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Evolution and Trend of Deep Learning in Agriculture: A Bibliometric Approach

Kimba Sabi N'goye[1], Henoc Soude[1], Yêyinou Laura Estelle Loko[2]

[1]Institute of Mathematics and Physics, Porto-Novo, Benin
[2]High School of Applied Biosciences and Biotechnologies (ENSBBA), Dassa-Zoumé, Benin
Email: kimba.sabi@imsp-uac.org, henoc.soude@imsp-uac.org, lokoestelle@yahoo.fr

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Abstract

Deep Learning has recently gained a great deal of attention. From this, resulted many applications in a variety of industries, including agriculture. An essential study goal is to understand what has been done in the use of deep learning in agriculture (DLA) thus far in order to establish a robust research agenda to address its future challenges. The present state of research on the DLA with special attention to Africa was evaluated in this study using bibliometric analysis. A search of documents dealing with DLA was realized in the Web of Science database, a world-leading publisher-independent global citation database. A bibliometric program named Bibliometrix was used to examine the data after the search yielded 3207 items. Key findings are highlighted and discussed, and then some directions for potential future research are suggested.

Keywords

Machine Learning, Deep Learning, Agriculture, Bibliometric, Africa

1. Introduction

With the growth of the population, the demand for food products is constantly increasing despite limited or even dwindling agricultural resources. To meet this demand, farming practices must reduce waste and optimize usage of resources. In other words, it is "doing the right thing, at the right time, in the right place, in the right way" [1]. In this sense, the rise for machine learning has paved the way to applications in agriculture.

Machine Learning (ML) could be defined as the scientific field that gives machines the ability to learn without being strictly programmed [2]. ML has evolved over the years and give rise to sub-field like deep learning. Deep learning

distinguishes itself from classical machine learning by the type of data that it works with and the methods in which it learns. Deep learning eliminates some of data pre-processing that is typically involved with machine learning. These algorithms can process text and image data that is unstructured and automate feature extraction, reducing the need for human experts. Thus the building of models has become more accessible to all, leading to the birth of several applications in areas such as agriculture. Among applications in agriculture, Sharma and *et al.* [3] soil properties and weather prediction, crop yield prediction, disease and weed detection, drip irrigation, intelligent harvesting techniques [3]. In order to map out the recent developments, critical issues, and key research gaps in this field of study, a bibliometric analysis can be conducted. In this way, several bibliometric analysis conducted by many authors. Riccardo *et al.* [4] conducted a bibliometric study to find evidence of the ongoing Digital Agriculture Revolution (DAR) and clarify its roots, what it means, and where it is heading. Their study is based on 4995 articles collected from Web of Science (WoS) database in the timespan 2012-2019. Their work embraces a wide range of themes such as Climat-Smart Agriculture, Site-Specific Management, Remote Sensing, Internet of Things, Artificial Intelligence. Another bibliometric analysis was done by Shivali *et al.* [5] on the field of plant disease classification with Artificial Intelligence (AI) based on scopus and WoS. The bibliometric analysis, by its ephemeral nature, requires a regular update of the results. On one hand, the present work is intended to be an updated version of the above-mentioned works, but specifically focusing in the use of deep learning in agriculture. On the other hand, it highlights the contribution of Africa in this field. The outcome can help to choose a research topic and establish research collaboration.

Through this paper, the following research questions are addressed:

- What is the current level of research in application of Deep Learning in Agriculture (DLA)?
- Who are the most productive and most-cited authors in the field of DLA?
- Which are the most influential institutions, countries, and journals in the DLA?
- What are the potential research avenues on DLA?

Special attention has been given to African countries.

The paper uses a macroscopic study of the DLA publications from the Web of Science database based on bibliometric analysis to answer these research questions. The document is organized as follows: Section II presents the methodology of our research. Section III presents our results and discussion. Finally, section IV presents the conclusion and avenues for future research works.

