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Machine Learning Application of Oil Palm: A Bibliometric Analysis

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Abstract

The advancement of machine learning-based technology spread widely, especially in oil palm. Oil palm has become a main source of domestic products because of its high production and a leading commodity where it cannot be separated from the use of machine learning. However, the potential of machine learning has not yet been identified specifically through bibliography aspects where those aspects are needed for future research. The main objective of this research is to analyze trends of machine learning utilization and potential topics in oil palm by using bibliometric analysis to obtain year distribution, author productivity, citation, and keyword co-occurrence. As a result, the highest peak number of publications is 2023 where the most cited authors are Haohuan Fu and Weijia Li. Then, the most used algorithms are deep learning, ANN, SVM, RF and CNN based on the occurrences while the tree detection and counting topic has the highest citation articles. The result indicates that scientific interest in the study of this research benefits as a starting point for future works.

A. Introduction

Machine learning plays a significant role in the advancement of Artificial Intelligence (AI) based technology that is used to optimize the performance of data based on learning model parameters (predictive and descriptive) through computer programs. This learning model makes machine learning capable of conducting its learning using certain algorithms without being specifically programmed by humans [1]. The advancement is marked by the development of medical equipment in the health sector to the use of technology in the agricultural sector [2].

Agriculture is a sector that practically processes food, foodstuffs, and food fiber originating from plants and animals with the help of humans until it becomes a product that is necessary for life. The agricultural sub-sectors are food crops, horticulture, fisheries, animal husbandry, forestry, and plantation. The plantation sub-sector consists of a few commodities, one is oil palm. This commodity is used as a superior commodity in several Southeast Asian countries such as Indonesia, Malaysia, Thailand, Colombia as well as countries in West Africa and South America [3]. The development of production and significant import-export activities for oil palm means that this commodity has greater opportunities than other plantation commodities as the main source of producing domestic products for a country [4]. Based on Indonesian Plantation Statistics for 2021-2023 [5], oil palm plays a significant role in economic growth as the largest contributor of Gross Domestic Product (GDP) especially in Indonesia. This is characterized by the area of land distribution, production volume, productivity, and import-export activity which have increased significantly from year to year. The land distribution area is divided into 3 (three) types of plantations, namely People's Plantations (PR), Large Private Plantations (PBS), and Large State Plantations (PBN). Of the three, the third-large private plantation is ranked first as a plantation with the largest land area, followed by the community plantation and large state plantation which are in third place [6]. In other countries, even though dominated by Indonesia and Malaysia as the highest production in the world, Thailand, Colombia, and Nigeria are expected to produce the production of oil palm in optimal conditions with adequate quantities [7].

The growth of oil palm as a superior commodity cannot be separated from the role of current technological advances called machine learning, which is the scientific study of algorithms and statistical models used by computer systems to conduct certain specific tasks without being explicitly programmed and can manage data efficiently. Machine learning is classified into several types. First supervised learning which is a type of machine learning that works by mapping input and output based on labeled training data. The output dataset then needs to be predicted and/or classified. Meanwhile, unsupervised learning is the opposite of supervised learning which the dataset is not yet labeled. So, the algorithms need to recognize the class of the data themselves. Semi-supervised learning is a type of machine learning that combines between the two [8]. Besides that, the application of machine learning applied in many different fields of work such as lung cancer and heart attack prediction [9][10], neurosurgery [11], social networking [12], insurance industry [13], energy markets [14], Islamic study in Hadith [15], security and privacy in blockchain [16], insects pest control [17], teaching and learning in education [18], etc. These studies indicate machine learning reliability in solving problems is widely recognized and proven to have a significant impact as a current sophisticated technology.

Based on research conducted by N'goye, Soude, and Loko [19], bibliographic mapping AI-based technology is found in the use of deep learning in precision agriculture in general. It is known that deep learning is part of machine learning with a smaller scope of algorithms based on neural networks [20]. Apart from that, agriculture which was used as the object of mapping was considered too broad and not specific enough [21]. Therefore, specific mapping is needed to give detailed bibliographic information precisely.

