to improve livestock management by enabling more transparent and interpretable machine-learning models, there is a notable gap in our understanding of using XAI and blockchain to smart farming. The authors argue that XAI can help improve the accuracy and reliability of machine learning models used in livestock management and increase trust among farmers and other stakeholders [38].

The process of selecting research questions plays a critical role in delineating the extent and emphasis of a study. The following questions center around intelligent agriculture, blockchain technology, and research on explainable artificial intelligence. The first research question investigates the publishing patterns during one year, aiming to discern prevailing trends and changes in research emphasis. The second question investigates the respective contributions made by nations, organizations, and scholars in smart agriculture, blockchain technology, and explainable artificial intelligence (AI) research. The third question is to ascertain prominent scholarly journals within these disciplines, assessing the significance and dissemination of research articles published in those publications. The fourth inquiry investigates the significance of writers' keywords in advancing smart agriculture, blockchain, and explainable artificial intelligence research. These studies offer a comprehensive perspective of the terrain in various domains, guiding research endeavors and informing the decision-making process for further inquiries. Through analyzing these inquiries, scholars can acquire valuable insights pertaining to the most pertinent subjects and issues within their respective domains.

RQ1: Over a year, what patterns do you see concerning publication output and specific subject areas?

RQ2: In what ways have countries, institutions, and authors helped with smart agriculture, blockchain, and explainable AI research?

RQ3: Which journals in the smart agriculture, blockchain, and explainable AI research field have the most significant citations and impact on researchers?

RQ4: How authors' keywords are contributing to smart agriculture, blockchain, and explainable AI?

3. Methodology

Various analytical methods are available for a comprehensive quantitative and qualitative literature study [39]. A scientometric review is a type of scientific mapping used to investigate and identify unusual patterns and developments within a given field [40,41]. In Webometrics/cybernetics studies, the information related to websites, webpages, or any web content is provided for any specific field [42,43]. Altmetrics, also known as alternative metrics, is a technique for measuring the influence of a topic on social media by examining user activity on several social media platforms [44], like Twitter and Facebook [45]. Finally, bibliographic analysis is a statistical method for cataloging, examining, and ranking scholarly works [46]. This study focuses on bibliometric analysis for smart agriculture, blockchain, and explainable artificial intelligence and proposed methodology is represented in Fig. 1.

This study uses Excel and Vosviewer to display the visualization networks and the visual analysis results, which help clarify research foci and growth trends [47,48]. Vosviewer is a widely available software tool

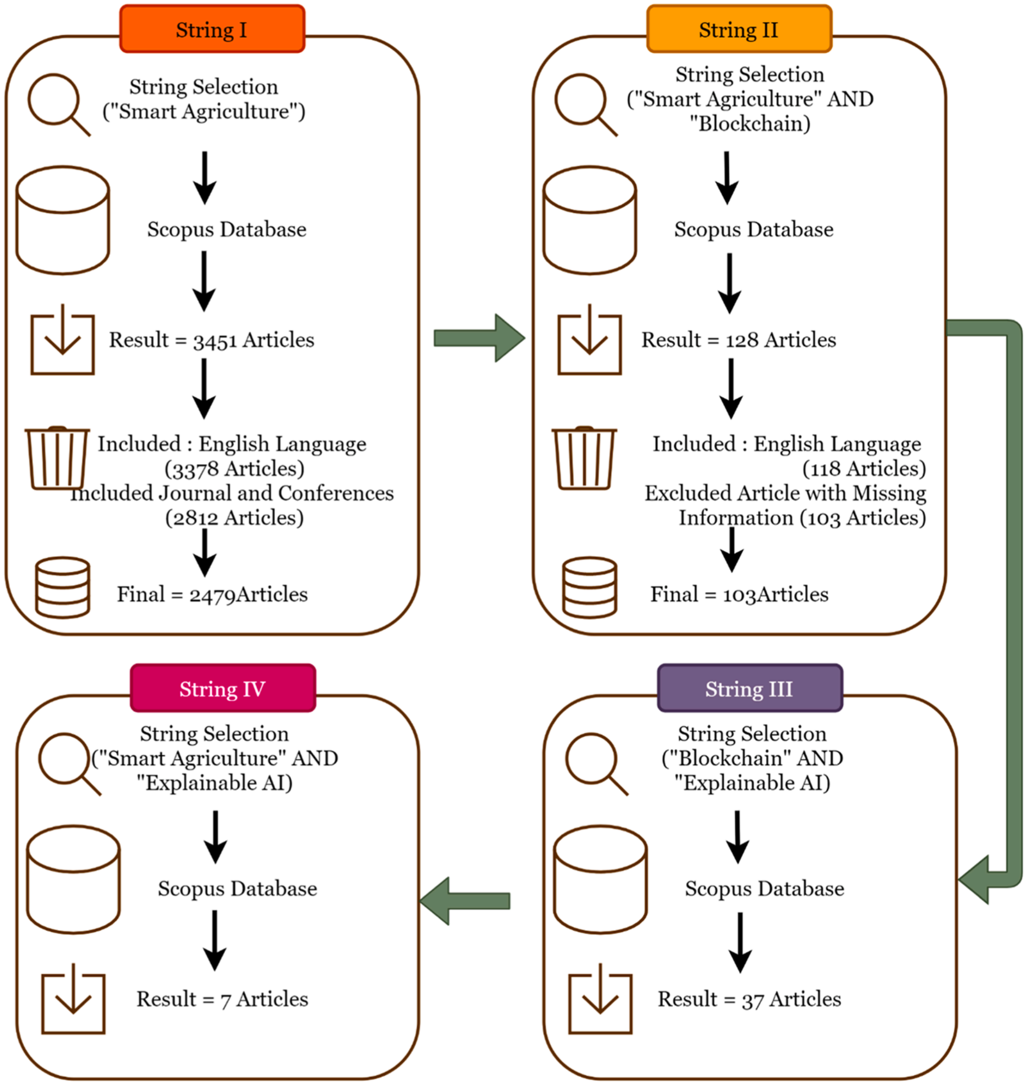

Fig. 1. Proposed Methodology.

for visualizing and analyzing bibliometric data. It is commonly used in research and academia to create maps and visual representations of relationships between scientific articles, authors, and keywords, helping researchers identify trends and connections in their field of study [49]. The method has found widespread application thanks to its adaptable mapping visualization and robust user graphic interface [50,51]. The methodology used in this study is shown in Fig. 1.