2. Methodology

The bibliometric investigation was based on data retrieved from the Web of Science (WoS) database. It is a large collection of citation indexes that indicate the citation relationships between scholarly research articles published in the

world's most widely read journals, books, and proceedings in the sciences and humanities. On April 27, 2022, in the WoS database, a query was performed using the following search string: "Deep Learning" and "Agriculture". For further analysis, 3207 publications related to DLA were identified. Furthermore, previously selected records, including authors, publication year, title, abstract, subject categories, source journal, and references, were saved as BibTeX format files. As a result, the relevant data could be effectively used to perform bibliometric analyses using biblioshiny, the Bibliometrix software's shiny interface. Bibliometrix is an R-based tool that analyzes scientific literature for complete science mapping. It also makes it easier to integrate with other statistical and graphical packages [6].

3. Results and Discussion

Within the sections underneath, key discoveries from the bibliometric analysis are going to be exposed.

3.1. Main Documents on Deep Learning in WoS

Table 1 presents primary information about the dataset extricated from WoS containing papers related to DLA. The table gives an extended of curious data. For example, it take cognizance of the fact that the dataset is constituted mainly of articles (74.49% of all documents) published through 1051 sources (articles, book, letters, proceeding, editorial). The first publication dates from 2005.

3.2. Annual Scientific Production and Key Sources Annual Scientific Production

Figure 1 presents the yearly scientific production of documents on DLA. According to this figure, the number of papers published on DLA in the WoS database is steadily increasing over years and the annual growth rate cumulate about 95.28%. This displays that the adoption of more focused agriculture is in a growing dynamic. Also, by the 27th of April 2022, the WoS database had already recorded 413 documents published on DLA. This represents 36.10% of previous year. So, the scientific production dynamic related to this field will be surely maintained.

The distribution of top 20 most relevant sources on DLA is displayed in Figure 2. It is clearly showing up that this shortlist is dominated by specialized journals on application of Information and Communication Technology (ICT) in agriculture. COMPUTERS AND ELECTRONICS IN AGRICULTURE is topping the list with 363 documents published on DLA. Seconded by REMOTE SENSING, with 169 documents. Thirded by IEEE ACCESS with 134 documents. SENSORS in the fourth place with 116 papers, and followed by FRONTIERS IN PLANT SCIENCE which has 77 publications. The remaining have between 58 and 15 publications dealing with DLA.

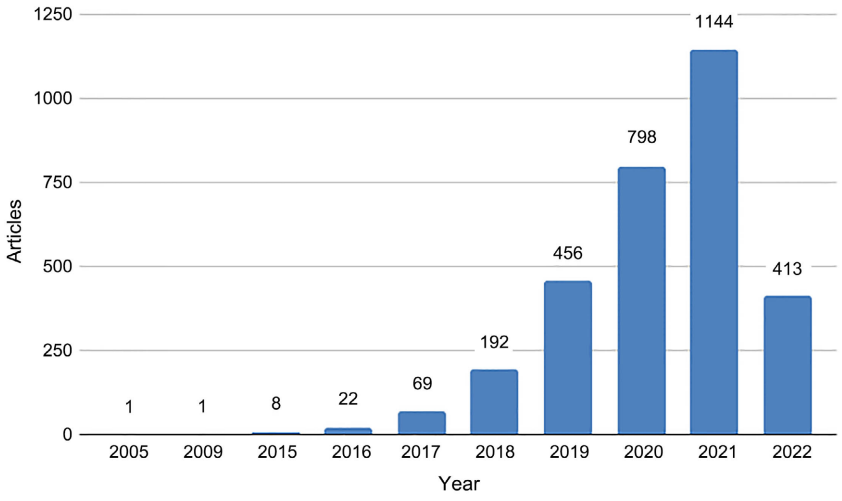

Figure 1. Annual scientific production.

