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Bibliometric Computation Mapping Analysis of Publication Machine and Deep Learning for Food Crops Mapping using VOSviewer

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ABSTRACT

Machine learning and deep learning are currently widely used in various fields, including remote sensing for food security. However, there is no research that specifically examines the interests, developments, and trends of this research in the future. This study aims to examine the development of machine and deep learning research for mapping food crops through a bibliometric approach with computational mapping analysis using VOSviewer. Article data was obtained from the Google Scholar database using the publish or perish reference manager application. The title and abstract of the article were used to guide the search process by referring to the keyword “Machine and Deep Learning Mapping Food Crops”. 114 relevant articles were discovered. Google Scholar-indexed articles over the last ten years, from 2014 to 2023, were used as study material. The results show that machine research and deep learning for mapping food crops can be separated into three terms: machine learning, deep learning, and plant mapping. The term “Crop Mapping” has 57 links for a total of 199 links. The term "machine learning" has 41 links for a total of 79 links, and the term "deep learning" has 26 links for a total of 41 links. The results of the analysis of machine development and deep learning publications for mapping food crops in the last 10 years show a constant increase. The peak of the increase occurred in 2021 and 2022, namely 25 articles published per year, respectively. This means that this research topic is still relatively new in terms of interest and exploration, therefore there is still room further research. We examine numerous articles that have been published on machine and deep learning for crop mapping and their relation to the field studied with VOSviewer. This review can serve as a starting point for further research in different domains.

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1. Introduction

Food insecurity is a major problem for the world's population, which continues to increase [1-3]. That is why much research on food, including for educational purposes, has been well-documented [4-13].

While agricultural production has increased substantially over the last few decades, the demand for food to sustain the population has continued to grow higher [4,5]. On the other hand, the availability of fertile land and water resources, the impact of climate change, and agricultural management that is not environmentally friendly lead to pressure on the food production system [14 -20].

Sustainable agricultural management has become a strategic issue to address this challenge [21, 22]. Reliable and up-to-date information is needed on the types of food crops and their spatial distribution in sustainable agricultural resource management [23, 24]. Accurate mapping of diverse agricultural landscapes is an inseparable part of agricultural management [25, 26]. Food crop maps are useful for precision agriculture, monitoring agricultural activities, compiling plant databases, and studying environmental impacts on food crops [27]. The regional scale yield prediction model also uses crop maps as its basic data, the accuracy of food crop production depends on the accuracy of the crop map [28]. Early warning can be carried out when there is information on harvest predictions for food security and to support decision-making regarding the export and import of food crops [29], [30]. A map of food crops can be identified for areas with low productivity as a basis for site-specific fertilization interventions, insecticides, and increasing land productivity [31]. This information also provides benefits to the agricultural industry in determining crop prices, stock planning, and so on [32]. Food crop mapping provides a comprehensive picture of food crop production and its spatial distribution. Therefore, the mapping of food crops is very important to maintain the stability of food security.

Remote sensing is the science, technique, and art of obtaining information without direct contact with the object under study [33-36]. Remote sensing, with its machine learning and deep learning methods, has proven its benefits in mapping food crops with reliable accuracy [37-43]. Currently, the interest in optimizing machine and deep learning for mapping food crops is expanding [44-46]. Therefore, it is necessary to have an initial study that reports further research trends. One approach that can be used to analyze trends in a research area is through bibliometric analysis [47-48]. Bibliometric analysis is a statistical analysis tool used in understanding global research trends and provides interesting quantitative information in the academic literature [1, 49-51]. This type of approach distinguishes how a bibliometric analysis differs from a review article, which primarily wants to focus on recent advances, challenges, and future directions of the topics covered [52, 53]. Detailed information regarding previous studies on bibliometric analysis is in Table 1.

Table 1
Previous studies on bibliometric

No	Title	Ref.
1	Involving Particle Technology in Computational Fluid Dynamics Research: A Bibliometric Analysis	[54]
2	Bibliometric Computational Mapping Analysis of Trend Metaverse in Education using VOSviewer	[55]
3	The Use of Information Technology and Lifestyle: An Evaluation of Digital Technology Intervention for Improving Physical Activity and Eating Behavior	[56]
4	Strategies in language education to improve science student understanding during practicum in laboratory: Review and computational bibliometric analysis	[57]
5	How language and technology can improve student learning quality in engineering? definition, factors for enhancing students' comprehension, and computational bibliometric analysis	[58]
6	Mapping of nanotechnology research in animal science: Scientometric analysis	[59]