Machine learning on oil palm can predict aspects of production, productivity, and land area with certain algorithms so it is hoped that there will be a measurable increase in the future [22]. Even though there has been an increase in these aspects, and it has become a leading commodity [23], the specific use of machine learning has not yet been identified and there is a lack of knowledge because no one has carried out the mapping from the bibliographic aspect for this commodity.

This research contributes by analyzing trends in machine learning utilization and potential research topics on oil palm commodities through bibliometric analysis. Bibliometric analysis is conducted by discovering bibliographic aspects such as the distribution of publications by year, the most productive authors, publications with the most citations, and keyword co-occurrence which is presented using diagrams, tables, and scientific visualizations. It is hoped that this research can be used as a starting point and opportunity for other researchers to conduct further research, especially on machine learning and oil palm.

B. Research Method

This research conducts bibliometric analysis by mapping a few bibliographic aspects such as year distribution, author productivity, citation, and keyword co-occurrence of machine learning algorithms application on oil palm. The research method adopts a mapping stage based on research [20] which is divided into 3 (three) major stages, namely: Dataset Collection, Data Analysis and Interpretation, and Data Visualization with Vos Viewer. The following is each stage explanation of the research method:

1. Dataset Collection

This research dataset was taken from Google Scholar and Scopus databases, where Google Scholar has coverage of research publications in various scientific disciplines [19][24] and Scopus has wider coverage than Web of Science (WoS) in the field of science and technology [20]. The publications are limited to English which is in the period between 2004 – 2024. Apart from that, the types of publications are also limited to proceeding and journal articles. The keywords used in searching are shown in Table 1. Keywords can be in the title, keywords, and/or both from the publications.

Based on Table 1, the total number of publications based on searches using keywords is 2315. This data will be entered into the next stage in data collection until it is eligible for use in the research. The overall stages of data collection are shown in Figure 1.

Table 1. Collected Publications

	keywords "machine learning" AND/OR "oil palm"
Google Scholar	2110
Scopus	205

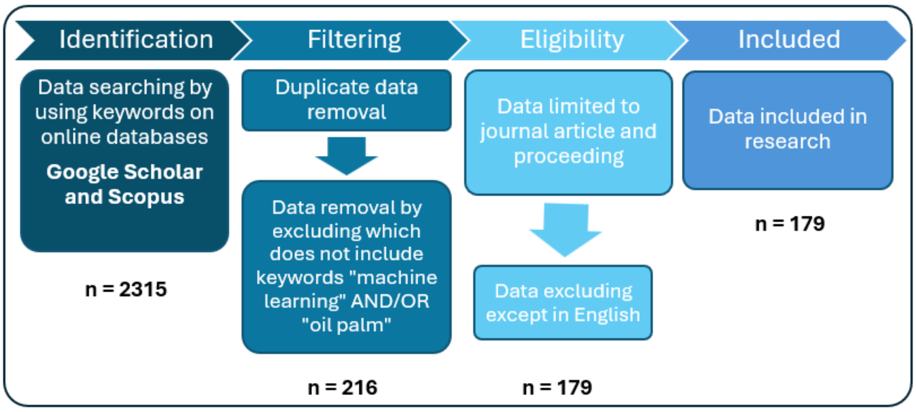

Figure 1. Data Collection

In Figure 1, after searching for data, filtering is conducted by removing duplicates from 2315, which is reduced to 2031. Then, the data are removed using criteria that do not have keywords in either the title and/or keywords listed in the publications. The results of the deletion obtained 216 data that matched the keywords. Next, the choice of data is based on types of proceedings and journal articles in English. From the entire dataset collection process, a total of 179 publications are obtained and eligible for research.