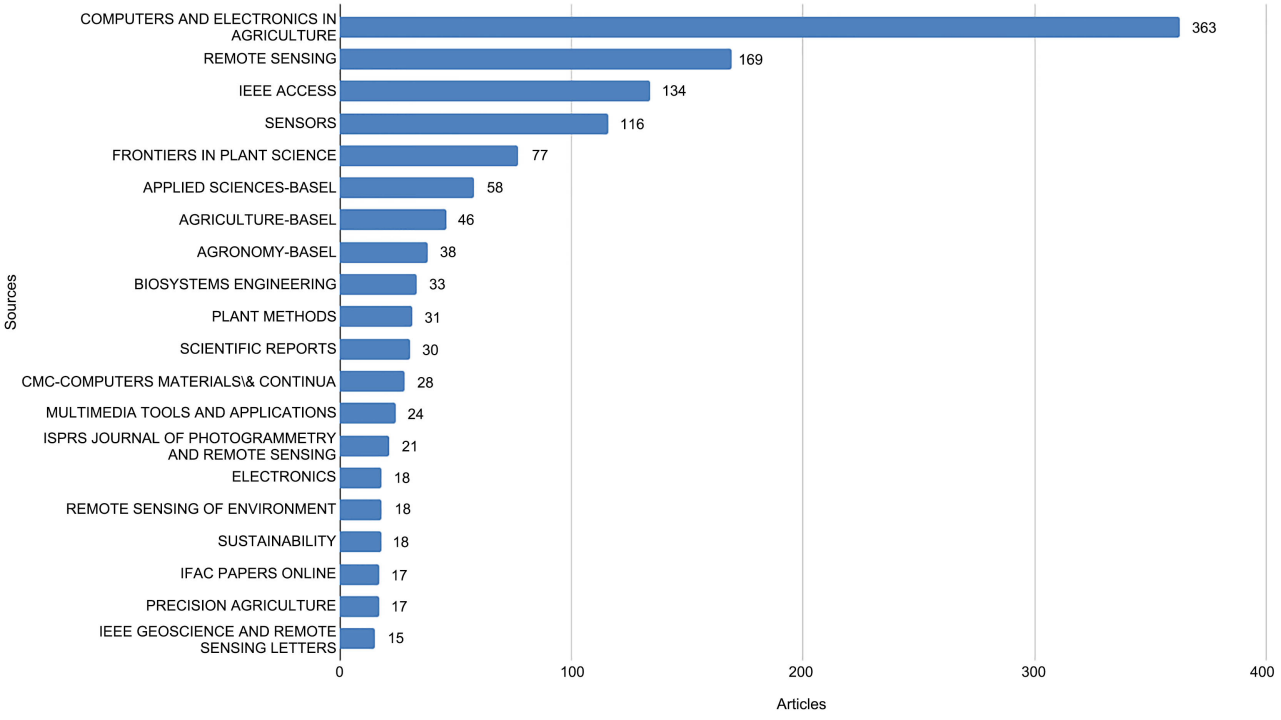

Figure 2. Top 20 most relevant sources.

3.3. Source Growth Dynamics

Figure 3 exposes the Source growth dynamics on DLA. Five journals are identified with the most relevant development based on the number of documents published, namely: COMPUTERS AND ELECTRONICS IN AGRICULTURE, REMOTE SENSING, IEEE ACCESS, SENSORS, FRONTIERS IN PLANT SCIENCE. Moreover, COMPUTERS AND ELECTRONICS IN AGRICULTURE experienced the most significant growth. All of these journals, except IEEE ACCESS, are related to application of ICT in Agriculture. This could explain why they are in these short lists.

Table 1. Main information about document published on DLA in the WoS database.