Table 1 (continue)
Previous studies on bibliometric

No	Title	Ref.
7	Scientific research trends of flooding stress in plant science and agriculture subject areas (1962-2021)	[60]
8	Introducing ASEAN Journal of Science and Engineering: A bibliometric analysis study	[61]
9	A bibliometric analysis of chemical engineering research using VOSviewer and its correlation with Covid-19 pandemic condition	[62]
10	A bibliometric analysis of materials research in Indonesian journal using VOSviewer	[63]
11	Bibliometric analysis of engineering research using Vosviewer indexed by google scholar	[64]
12	Bibliometric computational mapping analysis of publications on mechanical engineering education using VOSviewer	[65]
13	Research trend on the use of mercury in gold mining: Literature review and bibliometric analysis	[66]
14	Domestic waste (eggshells and banana peels particles) as sustainable and renewable resources for improving resin-based brakepad performance: Bibliometric literature review, techno-economic analysis, dual-sized reinforcing experiments, to comparison with commercial product	[67]
15	Bibliometric analysis of educational research in 2017 to 2021 using VOSviewer: Google scholar indexed research	[68]
16	Corncob-derived sulfonated magnetic solid catalyst synthesis as heterogeneous catalyst in the esterification of waste cooking oil and bibliometric analysis	[69]
17	The compleat lextutor application tool for academic and technological lexical learning: Review and bibliometric approach	[70]
18	Use of blockchain technology for the exchange and secure transmission of medical images in the cloud: Systematic review with bibliometric analysis.	[71]
19	Computational bibliometric analysis of research on science and Islam with VOSviewer: Scopus database in 2012 to 2022.	[72]
20	Digital transformation in special needs education: Computational bibliometrics.	[73]
21	Antiangiogenesis activity of Indonesian local black garlic (Allium Sativum 'Solo): Experiments and bibliometric analysis.	[74]
22	Characteristics of tamarind seed biochar at different pyrolysis temperatures as waste management strategy: experiments and bibliometric analysis.	[75]
23	The compleat lextutor application tool for academic and technological lexical learning: Review and bibliometric approach.	[76]
24	Corncob-derived sulfonated magnetic solid catalyst synthesis as heterogeneous catalyst in the esterification of waste cooking oil and bibliometric analysis.	[77]

Until now, computational mapping research on bibliometric analysis of published data in the field of machine and deep learning for food crops has not been carried out specifically to find out research developments and trends; not much has been done. Specifically, the bibliometric analysis for the last 10 years of research in the period 2014–2023 through the VOSviewer application. Therefore, this research was conducted to conduct computational research on the bibliometric analysis mapping of articles indexed by Google Scholar using VOSviewer software. This research was conducted with the hope that it could become a reference for researchers to conduct and determine research themes to be taken, especially those related to the field of machine and deep learning for mapping food crops.

2. Methodology

A bibliometric analytic strategy was applied in this study. This method incorporated statistical methods for handling scientific data that disclose research topics and scientific breakthroughs, as well as determining research impacts [50, 78-79]. Besides that, bibliometric analysis could parse and present more detailed, easily accessible, and comprehensive data [1]. Through the bibliometric method, the contribution of academic results to the progress of science could be analyzed objectively and quantitatively [50, 80]. Another advantage of bibliometric analysis was that it predicted the pattern and direction of development in a particular field of knowledge [49, 52].

The article data used in this study was based on research published in Google Scholar-indexed journals. The basis for choosing Google Scholar in this study was because the Google Scholar database was open source. Publish or Perish software was used to conduct a literature review on our selected topics. Detailed information for deploying and installing the software and a step-by-step process for obtaining data was described in the publication by Al Husein *et al*., [65]. Likewise, detailed information about library searches in searching for data on Google Scholar was explained in previous research conducted by Azizah *et al.,* [81].

This research was conducted through several stages:

i. Publication data collection using publish or perish,
ii. Bibliometric data processing for articles that had been obtained using the Microsoft Excel application,
iii. Computational mapping analysis of bibliometric publication data using the VOSviewer application, and
iv. Interpretation of computational mapping analysis results.

The search for Publish or Perish article data was used to filter publications using the keywords “Machine Learning and Deep Learning for Food Crop Modeling” based on the need for the title of the publication. The articles used were published between 2014 and 2023. All data was obtained in June 2023. The articles that had been collected and matched the criteria for this research analysis were then exported into two types of files: research information system (.ris) and comma-separated value formats (*.csv). VOSviewer was also used to visualize and evaluate trends using bibliometric maps. The article data from the source database was then mapped. VOSviewer was used to create three variations of mapping publications, namely network visualization, density visualization, and overlay visualization based on the network (co-citation) between existing items. When creating a bibliometric map, the frequency of keywords was set to be found at least 3 times. As a result, 59 terms and keywords that were less relevant were deleted.

3. Results

3.1 Published Data Search Result

Based on data tracking through published or perish reference management application from the Google Scholar database, 114 data articles that met the research criteria were obtained. The data obtained is in the form of article metadata consisting of the author's name, title, year, journal name, publisher, number of citations, article link, and related URLs. Figure 1 shows the spatial distribution of the number of studies in various countries around the world, related to the topic of machine and deep learning for mapping food crops. The geographic spread of this topic spans 37 countries. Most of the research was conducted in China with 28 publications, while in Indonesia it is still rare with only 3 publications.