2. Data Analysis and Interpretation

At this stage, data that is collected and eligible is conducted by bibliographic analysis, including year distribution, author productivity, citation, and keyword co-occurrence, which is based on bibliometric analysis. Bibliometric analysis is a quantitative analysis of a scientific publication and an analysis of the connections between the bibliographic aspects contained in it [25]. The use of this analysis has been widely used in various scientific fields such as health [26], finance [27], education [28], food security [29], to tourism and hospitality [30].

There are four bibliographic aspects which are used in this research. First year distribution, which is a key part that must be listed to indicate the time of research for the publication was conducted. The year can also be a benchmark for the development of a research topic, where the more recent the year, the more recent the scientific development of research can be. Therefore, it is necessary to have a year distribution to map each publication based on the year of publication. The second is author productivity. This aspect is useful for seeing the level of research productivity which is marked by the publications that have been conducted. This productivity is also closely related to the number of citations of a publication, because the more citations a publication gets by an author, the better the author's reputation, especially in the scientific field of research. The third is citation which is how many publications are used as references for other research. The more a publication is cited by other research, the greater the level of scientific novelty that the publication has. Then, the fourth is keyword co-occurrence which shows the frequency of occurrence of terms contained in the title, abstract, and/or core content of the research itself. Keyword co-occurrence can be used as material for analyzing trends in certain topics of research.

3. Data Visualization with Vos Viewer

At this stage, visualization of data analysis in the earlier stage is conducted. The data visualization uses Vos Viewer [31] and visualizes data based on bibliographic aspects such as citation, keyword co-occurrence, and so on. The visualization is presented by network visualization which gives links among terms that are differentiated by colors. These colors are cluster representations that are formed.

C. Result and Discussion

In this section, we perform a bibliometric analysis of the application of machine learning on oil palm. The analysis includes all publications in English which have been searched in the range of time between 2004-2024 or two decades. As a result, 179 publications including 123 journal articles and 56 proceedings were discovered where the percentage is shown in figure 2. Figure 2 shows that articles from journals have a substantial part than proceedings from conferences in this research with 69% and 31% consecutively.

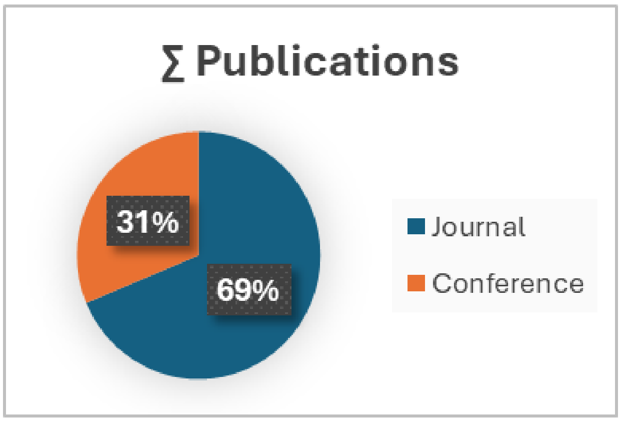

Figure 2. Publications Percentage

Bibliometric analysis by bibliographic aspects such as year distribution, author productivity, citation, and keyword co-occurrence can be presented consecutively throughout the sub-sections below.

1. Year Distribution

Based on Figure 3, the first published article was in 2004. The distribution of publications since 2004 has been increasing year by year. The highest peak number of publications is 2023 with a total of forty-nine. In 2024, it does not reach its end of the year, so it still has opportunities to produce more publications. The development of publications can be seen from the continued increase in the number of articles produced.