Description	Results
Documents	3207
Sources (Journals, Books, etc)	1051
Keywords Plus (ID)	3390
Author's Keywords (DE)	7820
Period	2005-2022
Average citations per documents	10.1
Authors	9495
Author Appearances	16,865
Authors of single-authored documents	55
Authors of multi-authored documents	9440
Single-authored documents	62
Documents per Author	0.338
Authors per Document	2.96
Co-Authors per Documents	5.26
Collaboration Index	3
Document types	
Article	2389
Article, early access	92
Article, proceedings paper	16
Article, data paper	7
Article, book chapter	5
Correction	2
Editorial material	4
Letter	1
Meeting abstract	4
Proceedings paper	523
Review	153
Review, early access	11

3.4. Top 20 Authors Based on the Number of Papers

In terms of the number of articles published, Table 2 displays the ranking of the 20 most productive authors on DLA as provided in the WoS database. It's worth noting that each of the top 5 authors produced more than 60 publications in the following order: LI Y. (74 papers) leads the race, followed by ZHANG Y. (71 articles). WANG Y. (69 papers) and ZHANG J. occupied respectively the 3rd and 4th places. At the 5th place there is LI J. (64 papers). The remaining authors in this shortlist published between 57 and 36 papers. Most of the authors in this list are mainly from Asia, which shows that scientists in this region are very interested by DLA.

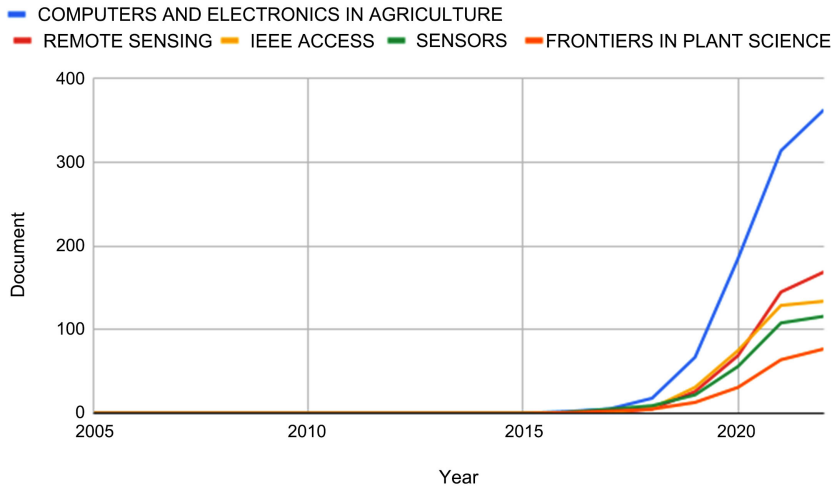

Figure 3. Sources growth dynamics.

Table 2. Most relevant authors.

Rank	Authors	# Articles
1	LI Y	74
2	ZHANG Y	71
3	WANG Y	69
4	ZHANG J	66
5	LI J	64
6	WANG X	57
7	LIU J	52
8	ZHANG Z	50
9	CHEN Y	49
10	ZHANG X	49
11	WANG H	47
12	WANG J	44
13	LIU Y	42
14	ZHANG C	42
15	LI H	41
16	LI X	41
17	WANG Z	40
18	LI Z	38
19	ZHANG L	37
20	HE Y	36

3.5. Top 20 Most Relevant Affiliations

Table 3 displays the 20 most important affiliations on DLA papers distributed within the WoS database. The biggest number of articles goes to the China Agricultural University (1st position) with 403 records, taken after by Zhejiang

University which has 191 reports (2nd position) and South China Agricultural University with 178 records (positioned 3rd). The fourth position is held by Nanjing Agricultural University with 135 papers, taken after by Northwest AANDF University with 135 reports. It can be notice that as for author's ranking 2 this list is also dominated by universities from Asia. This confirms that Asian scientists are very interested in DLA. 2. It also showed that few African institution appear in this list. This could be explained by the fact that, agriculture remains essentially traditional in this area.

3.6. Top 20 Most Cited Documents

Most globally cited documents are listed in **Figure 4**. It shows that the paper by Kamilaris A. (2018) has the most elevated add up to citations (929 citations) based on the WoS database. It's taken after by Mohanty SP. (2016) with 774 citations. The third position is occupied by Kussul N. (2017) with 615 add up to citations within the WoS database. The paper by Ferentinos KP. (2018) is at the fourth position (485 citations), whereas Fuentes A. (2017) is positioned at the fifth position with 316 citations.

Table 3. Most relevant affiliations.