Table 2 shows some examples of published data used in the VOSviewer analysis from this study. The sample data taken are the 30 best articles with the most citations. The number of citations of all articles used in this study are 1354, the number of citations per year is 150.44, the number of citations per article is 11.67, the average author citation in the articles used is 3.60, and all articles have the average h-index 20 with g-index 33.

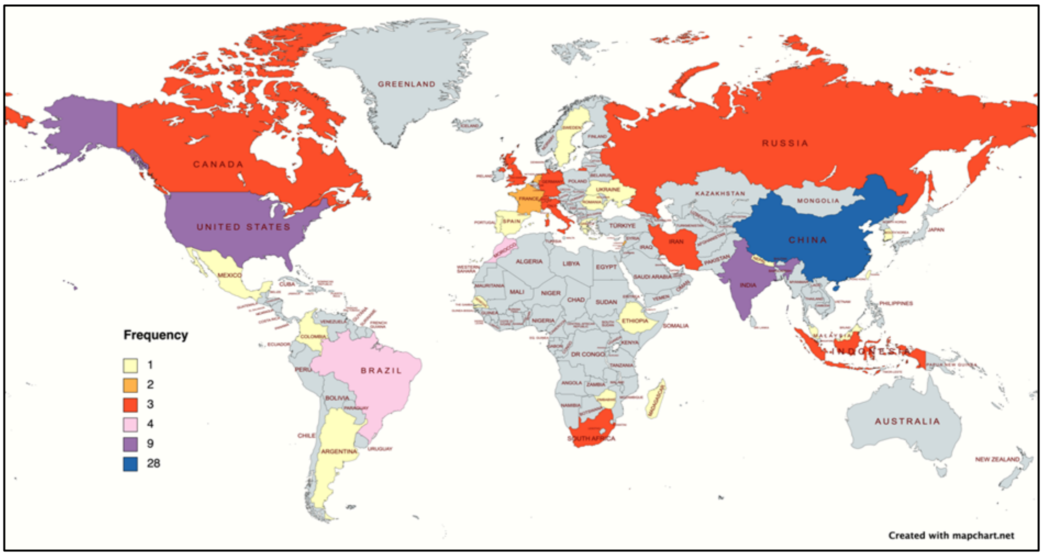

Fig. 1. Spatial distribution and frequency of machine & deep learning for crops mapping

Table 2
Machine and deep learning published data for mapping food crops

No	Author	Title	Year	Cites	Ref.
1	You and Dong	Examining the earliest identifiable timing of crops using all available Sentinel 1/2 imagery and Google Earth Engine	2020	118	[82]
2	Nguyen *et al.,*	Characterizing land cover/land use from multiple years of Landsat and MODIS time series: A novel approach using land surface phenology modeling and random forest classifier	2020	106	[83]
3	Tian *et al.,*	Mapping winter crops in China with multi-source satellite imagery and phenology-based algorithm	2019	89	[84]
4	Kolecka *et al.,*	Regional scale mapping of grassland mowing frequency with sentinel-2 time series	2018	79	[85]
5	Csillik *et al.,*	Object-based time-constrained dynamic time-warping classification of crops using Sentinel-2	2019	73	[86]
6	Heupel *et al.,*	A progressive crop-type classification using multitemporal remote sensing data and phenological information	2018	60	[87]
7	Song *et al.,*	An evaluation of landsat, sentinel-2, sentinel-1, and MODIS data for crop type mapping	2021	47	[88]
8	Gella *et al.,*	Mapping crop types in complex farming areas using SAR imagery with the dynamic time warping	2021	43	[89]
9	Tian *et al.,*	Garlic and winter wheat identification based on active and passive satellite imagery and the google earth engine in northern China	2020	40	[90]
10	Csillik *et al.,*	Cropland mapping from Sentinel-2 time series data using object-based image analysis	2017	32	[91]
11	Nemmaoui *et al.,*	Greenhouse crop identification from multi-temporal multi-sensor satellite imagery using the object-based approach: A case study from Almería (Spain)	2018	30	[92]
12	Zhang *et al.,*	Compact polarimetric response of rape (Brassica napus L.) at C-band: analysis and growth parameters inversion	2017	30	[93]
13	Belgiu *et al.,*	Phenology-based sample generation for supervised crop type classification	2021	28	[94]
14	Hao *et al.,*	Early-season crop mapping using improved artificial immune network (IAIN) and Sentinel data	2018	26	[95]
15	Useya and Chen	Comparative performance evaluation of pixel-level and decision-level data fusion of Landsat 8 OLI, Landsat 7 ETM+, and Sentinel-2 MSI for crop ensemble classification	2018	25	[96]

Table 2 (continue)
Machine and deep learning published data for mapping food crops