Scopus database was used to do Bibliometric Analysis [21]. Scopus represents a string of top journals, an internationally recognized benchmark for quality publications. This research focuses on how smart agriculture grows with time and how blockchain comes into existence for security. In addition, the author focuses on finding the relationship between smart agriculture and blockchain collaboration with explainable artificial intelligence to make smart agriculture more smart and secure. To elaborate on this whole concept, the author divided its methodology into four major parts in which initially, authors provided deep insight analysis of smart agriculture. In the second phase, the smart agriculture keyword is combined with blockchain, and deep analysis is provided to correlate their relationship. In the third phase, blockchain is mixed up. Explainable AI and Analysis show the growth and analysis of the combined string. Finally, the smart agriculture keyword is combined with explainable AI to seek how smart agriculture models can be made smarter according to new-era requirements. The authors have conducted a Scientometric literature survey. Therefore, the current study investigates the importance of these keywords through a broad focus on important aspects, specifically the efficiency and effectiveness of their publications based on a variety of bibliometric indicators such as (i) a total number of publications, (ii) a total number of citations, and (iii) the average citations per publications. This paper also presents the visual analysis results of the smart agriculture, blockchain, and explainable AI literature using Vosviewer, including the identification of the most cited authors, (ii) the countries that have made significant contributions, (iii) the journals that have published the research, (iv) the keywords used in the research, and (v) the authors who have worked together on the research [52,53].

4. Result analysis

The result analysis process followed by the authors in this research is shown in Fig. 2.

4.1. Phase I: smart agriculture

In the first phase, as mentioned in the methodology section, the “smart agriculture” keyword is selected to extract the data from the Scopus database, considered one of the largest and most reliable databases. In the first pass, 3451 articles were extracted from the database. Then, the authors applied inclusion/exclusion criteria to the extracted

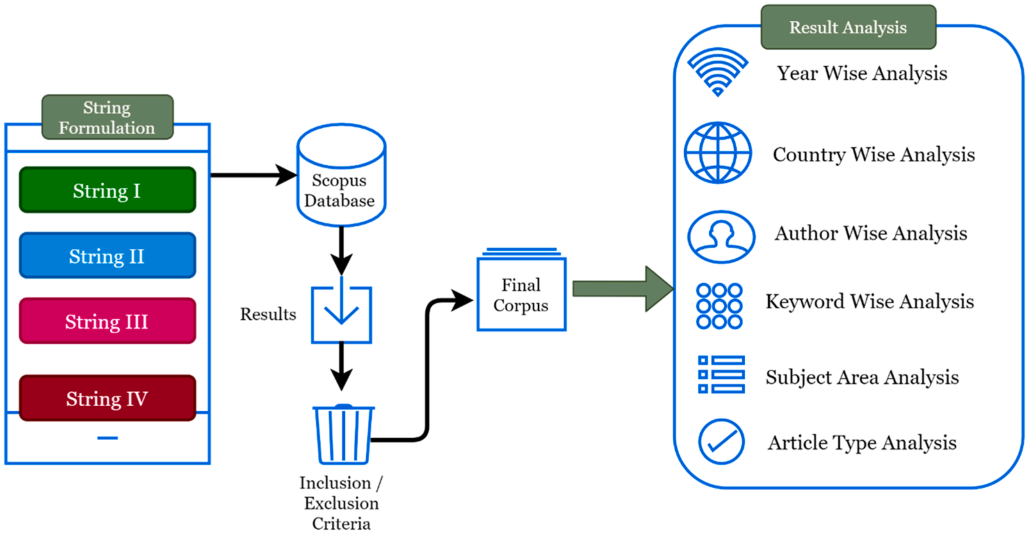

Fig. 2. Result Analysis Process.

data, like considered articles written in English and articles published in journals and conferences, and excluded those in which information is missing, like the author, year, title, etc. Finally, 2479 articles are considered for the experiment after applying these criteria.

In this study, the authors provide a deep Analysis to answer the formulated research question.

4.1.1. *Year wise growth in publication*

Fig. 3 represents a year-wise rising trend since the first paper's publication in the Smart Agriculture field. In the era of smart agriculture, there are very few publications as in 2008, there was only 01 paper published, but the general trend is towards an overall increase. In 2022, the maximum number of publications was 754, which is 30.42% of total publications. More articles may be published after the timeline taken by the authors.

4.1.2. *Subject area wise analysis*

Fig. 4 represents a subject-wise rising trend. Here in this Figure, it is evident that research in the Health professions using smart agriculture is significantly less. Still, the general trend is towards an overall increase in different subjects, as shown below in Figure. The subject computer science saw the maximum number of publications at 1271. In engineering, it is 941. More articles may be published after the timeline taken by the authors.

4.1.3. *Journal wise analysis*

The network graph for the research publishing based on the Journals is depicted in Fig. 5. The link strength of the journals can also be understood through this approach. According to link strengths, the best journals are Sustainability in Smart Agriculture and Sensors.

4.1.4. *Author wise analysis*

In Table 1, the author, Jat m.l. from "International Maize and Wheat Improvement Center," has published 21 documents in the field of smart agriculture. Jat m.l. from India led the publications on smart agriculture with 21 publications, and wang y. from "The Chinese Academy of Agricultural Engineering" China with 20 publications, each shown in Table 1. Jat m.l. has 301 citations, followed by wang y. with 184 citations. Li x. is in third place with 171 citations. Dougall a.j. from "Sustainability Research Institute, School of Earth and Environment, University of Leeds" has minor publications, which are 15, but has the highest number of citations, 333.

4.1.5. *Country wise analysis*

In India, the total number of publications is 546 based on smart agriculture, which is the highest compared to other countries. However, it is the lowest in the United Kingdom, 113, as shown in Table 2. Based on Citation, in India, it is 6659, followed by the US, 4269; in the Netherlands, it is the lowest, 2243.