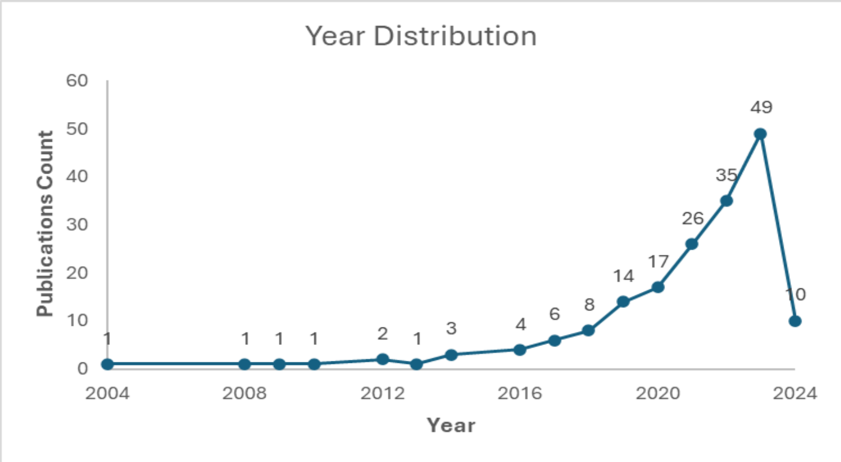

Figure 3. Year Distribution

2. Author Productivity

The productivity of the author can be seen from the publication which has been published. In this research shown in Table 2, there are two authors with the highest number of publications with a total of 9 each. Followed by another two authors with a total of 8 and 7 consecutively. For the rest of the authors, the total of publications is 6 and 5 each of two. Moreover, from the table, the highest of total cited publications is held by Haohuan Fu and Weijia Li with 680 each, although they are ranked 5 and 6 consecutively. Siti, the most productive author with 9 publications is only 96 cited in total, still far below Haohuan and Weijia. These productive authors belong to only a small part of the whole that can be observed in Figure 4.

Table 2. The Most Productive Author

References	Author	Total Publications	Total Cited
[32][33][34][35][36][37][38][39][40]	Siti Khairunniza-Bejo	9	96
[41][33][35][42][43][36][37][38][44]	Abdul Rashid Bin Mohamed Shariff	9	86
[45][46][47][48][35][49][50][39]	Farrah Melissa Muharam	8	149
[51][52][53][54][55][56][57]	Helmi Zulhaidi Mohd Shafri	7	71
[58][59][60][61][62][63]	Haohuan Fu	6	680
[58][59][60][61][62][63]	Weijia Li	6	680
[64][65][66][67][68]	Bens Pardamean	5	81
[59][60][61][62][63]	Le Yu	5	650

In this research, there are 580 authors in total. As shown in Figure 4, the chart indicates that 88% of authors have only one publication with 508 in number. Moreover, the other 12% has several publications in the range of 2 to 9.

Figure 4. Distribution of Authors Publication

3. Citation

Based on Table 3, the highest citation is 431 with research topic tree detection and counting. The article was published in 2016. Besides that, from the top ten publications, 4 of 10 are about tree detection and counting. Three out of ten are about the maturity or ripeness of oil palm fruit. On the other hand, the remaining three are about waste, nutrient deficiencies, and emissions of mills. These topics are the most potential areas within oil palm that are still used in today's research. The highest citation of publication topic is in 2016 and the newest is in 2021 with 73 citations about fruit maturity/ripeness.

Table 3. Top 10 Most Cited Publications

Reference	Citation	Title	Topic	Year
[63]	431	Deep learning-based oil palm tree detection and counting for high-resolution remote sensing images	tree detection and counting	2016
[69]	114	Artificial neural network approach for the steam gasification of palm oil waste using bottom ash and CaO	waste	2019
[70]	107	Intelligent color vision system for ripeness classification of oil palm fresh fruit bunch	fruit ripeness/maturity	2012
[71]	101	A comparative study in kernel-based Support Vector Machine of oil palm leaves nutrient disease	nutrient deficiencies	2012
[59]	96	Large-scale oil palm tree detection from high-resolution satellite images using two-stage convolutional neural networks	tree detection	2019
[72]	91	Automatic detection of individual oil palm trees from UAV images using HOG features and an SVM classifier	tree detection	2019
[73]	81	Automated grading of palm oil fresh fruit bunches (FFB) using neuro-fuzzy technique	fruit ripeness/maturity	2009