No	Author	Title	Year	Cites	Ref.
16	Ghani *et al.,*	Sustainable bioeconomy that delivers the environment–food–energy–water nexus objectives: The status in Malaysia	2019	24	[97]
17	Qian *et al.,*	Mapping regional cropping patterns by using GF-1 WFV sensor data	2017	22	[98]
18	Farhadi *et al.,*	Flood monitoring by integration of remote sensing technique and multi-criteria decision-making method	2022	22	[99]
19	Lou *et al.,*	Comparison of machine learning algorithms for mapping mango plantations based on Gaofen-1 imagery	2020	21	[100]
20	Pascucci *et al.,*	Special issue "hyperspectral remote sensing of agriculture and vegetation"	2020	21	[101]
21	Seydi *et al.,*	A dual attention convolutional neural network for crop classification using time-series Sentinel-2 imagery	2022	19	[102]
22	Plotnikov *et al.,*	Accuracy assessment for winter crops mapping in the spring-summer growing season with MODIS data	2017	18	[103]
23	Wu *et al.,*	Benchmarking variant identification tools for plant diversity discovery	2019	18	[104]
24	Prasai *et al.,*	Application of Google Earth engine python API and NAIP imagery for land use and land cover classification: A case study in Florida, USA	2021	18	[105]
25	Estévez *et al.,*	Gaussian processes retrieval of crop traits in Google Earth Engine based on Sentinel-2 top-of-atmosphere data	2022	18	[106]
26	Плотников *et al.,*	Product Description	2017	17	[107]
27	Chaves *et al.,*	Time-weighted dynamic time warping analysis for mapping interannual cropping practices changes in large-scale agro-industrial farms in Brazilian Cerrado	2021	16	[108]
28	Delafield *et al.,*	Conceptual Framework for balancing society and Nature in net-zero energy Transitions	2021	13	[109]
29	Rawat *et al.,*	Deep learning-based models for temporal satellite data processing: Classification of paddy transplanted fields	2021	13	[110]

3.2. Research Developments in the Field of Machine and Deep Learning for Mapping Food Crops

Research developments in the field of machine and deep learning for crop mapping published in Google Scholar-indexed journals can be seen in Table 3. Based on the data shown in Table 3, there have been 114 articles published in the field of machine and deep learning for crop mapping between 2014 and 2023. In 2014 there were 2 articles, in 2015 there were 2 articles, in 2016 there were 2 articles, in 2017 there were 7 articles, in 2018 there were 8 articles, in 2019 there were 12 articles, in 2020 there were 21 articles, in 2021 it continued to increase to 25 articles, in 2022 there were as many as 25 articles, and as of mid-2023 there are as many as 10 articles, with the number likely to increase.

Based on these findings, research into machine and deep learning for mapping food crops has increased dramatically since 2020. Figure 2 clearly shows the developments that have continued to rise.

Figure 2 shows the development of machine and deep learning research for mapping food crops over the last 10 years, from 2014 to mid-2023. Based on Figure 1, research developments related to this topic have continued to increase from year to year, with the peak being in 2021 and 2022, and there are already 10 publications in mid-2023, indicating that it will likely continue to grow in the future.

Table 3
Research development machine & deep learning for crops mapping

Year of Publications	Number of Publications
2014	2
2015	2
2016	2
2017	7
2018	8
2019	12
2020	21
2021	25
2022	25
2023	10
Total	114
Average	11,4

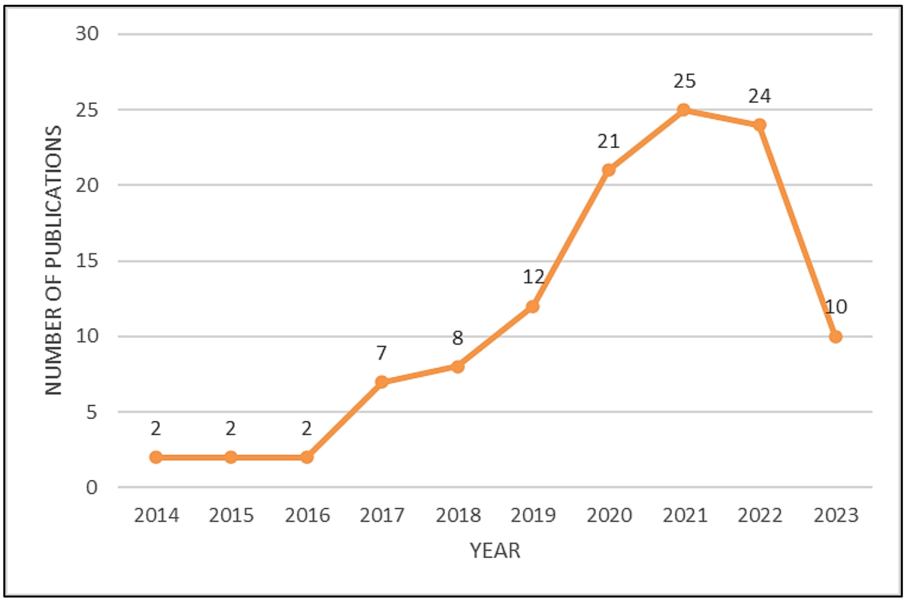

Fig. 2. Level of development in machine & deep learning for crops mapping

3.3 Visualization of the Machine and Deep Learning Topic Areas for Crop Mapping using VOSviewer

The article data is subjected to computational mapping. In the computational mapping, VOSviewer is employed. The results of the computational mapping revealed 59 items. Each item discovered in the VOSviewer mapping data connected to machine and deep learning for mapping food crops is grouped into six clusters, as shown in Table 4.