Fig. 6 represents the network graph of countries based on their research documents. A positive numerical value is assigned for each link,

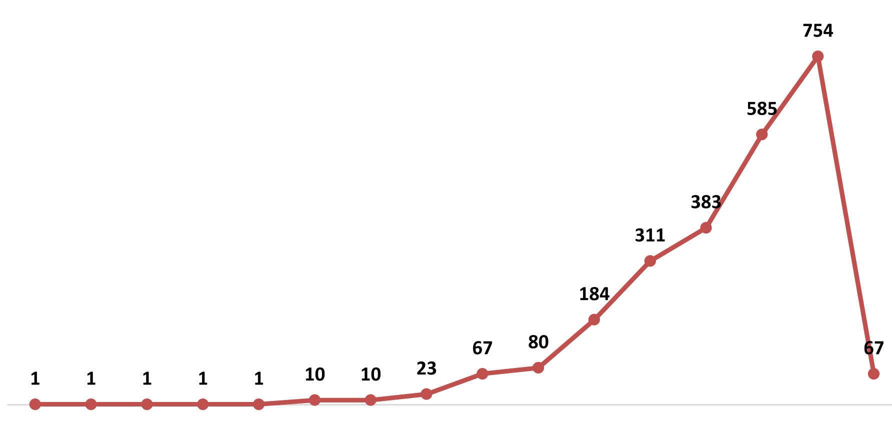

Fig. 3. Year-Wise Publication Analysis of Phase I.

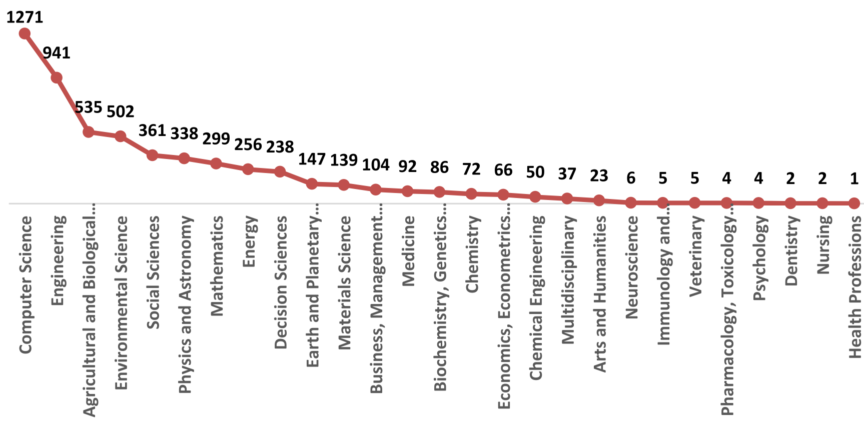

Fig. 4. Subject Area Analysis of Phase I.

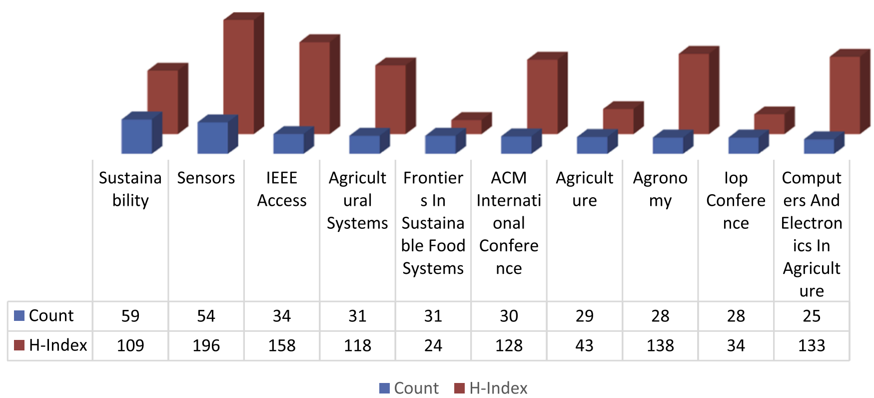

Fig. 5. Journal Wise Analysis of Phase I.

Table 1
Top Author Analysis of Phase I.

Author	Documents	Citations	Country	Affiliation
Jat M.L.	21	301	India	"International Maize and Wheat Improvement Center"
Wang Y.	20	184	China	"Chinese Academy of Agricultural Engineering"
Li X.	18	171	China	"College of Information Science and Technology, Zhongkai University of Agriculture and Engineering"
Liu Y.	17	91	USA	"Department of Electrical, Computer, Software, and Systems Engineering, Embry-Riddle Aeronautical University"
Dougill A.J.	15	333	UK	"Sustainability Research Institute, School of Earth and Environment, University of Leeds"

Table 2
Countries' contribution based upon Publication and Citation of Phase I.

Ranking based on publication			Ranking based upon citation		
Rank	Country	TP	Rank	Country	TC
1	India	546	1	India	6659
2	China	334	2	United States	4269
3	United States	251	3	China	3430
4	Italy	153	4	Italy	2443
5	United Kingdom	113	5	Netherlands	2243

described as link strength. The stronger the connection, the higher this number should be. The amount of times two keywords appear together in a publication is reflected in the total link strength. This analysis states that India has the most significant publications of 546, the highest number of citations of 6659, and a link strength of 213, as shown in Fig. 6. China is a distant second, with 334 publications and 3430 citations with a link strength of 197. The United States is in third place with 251 publications, and China is in third place regarding Citations.

4.1.6. *Keyword analysis*

Fig. 7 provides a visual representation of the most commonly used search terms. With 797 occurrences and a link strength of 2265, "smart agriculture" tops the list, followed by "internet of things" with 294 occurrences and a link strength of 951. The article's keyword network is depicted in Fig. 8 as well. Smart agriculture, the Internet of Things, and IoT are the three most popular search terms measured by link popularity. This demonstrates the prominence and usefulness of these terms by utilizing anchor text abundant with those terms. When discussing keywords, "link strength" can mean the quantity and quality of inbound links to a given document, the "keywords" of that material appearing in the linked text. In addition, a wide range of colors is used in the graph to draw attention to specific data points or trends or to help visually distinguish between the various data sets. There's a chance this might make the data displayed on the graph less complicated to read and evaluate. To put it another way, terms like "available nutrients," "biomass," "business model canvas," and "etc." are just some of the 1137 author keywords that have been used exactly once and have one link strength.