[74]	73	Machine vision for the maturity classification of oil palm fresh fruit bunches based on color and texture features	fruit ripeness/maturity	2021
[75]	68	Emission control in palm oil mills using artificial neural network and genetic algorithm	emissions of mills	2004
[61]	61	Cross-regional oil palm tree counting and detection via a multi-level attention domain adaptation network	tree detection and counting	2020

4. Keywords Co-occurrence

Keywords co-occurrence can be visualized by using VosViewer, especially the link among terms. As shown in Figure 5, the visualization of the network among terms can be observed that consists of 13 clusters with different colors of each other. Each cluster consists of a different number of terms. Cluster 1 to 11 has 19 terms, 17 terms, 16 terms, 13 terms, 11 terms, 10 terms, 8 terms, 6 terms, 5 terms, 4 terms, 3 terms respectively. Cluster 12 and 13 consist equal number of 1 term. Before that, we select the threshold of term occurrence as minimum two and 114 terms meet the criteria.

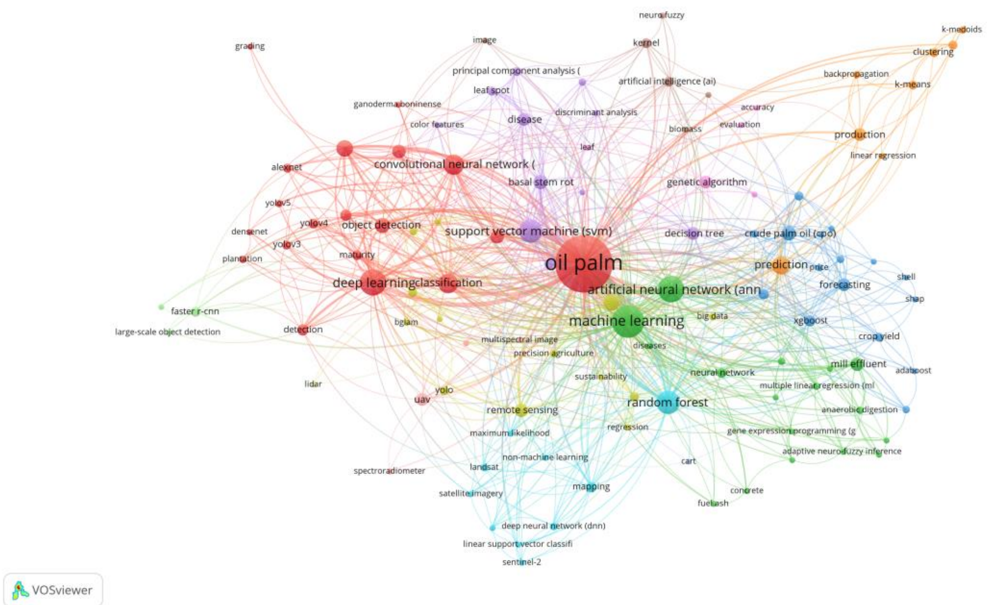

Figure 5. Network Visualization of keywords

Network visualization is a representation of a connection between two topics or more among publications. We can see the main topic "oil palm" located in the middle of the visualization indicates that the center connection revolves around it. As the main topic, oil palm has many links to other topics. Table 4 shows further details about the term's occurrence.

Table 4. Top 5 Ranks of Terms Occurrence

Ranks	Terms	Occurrences	Link Strength
1	oil palm	161	864
2	machine learning	52	357
3	deep learning	35	178
	artificial neural network (ANN)	35	205
4	support vector machine (SVM)	28	172
	random forest	28	180
5	convolutional neural network (CNN)	21	109

Based on Table 4, the highest rank of the term is "oil palm" with 161 occurrences. Followed by "machine learning" in the next position with 52 occurrences. The third rank is occupied by two terms which are "deep learning" and "artificial neural network (ANN)" with 35 occurrences each. Then, the fourth rank with 28 occurrences is occupied by "support vector machine (SVM)" and "random forest". The term "convolutional neural network (CNN)" is in the fifth rank with 21 occurrences.