The linkage between one term and another term is shown in each existing cluster. Labels are given for each term with colored circles. The size of the circle for each tribe varies depending on the frequency of occurrence of that tribe. The circle size of the label shows a positive correlation with the appearance of the term in the title and abstract. The more frequently the term is found, the larger the label size is. The mapping visualization analyzed in this study consists of 3 parts: network visualization (see Figure 3), density visualization (see Figure 4), and overlay visualization (see Figure 5).

Figure 3 shows the relationship between terms. The relationships between terms are described in an interconnected network. Figure 3 shows a cluster of each term that is frequently researched and associated with machine and deep-learning research topics for crop mapping. From the clusters contained in the network visualization, research on the machine and deep learning for mapping food crops can be separated into 3 areas, namely the term crops mapping which is included in cluster 1 with a total link of 57, a total link strength of 199, and 38 events (see Figure 6). The second term is machine learning which belongs to cluster 1 with a total of 41 links, a total link strength of 79, and occurrences of 20 (see Figure 7), and the term deep learning which belongs to cluster 1 with a total of 26 links.

Table 4
Bibliometric map based on cluster color

Clusters	Number of Items	Items
1 – Red	20	Agriculture, algorithm, application, classification, cloud, crops mapping, deep learning, machine learning algorithm, model, monitoring, performance, potential, random forest, remote sensing, research, review, SVM, technique.
2 – Greens	11	China, crop type mapping, deep learning method, google earth engine, image, imagery, mapping, satellite image, sentinel, time series data, time series sentinel
3 – Blue	10	Agricultural application, analysis, development, object, paper, soybean, study, system, use, vegetation index
4 – Yellow	7	Assessment, automatic winter crops mapping, case study, remote sensing data, time series, winter crop, year
5 – Purple	7	Accuracy, addition, crop type, data, DTW, dynamic time, dynamic time warping
6 – Cyan	4	Approach, classifier, crop, Landsat

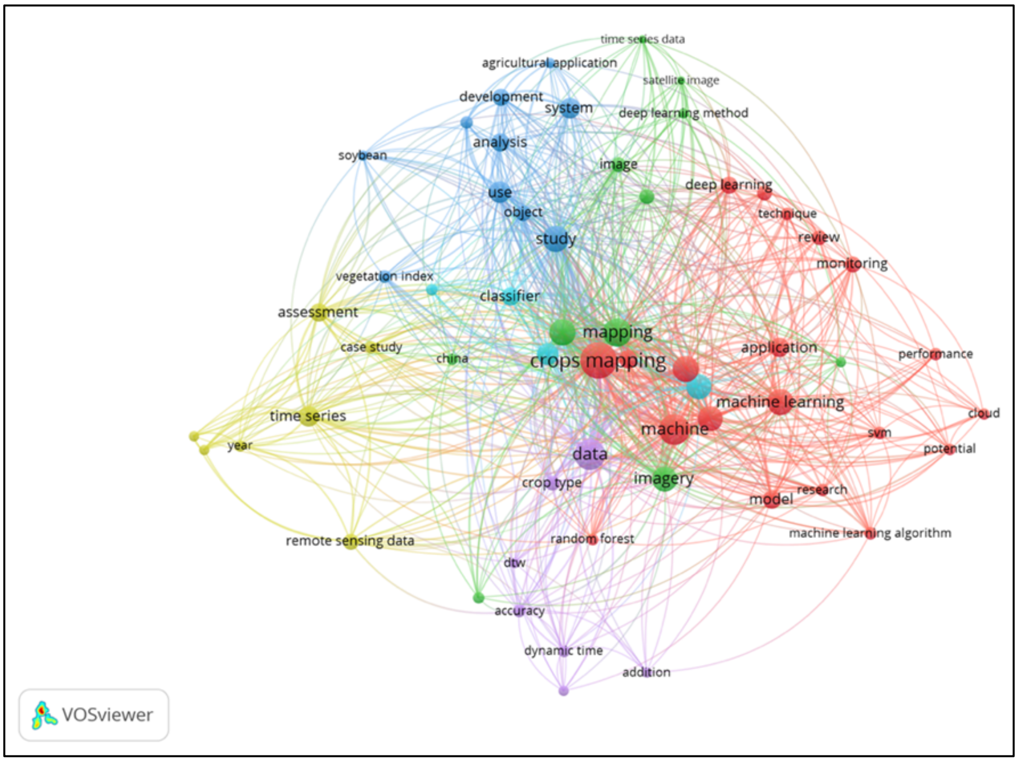

Fig. 3. Network visualization keyword machine and deep learning for crops mapping

Figure 4 shows the density visualization. Density visualization means that the brighter the yellow color and the larger the diameter of the term label circle, the more frequently the term appears. This means that a lot of research on related terms has been done. And vice versa, if the color of the term fades closer to the background color, then the amount of research on the term is small. Based on

Figure 4, it can be seen that research related to the term's crops mapping, mapping, machine, data, and machine learning has a fairly high number of studies and others that are relatively low.