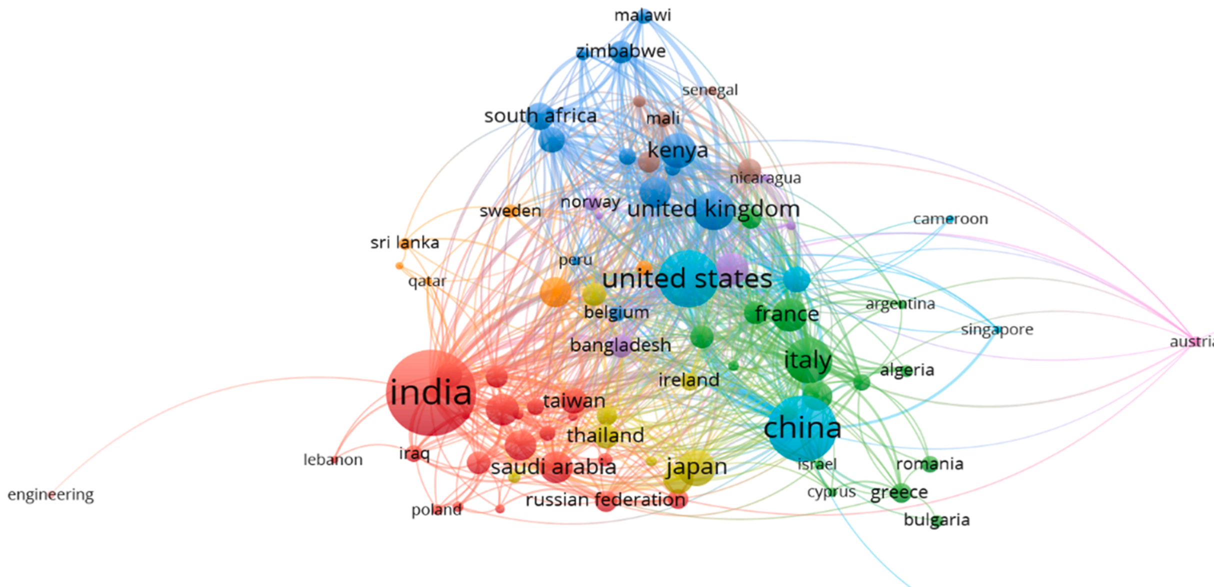

Fig. 6. Screenshot of Network Analysis Based upon Document and Citation of Phase I.

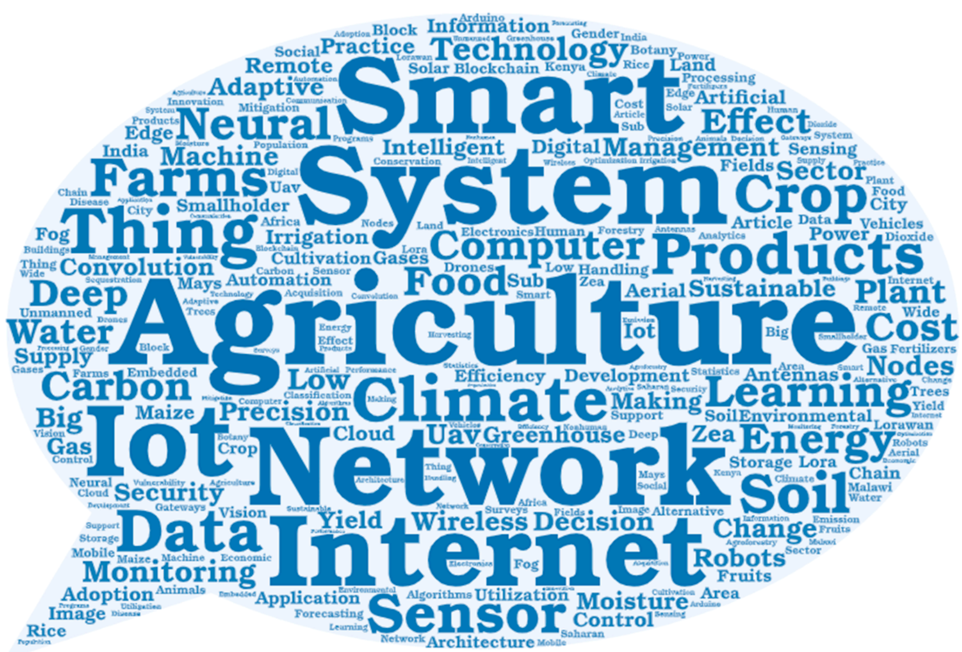

Fig. 7. Word Cloud of Keyword Analysis of Phase I.

4.2. Phase II: ("Smart agriculture") and ("Blockchain")

In the second phase, as mentioned in the methodology section, the "smart agriculture" and "blockchain" keywords are selected to extract the data from the Scopus database, considered one of the most extensive and reliable databases. In the first pass, 128 articles are extracted from the database. Then, the authors applied inclusion/exclusion criteria to the extracted data, like considered articles written in English and articles published in journals and conferences, and excluded those in which information is missing, like the author, year, title, etc. Finally, 103 articles are considered for the experiment after applying these criteria.

In this study, the authors provide a deep Analysis to answer the formulated research question.

4.2.1. Year wise growth in publication

Fig. 9 represents a year-wise rising trend since the first paper's publication in the Smart Agriculture and Blockchain field. In the era of Smart Agriculture and blockchain, there are very few publications as in 2018, there were only 02 papers published, but the general trend is towards an overall increase. The year 2022 saw the maximum number of publications at 54, and More articles may be published after the timeline taken by the authors.

4.2.2. Subject area wise analysis

Fig. 10 represents a subject-wise rising trend. Here, in Fig. 8, it is apparent that research in Neuroscience using smart agriculture and blockchain is significantly less. Still, the general trend is towards an overall increase in different subjects. The subject computer science saw

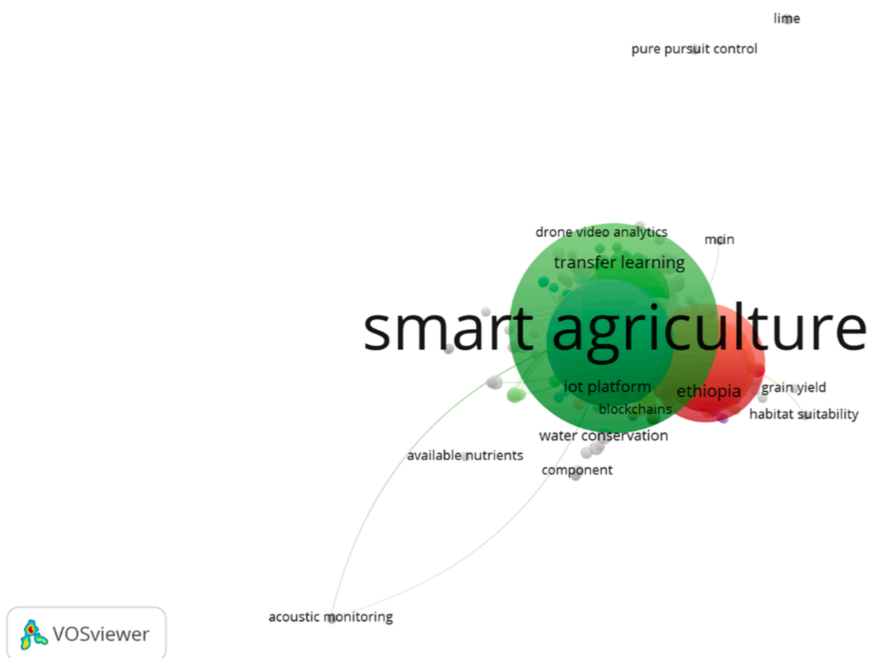

Fig. 8. Network Connection of Keywords of Phase I.