Rank	Affiliations	Articles
1	CHINA AGR UNIV	403
2	ZHEJIANG UNIV	191
3	SOUTH CHINA AGR UNIV	178
4	NANJING AGR UNIV	135
5	NORTHWEST AANDF UNIV	135
6	HUAZHONG AGR UNIV	113
7	SICHUAN AGR UNIV	99
8	PURDUE UNIV	83
9	SEOUL NATL UNIV	79
10	UNIV FLORIDA	74
11	IOWA STATE UNIV	71
12	NORTHEAST AGR UNIV	71
13	UNIV CHINESE ACAD SCI	69
14	TOKYO UNIV AGR AND TECHNOL	66
15	FUJIAN AGR AND FORESTRY UNIV	63
16	WASHINGTON STATE UNIV	62
17	WUHAN UNIV	59
18	UNIV SYDNEY	56
19	WAGENINGEN UNIV AND RES	55
20	UNIV TOKYO	53

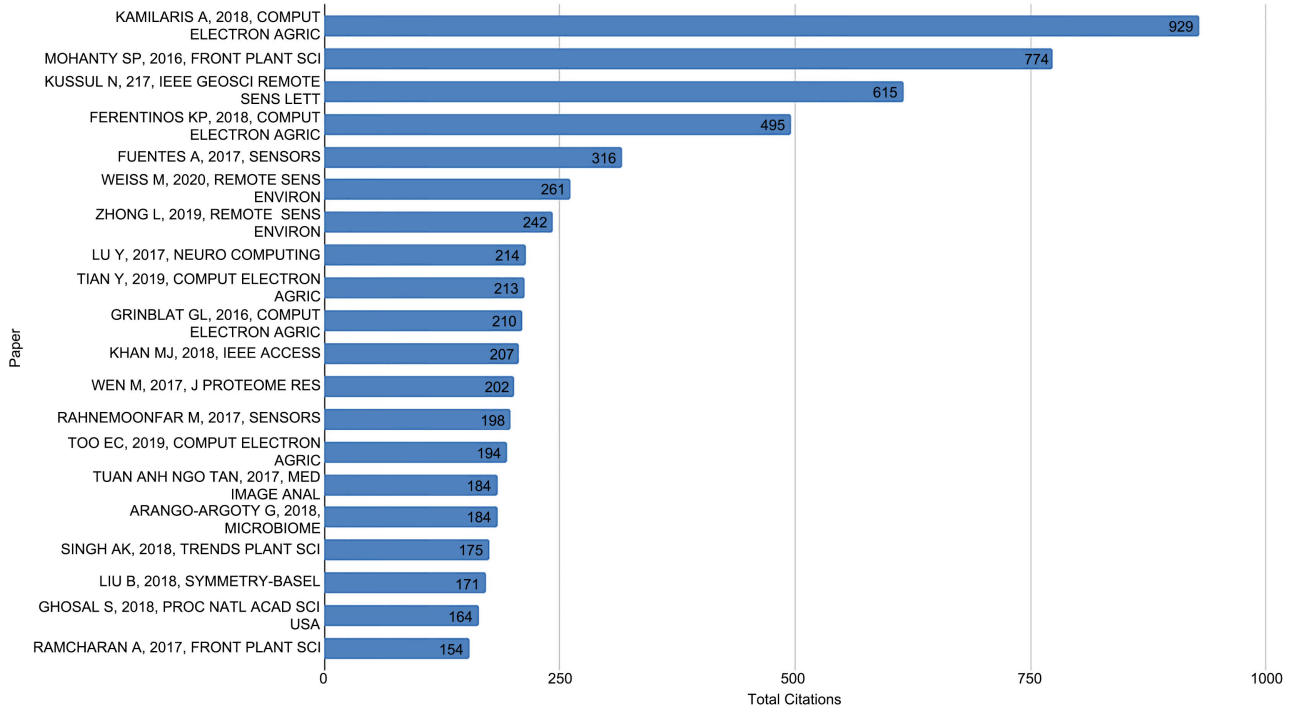

Figure 4. Top 20 most cited documents.