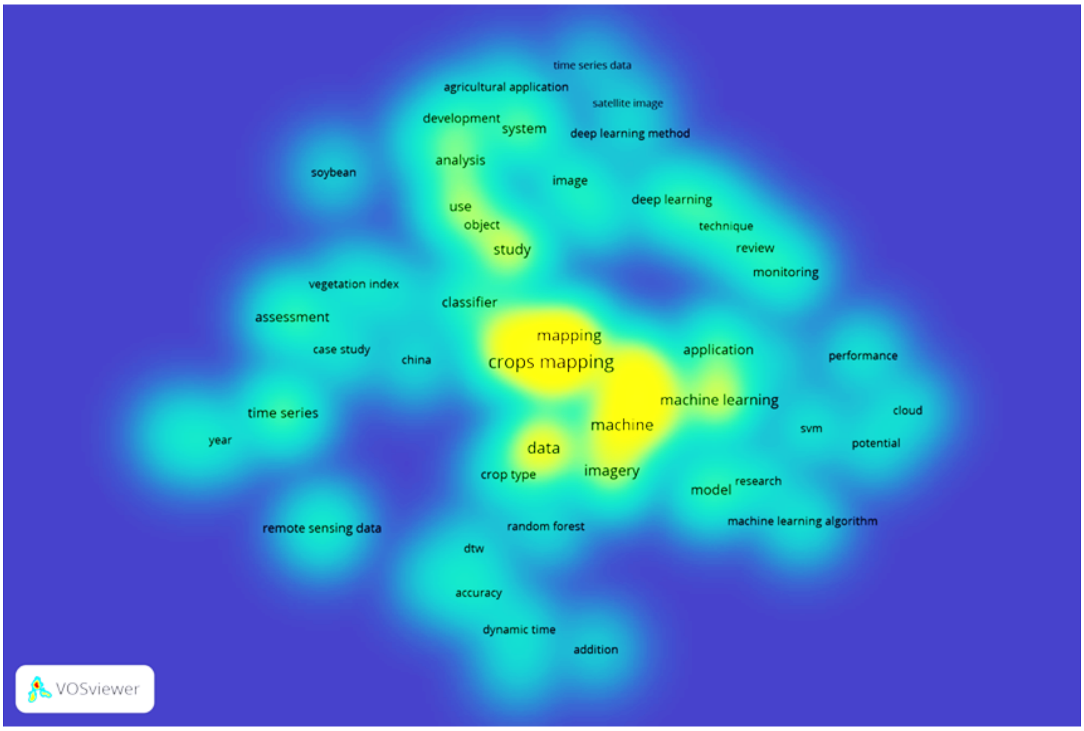

Fig. 4. Visualization of the machine and deep learning keyword density for mapping food crops

Figure 5 shows an overlay visualization of machine research and deep learning for mapping food crops. This visualization overlay shows the novelty of research on related terms. Figure 5 which is clarified in Figure 9 shows that most research on machine and deep learning for mapping food crops was carried out from 2019 to 2020. The popularity of the terms machine and deep learning for mapping food crops in research is still relatively new and rarely carried out. Thus, we still have opportunities to conduct new research on the machine and deep learning for mapping food crops.