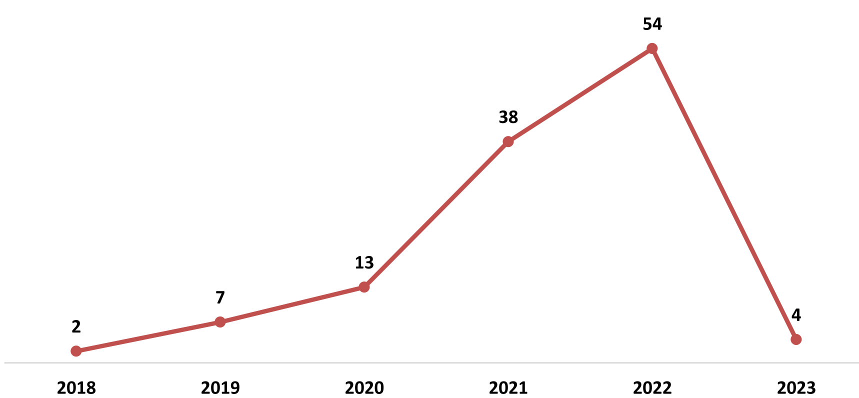

Fig. 9. Year-Wise Publication Analysis of Phase II.

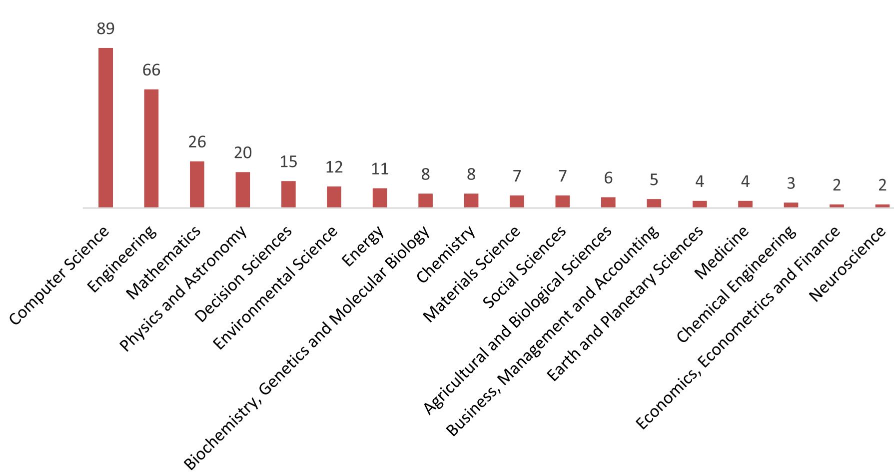

Fig. 10. Subject Area Analysis of Phase II.

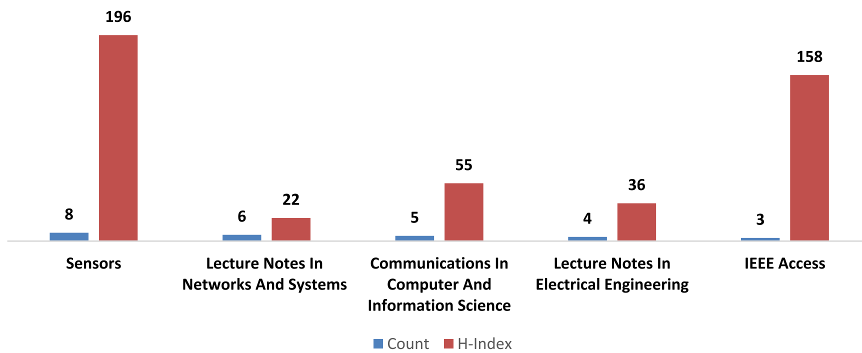

Fig. 11. Journal Wise Analysis of Phase II.

the maximum number of publications at 89. In engineering, it is 66. More articles may be published after the timeline taken by the authors.

4.2.3. Journal wise analysis

The network graph for the research publishing based on the Journals is depicted in Fig. 11. The link strength of the journals can also be understood through this approach. According to link strengths, the best journals are Sensors in Smart Agriculture and the Blockchain, then Lecture Notes in Networks and Systems.

4.2.4. Author wise analysis

In this Table 3, the author, kougianos e., from the USA, has published a comprehensive 04 documents in smart agriculture and blockchain. On the other hand, Das a.k. from India, led the publications on smart agriculture and blockchain with 03 publications. Therefore, the ranking based upon Citation is 363 of the author Kumar n. from India. The lowest is 275, which is of the author from the UK.

4.2.5. Country wise analysis

In India, the total number of publications is 42 based on smart agriculture and blockchain, which is the highest compared to other countries. On the other hand, in Pakistan, it is the lowest, which is 07, as shown in Table 4. Based on Citations, in India, it is 557, followed by China at 546, then in Saudi Arabia, it is the lowest, 234.

4.2.6. Keyword analysis

Fig. 12 provides a visual representation of the most commonly used search terms. With 69 occurrences and a link strength of 365, "blockchain" tops the list, followed by "smart agriculture" with 49 occurrences and a link strength of 258. blockchain, smart agriculture, and IoT are the three most popular search terms, as measured by link popularity. This demonstrates the prominence and usefulness of these terms by utilizing anchor text abundant with those terms. When discussing keywords, "link strength" can mean the quantity and quality of inbound links to a given document, the "keywords" of that material appearing in the linked text. In addition, a wide range of colors is used in the graph to draw attention to specific data points or trends or to help visually distinguish between the various data sets. There's a chance this might make the data displayed on the graph less complicated to read and evaluate. To put it another way, terms like development path, agri-food security system, agricultural data sharing, etc." are just some of the 284 author keywords used precisely once and have limited link strength.