3.7. Top 20 Scientific Production and Most Cited Countries on Deep Learning in Agriculture

Table 4 displays the country's scientific production on DLA distributed within the WoS database. China is taking the pace with 5858 reports, taken after by USA and India with 1697 and 756 articles respectively. At that point, we have JAPAN which is positioned fourth with 572 records, whereas South Korea is fifth with 560 reports. The remaining five nations of this confined list have less than 500 papers: Australia (467), Brazil (332), Pakistan (301), UK (283), and Germany (248). Tunisia (104) occupied the 28th place and is the most productive Africa country in term of number of documents published on DLA. In this category it is followed by SOUTH AFRICA (27 papers) and occupied 43rd place globally. The top 3 Africa countries is closed by KENYA (21 documents) which features at the 48th place in the general ranking.

Concerning citations, Table 5 presents the most cited countries. It shows that China, as the most productive country 4 in terms of number of papers published, has also the most elevated add up to citations number (11,229). It is taken after by the USA with 4555 add up to citations. All the remaining nations of this list have an add up to quotation check less than 2000 (between 1818 and 703). The first African countries in this list is TUNISIA (104 citations) which occupied the 28th rank globally. It is followed by EGYPT (35 citations, 44th global rank) and NIGERIA (11 citations, 56 global rank).

3.8. Wordcloud Related to Deep Learning in Agriculture

Figure 5 and Figure 6 present the most frequent words related to DLA accord-

ing to the WoS database.

These figures reveal that the top 5 keywords used by authors in their articles are *classification* (27%), *convolutional neural network* (11%), *model* (7%), *system* (7%), *agriculture* (5%). This points out that research on Deep Learning in Agriculture turn around making a convolutional neural network model based system to accurately classify plant diseases. It could guide farmer to choose the most appropriate treatments in their crop management.

Other words in the list are *segmentation* with 140 occurrences, *neural network* with 139 occurrences. Finally, *model*, *prediction* and *images* with respectively 133, 128, 95 occurrences. These words are related to tools that scientists deal with in machine learning in general and particularly in deep learning.

3.9. Country Collaboration

Figure 7 presents some key collaborations between nations. The most substantial partnerships are initiated by China scholars, who establish links with their peers in different countries worldwide. On the other hand, African countries scarcely collaborate between them and on an international scale.

Figure 5. Words cloud related to deep learning in agriculture.

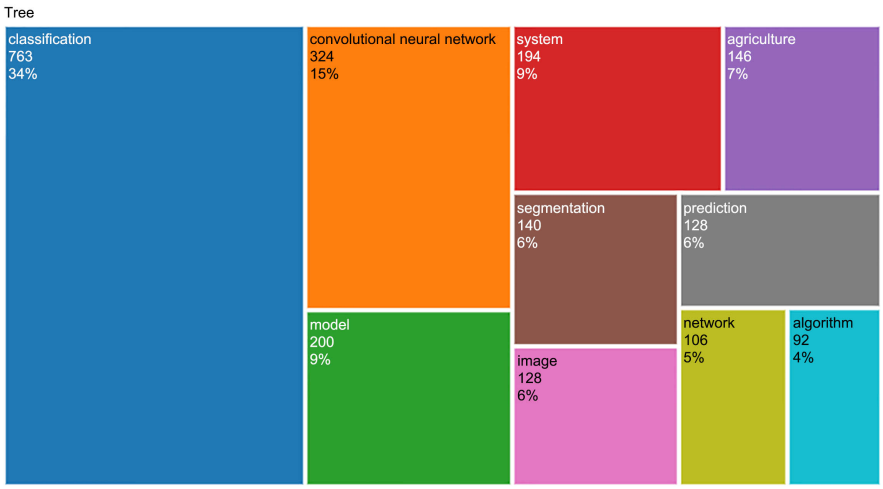

Figure 6. Words frequencies.