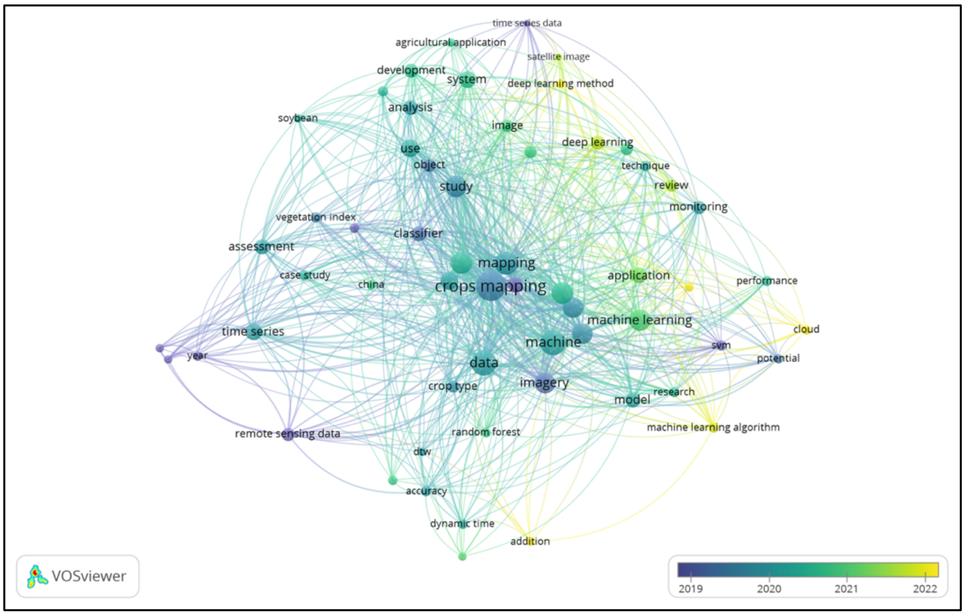

Fig. 5. Overlay visualization keyword machine & deep learning for crops mapping

Figure 6 shows the relationship network of crop mapping with other terms, namely mapping, machine, machine learning, data, crop type, imagery, system, analysis, remote sensing data, time series, assessment, cloud, machine learning algorithm, random forest, accuracy, remote sensing data, vegetation index, agriculture application, satellite image, deep learning method, deep learning, classifier, monitoring, review, technique, case study, dynamic time, addition, potential, SVM.

Figure 7 shows the network of relationships between the term machine learning and existing terms, including crops mapping, machine, application, imagery, mapping, study, research, model, SVM, performance, potential, cloud, machine learning algorithm, deep learning, technique, review, monitoring, time series, remote sensing data, accuracy, dynamic time, addition, random forest, object, analysis, development, agriculture application, image, and vegetation index.

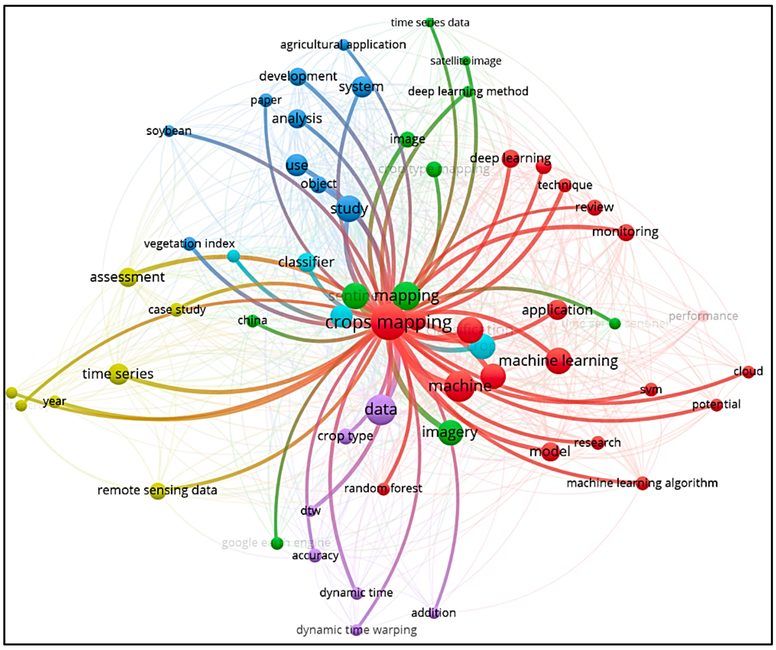

Fig. 6. Network visualization of crops mapping terms

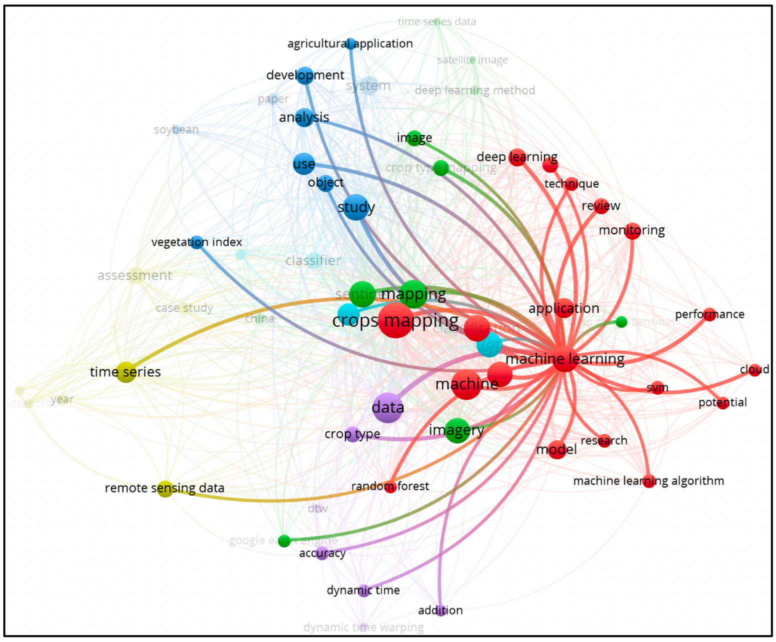

Fig. 7. Network visualization of machine learning terms

Further, Figure 8 shows a network of deep learning terms, which are associated with the term's crops mapping, mapping, machine, machine learning, research, model, review, potential, study, object, analysis, development, classifier, deep learning method, satellite image, time series data, remote sensing data, data.