Table 3
Author Analysis of Phase II.

Ranking Based on Publication				Ranking Based upon Citation			
Rank	Author	TP	Country	Rank	Author	TC	Country
1	Kougianos E.	4	USA	1	Kumar N.	363	India
1	Mohanty S. P.	4	USA	2	Ferrag M. A.	312	Algeria
2	Das A.K.	3	India	2	Shu L.	312	China
2	Ferrag M.A.	3	Algeria	3	Tanwar S.	296	India
2	Kumar N.	3	India	3	Mistry I.	296	India
2	Ray C.	3	USA	3	Tyagi S.	296	India
2	Shu L.	3	China	4	Maglaras L.	275	UK

Table 4
Countries' contribution based upon Publication and Citation of Phase II.

ranking based on publication			ranking based upon citation		
Rank	Country	TP	Rank	Country	TC
1	India	42	1	India	557
2	China	21	2	China	546
3	United States	12	3	Algeria	312
4	Saudi Arabia	8	4	United Kingdom	312
5	Australia	7	5	Saudi Arabia	234
5	Pakistan	7			

4.3. Phase III and IV

In the third and fourth phase, as mentioned in the methodology section, the "smart agriculture" AND "explainable AI," "blockchain," AND "explainable AI" keyword is selected to extract the data from the Scopus database. For string III, authors receive 37 articles from journals, conferences, book series, etc. For string IV, authors receive 7 articles from all types of sources. These results show that these are emerging areas where researchers are starting to work and explore the field.

The detailed analysis of years, country, source type, and subject areas is represented in Fig. 13 and Fig. 14.

In Fig. 13, the author represented the detailed Analysis of String III. The number of articles considered for string III is 37, as the number of articles is much less than for string I and String II. However, analysis shows that the article count is increasing with the year as researchers are exploring the field. Moreover, most articles are published at conferences, and many are published in journals. In countrywide analysis, it is concluded that India has the highest number of publications, and its contribution is 13.5%.

In Fig. 14, the author provided a comprehensive analysis of String IV. A total of seven articles were considered for inclusion in string IV. It is worth noting that the number of articles available for analysis is relatively small. However, it is essential to highlight that the investigation into the development of smart agriculture with explainable AI is a recent phenomenon, commencing in 2021. Consequently, only two relevant papers were identified during the research process.

In comparison, five articles have been discovered for 2022, indicating a notable growth trend. Academic Article Three articles were published at the conference, while two pieces were published in the journals "Computers, Materials and Continua" and "Journal of Experimental and Theoretical Artificial Intelligence". France and Italy are at

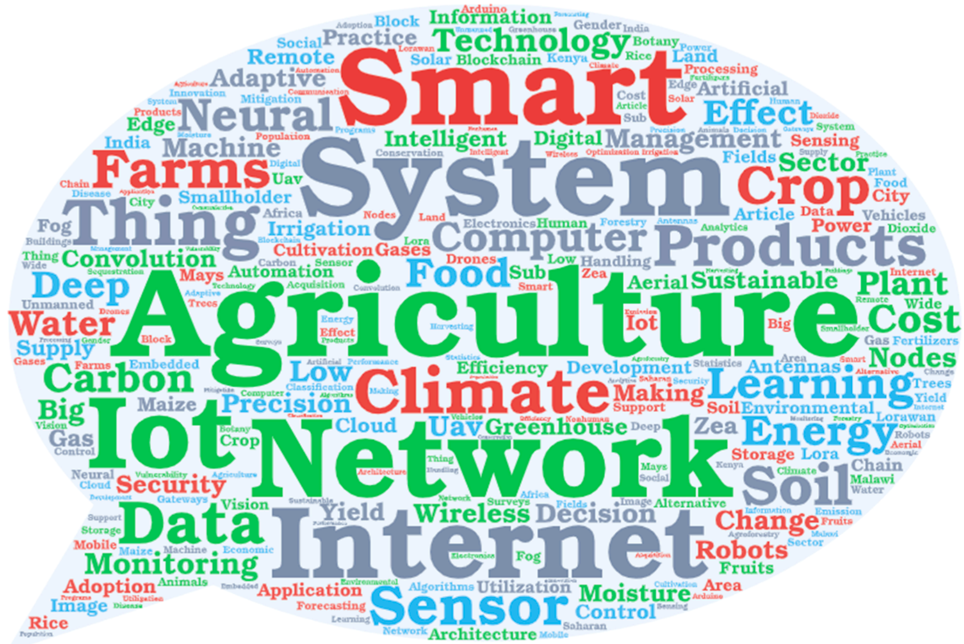

Fig. 12. Word Cloud of Keyword Analysis of Phase II.