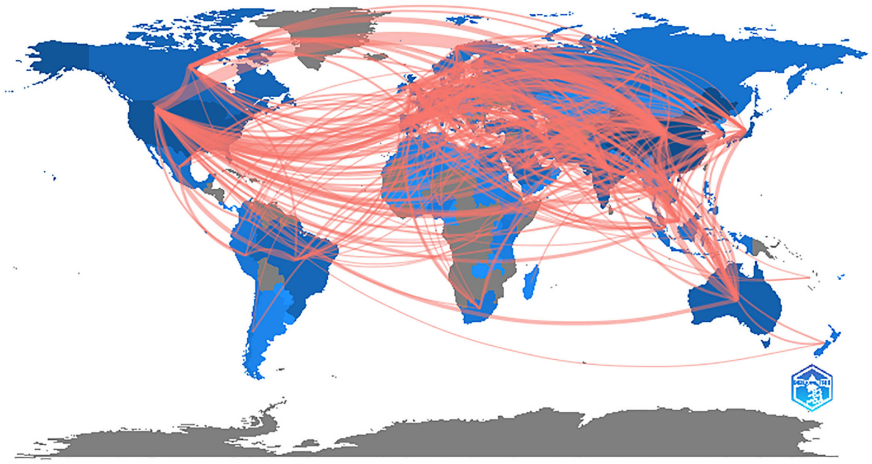

Figure 7. Collaboration worldmap.

Table 4. Country scientific production.

Rank	region	Frequency
1	CHINA	5858
2	USA	1697
3	INDIA	756
4	JAPAN	572
5	SOUTH KOREA	560
6	AUSTRALIA	467
7	BRAZIL	332
8	PAKISTAN	301
9	UK	283
10	GERMANY	248
11	IRAN	223
12	FRANCE	217
13	CANADA	211
14	ITALY	209
15	SPAIN	207
16	VIETNAM	160
17	MALAYSIA	148
18	SAUDI ARABIA	134
19	TURKEY	131
20	NETHERLANDS	121
…	…	…
24	EGYPT	79
…	…	…
43	SOUTH AFRICA	27
…	…	…
48	KENYA	21

Table 5. Most cited countries.

Rank	Country	Total Citations
1	CHINA	11,229
2	USA	4555
3	AUSTRALIA	1818
4	SPAIN	1346
5	KOREA	1266
6	FRANCE	1181
7	BRAZIL	1121
8	INDIA	875
9	SWITZERLAND	823
10	PAKISTAN	703
11	GERMANY	674
12	GREECE	644
13	UKRAINE	635
14	JAPAN	622
15	UNITED KINGDOM	485
16	CANADA	399
17	TURKEY	364
18	IRAN	336
19	ITALY	327
20	VIETNAM	324
…	…	…
28	TUNISIA	104
…	…	…
44	EGYPT	35
…	…	…
56	NIGERIA	11

4. Conclusion and Future Research Avenues

This report gave a global assessment of research trends in DLA articles from 2005 to 2022. Bibliometric data from the Web of Science (WoS) database on a worldwide scale was analyzed. The most prolific institutions, countries, and writers on DLA, as well as the most referenced journals, authors, and countries on the same issue, were acquired as important insights. The majority of the publications retrieved from WoS were article, according to the findings. Through this paper, it appears that African institutional contribution in the field of deep learning in agriculture (DLA) is very poor. It implies that considerable challenges (e.g., insufficient connectivity, analphabetism among others) remain. As a result, investigating the possibilities and needs for deploying precision agricul-

ture in Africa would be worthwhile. To achieve this, it will be required to take into account the unique characteristics of each country, such as the economic, social, and human elements that can be considered while adopting more focused precision agriculture. As this study is constrained by the utilized watchwords for the outlook, it cannot guarantee that it covers all distributed papers. Within the same thought, the choice for a database, in this case, WoS, might further limit its reach. Also, we utilized a conventional bibliometric approach. A combination of diverse sorts of writing surveys with bibliometric analysis can be used for deeper investigation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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