These findings show that machine learning and deep learning for mapping food crops are still poorly associated with other terms. According to the mapping results, machine learning and deep learning only contain 41 and 26 linkages, respectively. It is possible to conclude that the domains of machine learning and deep learning for mapping food crops will continue to be investigated and related with other terms, which will have a greater impact on research novelty.

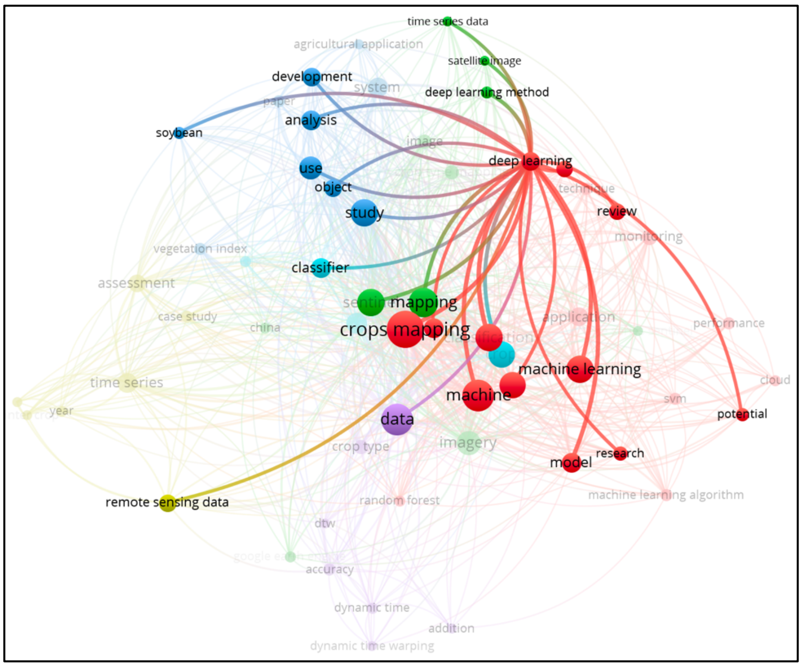

Fig. 8. Network visualization of deep learning terms

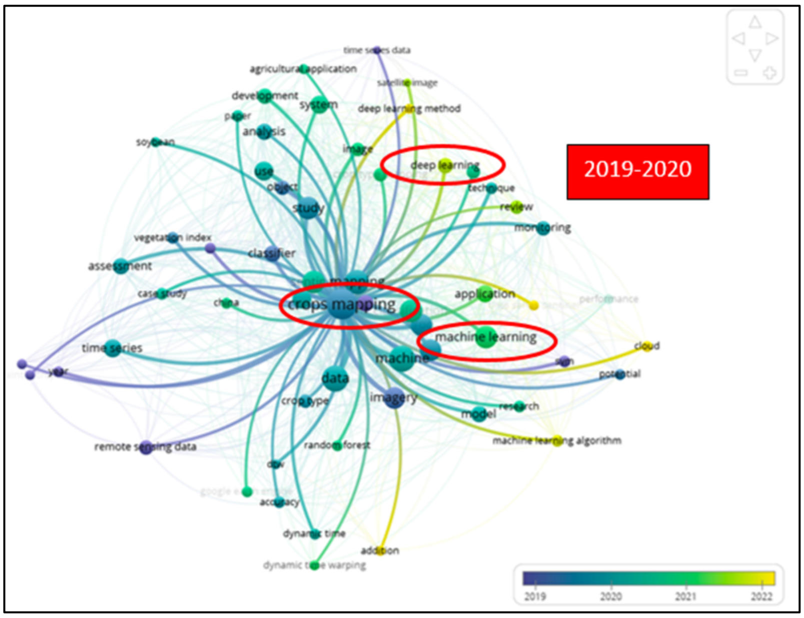

Fig. 9. Overlay visualization with keyword machine & deep learning for crops mapping

According to the findings of mapping the collected article data, machine and deep learning keywords for mapping food crops are still infrequently used in study. Most of the research exclusively employ crop mapping-related terminology or fields. According to the findings of this study, there is still need for further research into food crop mapping utilizing machine and deep learning methods, as illustrated in Figure 9, where the position of the keywords has a relatively long distance with relatively small circles.

4. Conclusions

This study aims to conduct a capture analysis of the bibliometric data of research articles. The topic of publication in this study is "Machines and deep learning about crop capture". Articles are taken from the Google Scholar database via Publish or Perish. The library data used in this study includes titles and abstracts. From the search results, 114 relevant articles were published between 2014 and 2023. The results show that machine and deep learning research on food crops is still relatively rare and relatively new, although it continues to increase from year to year. The peak of the increase in publications occurred in 2021-2022. These findings are evident from the results of the analysis using the VOSviewer application. The implications of this research for the future provide opportunities to conduct empirical research related to machine learning and deep learning using remote sensing data for food crop mapping.

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