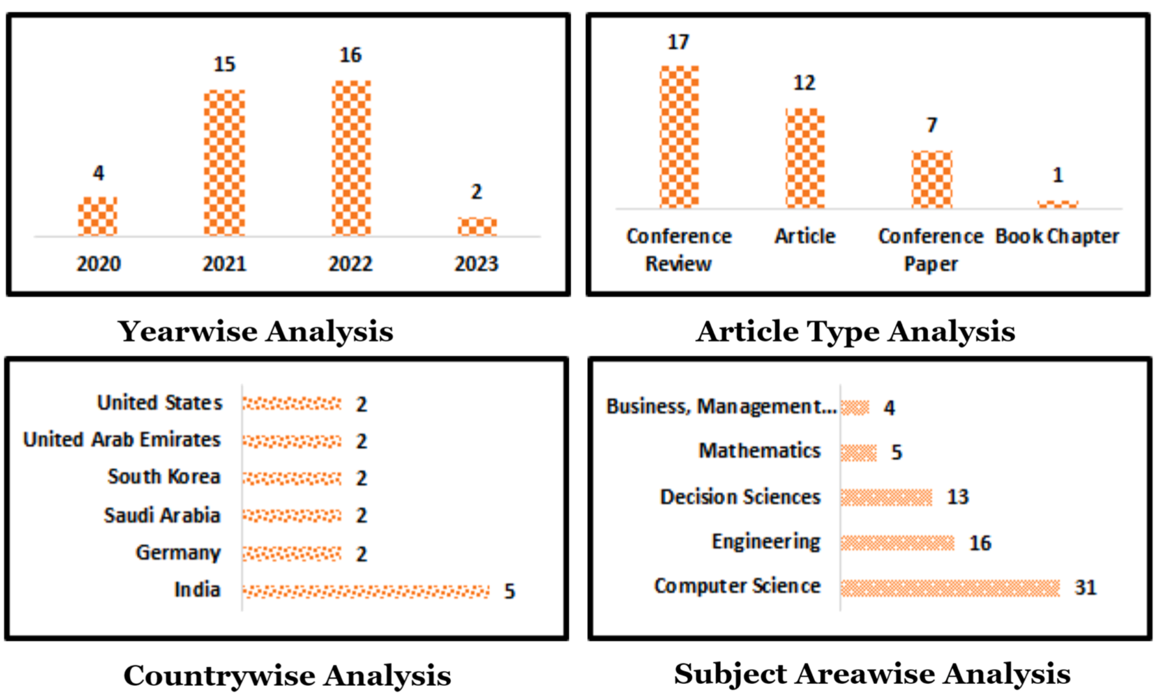

Fig. 13. Analysis of the String III (Blockchain and Explainable AI).

the forefront regarding their respective countries' contributions. The entirety of the article pertains to the discipline of computer science. Based on a comprehensive analysis, the authors conclude that this field is emerging.

5. Limitations of the study

Searching Scopus with the four strings taken into consideration by the authors may not have returned all of the papers related to smart agriculture, blockchain, and explainable AI. Regardless of how large the sample was, there is a chance that the current study is not as trustworthy as it may be. Limitations in search terms, synonyms, string construction, search engine variety, and the correct rejection of results for which the search string is insufficient all contribute to a poor retrieval of the literature corpus. Remembering that search terms and phrases may initially eliminate valuable functional research is vital. The next step is for authors to use these terms to determine the most valuable classifications for readers in the research, academic, and practical communities. There may be additional data and comparisons of methods in the future as authors try to keep up with the exponential data growth. The work hints at plans to compare many databases, including Scopus and the Web of Science. The Scopus tool is lacking, though. Using many data

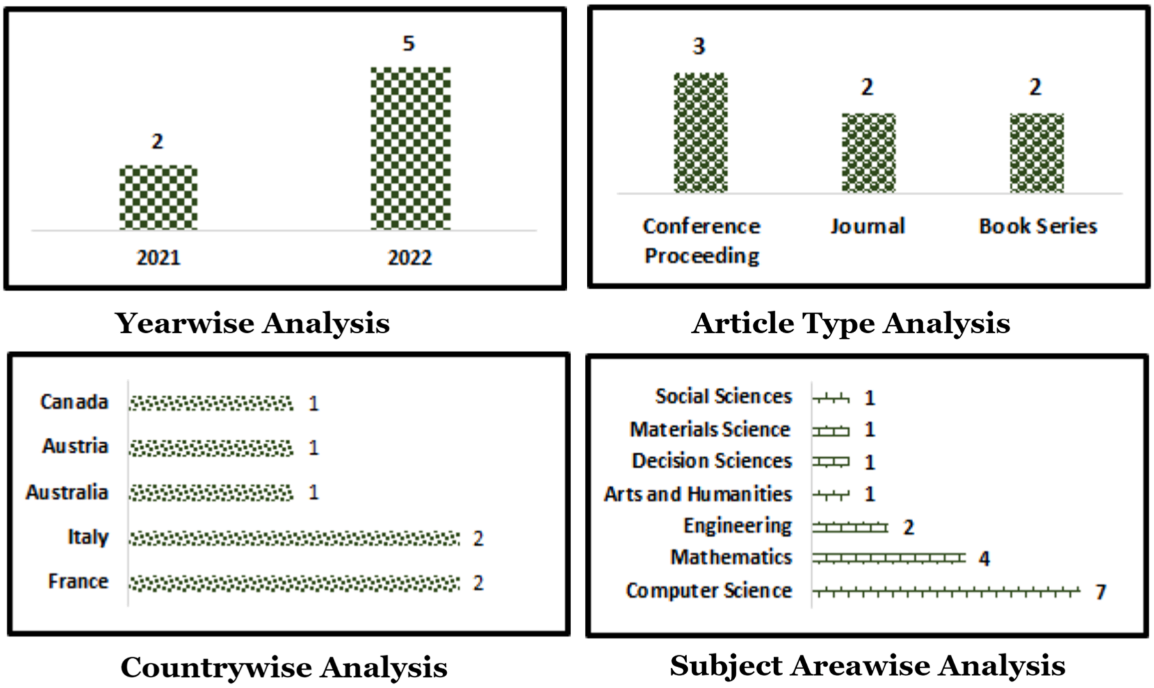

Fig. 14. Analysis of String IV (Smart Agriculture and Explainable AI).

sets that employ bibliometric analysis will help with the larger-scale investigation. It has been found that the greater the number of scientific publications used in a study, the more credible the study's overall findings. An innovative classification approach for researching labor trends and advancements needs further investigation. Since just one Vosviewer application was employed in this study, future investigations may benefit from using different bibliometric analysis techniques.

6. Discussion

Employing technological improvements in the agricultural industry to enhance output while minimizing inputs and extending harvest lifetime will lead to better outcomes in agriculture. Integrating new technologies into intelligent agriculture, such as blockchain and explainable artificial intelligence (XAI), has the potential to increase both the efficiency and accessibility of the practice. The blockchain is an irreversible and permanent digital database that is decentralized, transparent, and resistant to tampering. It may record transactions between members in a manner that cannot be changed. It can be utilized in "smart agriculture" to monitor crops from when they are planted until when they are harvested, ensuring that every facet of producing food is considered. The quality of the soil, the amount of irrigation, and the type of fertilizer are just a few examples of the growing process that can be monitored and recorded using blockchain technology. This provides customers with the ability to make more educated purchasing decisions.

Explainable AI is of the utmost consequence in intelligent agriculture, as algorithms driven by artificial intelligence analyze vast quantities of data to maximize agricultural productivity while minimizing waste. By making the models used to train AI technologies more transparent and explicable, it is possible to boost farmers' and other stakeholders' confidence in these technologies and encourage them to use them more widely. Integrating XAI with intelligent agriculture may lead to farming methods that are less harmful to the environment and more open to public scrutiny. For instance, data about the environment, the soil, and irrigation systems may be put into AI models to forecast future harvests. If farmers fully appreciate the logic behind these models, they will be in a better position to make decisions regarding the management of their crops. It is possible that as a consequence of this, the production of the fields will increase, there will be less waste, and farming will become more environmentally responsible. Integrating XAI, blockchain, and smart agriculture could improve the sustainability and openness of the agricultural sector. Farmers can reduce their harmful effects on the environment, boost their productivity and efficiency, and keep their food supply safe and trackable by utilizing these technologies. Technology progresses when integrated into society, so its presence is unobtrusive and natural.