The table above shows the algorithms that come out as terms that are the most emerging from publications. Besides "oil palm" as the top-rank term that is used in publications, machine learning algorithms are being used as the second most important because of their utilization for this study. By looking at that, the trend of machine learning utilization is observed clearly.

Table 5. Machine Learning Algorithms

Types of Algorithms	Number of Algorithms	Algorithms
Supervised Learning	55	Gradient Boosting, Random Forest, AdaBoost, Backpropagation, Fuzzy Time Series, Convolutional Neural Network (CNN), Faster R-CNN, GoogLeNet, Artificial Neural Network (ANN), Learning Vector Quantization (LVQ), Decision Tree, Support Vector Machine (SVM), AlexNet, MobileNetV1, MobileNetV2, Multiple Linear Regression (MLR), XGBoost, CART, Extreme Learning Machine (ELM), Long Short-Term Memory (LSTM), Support Vector Regression (SVR), Reccurent Neural Network (RNN), Multi-layer Perceptron (MLP), Deep Neural Network (DNN), Naïve Bayes, K-Nearest Neighbor (KNN), Gene Expression Programming (GEP), ANFIS, Weighted Nearest Neighbor (WNN), Discriminant Analysis, Logistic Regression, Partial Least Squares Regression (PLSR), Multivariate Adaptive Regression Splines (MARS), M5P, Probabilistic Random Forest (PRF), Ensemble Random Forest (ERF), Linear Support Vector Classifier (LSVC), Neural Network, LASSO, Logistic Model Tree, Gradient Boosting Decision Tree, CatBoost, Residual Network (ResNet), NGBoost, Multi-scale Anomaly Detection on Attributed Network (MADAN), DenseNet, Radial Base Function Neural Network (RBFNN), Particle Swarm Optimization (PSO), Multi-verse Optimizar (MVO), XCeption, Neuro Fuzzy, ResNet50
Unsupervised	10	K-Medoids, K-Means, C-Means, ANN, Principal Component

Learning		Analysis (PCA), RNN, DNN, Latent Dirichlet Allocation (LDA), MADAN, RBFNN
Semi-supervised Learning	8	YOLO, YOLOv5, YOLOv8, DNN, YOLOv3, YOLOv4, Fuzzy Regression, Active Learning

As shown in Table 5, we can observe algorithms used in publications. Algorithms are divided into three categories: supervised learning, unsupervised learning, and semi-supervised learning. These categories consist of different numbers of algorithms. Supervised learning has 55 algorithms, unsupervised learning has 10 algorithms, and semi-supervised learning has 8 algorithms. The significant gap in algorithms among categories shows that supervised learning is the most popular learning used among researchers. Besides that, as shown in Table 4, the most frequent algorithms that are used in publications belong to supervised learning which are artificial neural networks (ANN), support vector machine (SVM), random forest, and convolutional neural networks (CNN).

D. Conclusion

The rapid growth of technology has been developing machine learning and the use of it spreads widely across many fields. Especially in agriculture, it is used to solve problems related to oil palm in many parts of the commodity. By using it, there are lots of topics that can be solved and impact the oil palm's significant growth itself. This research aims to provide information needed by other researchers for future work and gives a current state of the research development in machine learning utilization in oil palm. In addition, analysis using bibliometrics gives a detailed and important view of research topics. As a result, the first published article emerged in 2004 and generated the highest number of publications in 2023 with the most productive authors being Haohuan Fu and Weijia Li. The current research potential topics are tree detection and counting, waste, fruit maturity/ripeness, nutrient deficiencies, and emissions of mills by looking at the number of citations. Besides that, supervised learning is the most popular method of learning that is used by researchers.

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