Keeping the objective of integrating these three different technologies, the current research focuses on retrieving data from a research database and applying statistical analysis. The findings indicate that much effort has been invested in "smart agriculture," which provides safety via blockchain technology and integrates blockchain with explainable AI to enhance decision-making. The findings of this research also indicate that further research is required to investigate the integration of these three technologies for the benefit of humanity.

7. Implications and conclusion

To summarize, the combination of XAI, blockchain technology, and intelligent agriculture has the potential to bring about profound changes in the manner in which food cultivation, transportation, and consumption. By combining artificial intelligence, blockchain technology, and "smart" agriculture, researchers can develop a food system that is more efficient, more open, and more environmentally friendly. XAI may be able to boost the possibility that farmers will adopt and employ AI technology by assisting farmers in comprehending the process by which AI models arrive at their findings. The safe and transparent transport of agricultural products from the farm to the consumer's table can be tracked using blockchain technology, which can also be used to build decentralized markets that link consumers directly with farmers. Blockchain technology can also build markets that link consumers directly with farmers. The capacity of blockchain to develop secure and privacy-preserving systems for exchanging data is crucial for both farmers and customers. It is fundamental to the success of smart agriculture, which relies heavily on the collection and analysis of data. In addition, AI models may analyze data obtained from various sources to guide farmers on how to raise crop yields.

Ultimately, the combination of XAI, blockchain technology, and smart agriculture could cause a significant shift in agriculture by raising output while reducing waste and enhancing sustainability. This would be a welcome development. Future research may concentrate on developing these technologies further and assessing their potential to contribute to the establishment of a food distribution system that is open, secure, and environmentally friendly. The intersection of explainable artificial intelligence (XAI), blockchain technology, and smart agriculture can potentially help many facets of agriculture and society. Farmers may be able to boost their productivity and profit with the assistance of XAI, which can enable them to make better-informed decisions and enhance the efficiency of their operations. This can help farmers raise their productivity and profit. Because blockchain technology can increase efficiency while reducing costs associated with tracking, certifying, and transacting food, it paves the way for a better supply chain. The implementation of blockchain technology in smart agriculture has the potential to enhance visibility by maintaining an immutable record of the origin of a product, its manufacturing processes, and its distribution. Because consumers now have access to this information, it is feasible for them to have greater trust and confidence in the food system. XAI and smart agriculture help a more ecologically friendly and sustainable agricultural sector by assisting farmers in reducing their use of resources such as water, fertilizer, and pesticides. The technology behind blockchain can also be used to construct supply networks that are both transparent and environmentally friendly. With XAI and blockchain technology, questions regarding food safety can be discovered and subsequently avoided. Food products can be tracked using the immutable and transparent ledger blockchain technology offers. This enables the quicker and more accurate detection of contaminated food, which leads to the product being removed from distribution. By cutting out the intermediaries and bringing farmers and consumers closer together, blockchain technology may make it possible for smart agriculture to improve the efficiency of the supply chain.

Consequently, local communities may experience an increase in their confidence regarding their capacity to provide an adequate supply of food for themselves. The combination of XAI, blockchain technology, and intelligent agriculture has wide-ranging implications for society and the economy. It has the potential to build a food system that is more favorable for farmers, consumers, and the environment as a whole by boosting efficiency, transparency, and sustainability. The implementation of blockchain technology might accomplish this.

8. Future directions

Integrating explainable artificial intelligence (XAI), blockchain, and smart agriculture can revolutionize how we produce and consume food. The potential research directions in this field are described in Table 5.

Ultimately, combining XAI, blockchain technology, and smart agriculture can revolutionize the agricultural sector by increasing productivity, reducing waste, and making the industry more environmentally friendly. Therefore, research in the future could concentrate on the further development of these technologies and the investigation of their potential to produce a food system that is more open, secure, and environmentally friendly.

Table 5
Future Direction.

Sr. no.	Potential research areas	Description
1	Developing XAI models for smart agriculture	Using XAI in smart agriculture may assist farmers in comprehending the decision-making process of AI models, which may lead to an increase in the farmers' level of trust in and adoption of the technology. In the future, research might concentrate on developing XAI models tailored to the agricultural sector, with the ability to explain how the models arrive at their suggestions or forecasts.
2	Building blockchain-based traceability systems	Tracking the transit of food goods from the farm to the consumer's table can be made safer and more transparent with the help of blockchain technology. Researchers have the opportunity to investigate the use of blockchain technology in developing traceability systems that can verify the authenticity of food products, ensure the product's safety, and provide information to consumers about the product's origins and the production methods used.
3	Enhancing data privacy and security	The collecting and processing of data from various sources, including sensors, drones, and satellite imaging, are critical components of what is known as "smart agriculture." As a result, there is a need to build secure and privacy-preserving systems for data sharing to preserve the privacy of both farmers and customers. In the future, the research could concentrate on establishing data-sharing platforms based on blockchain technology that would enable the safe sharing of agricultural data.
4	Developing decentralized marketplaces for smart agriculture	Blockchain technology can facilitate the development of decentralized markets that connect farmers and consumers directly, thereby removing intermediaries and cutting prices. The potential of blockchain for creating such markets that allow farmers to sell their produce directly to consumers and provide consumers with access to fresh and locally produced food can be investigated by researchers.
5	Exploring the use of AI for precision agriculture	The application of technology in agriculture is known as "precision agriculture," Its goals are to maximize agricultural productivity, cut down on waste, and improve sustainability. By analyzing data from sensors, weather forecasts, and soil samples with AI algorithms, farmers can obtain recommendations on improving their operations and making their businesses more profitable. Future research could focus on developing AI models that can explain their recommendations to farmers, boosting their confidence in the technology and encouraging them to use it more widely.

9. Ethics statement

Not applicable

This manuscript does not include human or animal research.

If this manuscript involves research on animals or humans, it is imperative to disclose all approval details.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Hsin-Yuan Chen reports financial support was provided by Zhejiang University.

Data availability

Data will be made available on request.

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