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A Comprehensive Analysis of Deep Learning Models in Agricultural Crop Yield Prediction

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Abstract

In comparison to machine learning algorithms, deep learning algorithms are more effective in terms of their ability to make accurate predictions about agricultural data. When trying to attain better outcomes, the accuracy and efficiency of the algorithm are highly crucial factors to consider. In order to help the farmers to accurately predict the yields of their crops, the study of agricultural data is of great assistance. This resulted in a significant amount of study, and the researchers used a variety of data to make predictions on the yields of the various crops. The primary objective of this study is to locate a more effective deep learning algorithm that may be used to forecast crop production. Hence the SLR was carried out and finally identified 20 opted research articles related to deep learning models utilized in agricultural data prediction. As a result, this SLR discovered that the LSTM-based deep learning models provide more accurate predictions when applied to agricultural data sets. A great number of research papers made use of the same model for better results.

***Keywords:** Deep Learning, SLR, Yield Prediction*

1. Introduction

In the agricultural sector, one of the most important predictive analytics techniques is crop production prediction. Agricultural practice is a method that may assist farmers and farming enterprises in predicting crop production during a certain season. This method can also help farmers choose when to plant a crop and when to harvest it in order to achieve a higher crop yield. When it comes to the economics of a growing nation, agriculture is the most essential industry and the backbone of the economy. Providing farmers with accurate crop production prediction models may give them with decision-making tools that can help them make better choices. The prediction of crop output has shown to be difficult for academics because of the presence of dynamic, noisy, non-stationary, non-linear characteristics, and complicated data Machine learning algorithms are a subset of AI programs that give more accurate results in software applications without being specifically designed to do it (Rashid et al. 2021). An ML model is established with a few parameters and learning. Learning is executing a program to optimize the model's parameters using training data or prior experience [1]. In order to successfully extract relevant crops for forecasting purposes, a wide range of techniques that are based on deep learning are used. The use of data mining in conjunction with deep learning results in the creation of a comprehensive agricultural yield prediction system that is able to establish a connection between raw data and anticipated crop yields. The purpose of

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deep learning is to tackle difficult issues and provide intelligent solutions. The structure and function of the human brain served as the inspiration for the deep learning notion that underpins the field. To perform data analysis and create predictions, deep learning makes use of artificial neural networks.Crop production forecasting, on the other hand, is extremely difficult because of several complex factors [2]. Weather, soil quality, temperature, rainfall, humidity landscapes, insect infestations, water quality and availability, genotype, harvest activity planning, and other elements all influence crop output [4]. In this paper, the survey is made to find the importance of deep learning methods imply in the agricultural sector.

2. Related Work

The purpose of this work is to examine the research around a deep learning system that is based on crop production prediction. Utilizing the crop, the methodology used, the statistics utilized, and the performance measures utilized, the survey classifies the many tactics that are now in use. Some of the deep learning algorithms that are used to forecast agricultural production include CNN, RNN, LSTM, and MLP. The CNN method is capable of producing exceptional results when applied to tasks involving object identification and picture categorization. Long short-term memory (LSTM) is able to identify and record complicated and nonlinear correlations in the data across extended time periods. Both CNN and LSTM are two of the most important deep learning algorithms for reliably calculating crop yields [5]. In this study, a comprehensive study and synthesis of the original research was carried out with regard to the fundamental motives, the crops that were targeted, the algorithms that were used, the characteristics that were utilized, and the data sources that were found to be available. Following our observations, the Convolutional Neural Network (CNN) method is the most often used technique, and it also has the greatest performance in terms of Root Mean Square Error (RMSE). The absence of a big training dataset is one of the most significant issues, as it increases the likelihood of overfitting, which in turn leads to a decrease in the performance of the model in actual implementations. As a result of the fact that researchers in this sector have a tendency to concentrate on the significance of unexplored research issues, it is beneficial for them to provide an indication of the existing problems and the possibilities of doing more study [6].According to the findings of researcher's investigation, the characteristics that are used the most in these models are temperature, rainfall, and soil type, and the methodology that is utilized the most prominently is Artificial Neural Networks. Following this discovery, which was based on the examination of fifty papers based on machine learning and also carried out an additional search in electronic databases in order to locate studies based on deep learning. Researchers were able to locate thirty articles based on deep learning, and extracted the deep learning algorithms that were using them. According to this further data, the deep learning algorithm that is used the most often in these studies is known as Convolutional Neural Networks (CNN). Long-Short Term Memory (LSTM) and Deep Neural Networks (DNN) are the other deep learning algorithms that are utilized frequently [3]. The researcher conducted a comparison between semi-supervised approaches and methods based on Deep Learning for the purpose of identifying and counting fruits in apple orchards. As far as yield mapping is concerned, they demonstrated that the older approaches, such as Gaussian Mixture Models, perform better than the later methods, which are based on CNN, Faster R-CNN, and U-Net [8]. The authors examined the use of Deep Learning techniques for the purpose of calculating productivity and counting individual fruits. In addition to advocating methods such as CNN detectors, deep regression, and LSTM for assessing the fruit load, they demonstrated that Deep Learning techniques are capable of extracting significant characteristics [9]. In this article, the researchers gave the detailed study about use of machine learning and deep learning algorithms for various crop predictions. The published literature contains researchers thorough descriptions of the answers

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they have validated to a variety of situations. In the event that prospective researchers make use of previous notions without first obtaining a competent evaluation, they will not get the outcomes that they are looking for. In the event that the researchers do not initially carry out an exhaustive analysis of the most recent indicators of performance, it is quite probable that they will not be able to discover any proof of future. Finally, they conclude which ML and DL algorithms are used most frequently and effectively in all the papers [10].

3. Methodology

The SLR (Systematic Literature Review) main focuses on use of deep learning techniques for agriculture crop and yield prediction. Artificial neural networks (ANNs) with representation learning are the foundation of deep learning, which is a subset of machine learning techniques. Deep learning architectures include Deep Neural Networks, Deep Belief Networks, Recurrent Neural Networks, Convolution Neural Networks, and transformers. The SLR process consists of two steps: (1) the research questions are framed to scrutinize the papers related to crop and yield predictions. (2) Based on the research questions criteria, a detailed study is made to project the deep learning algorithms role in the papers.

3.1 Framing Research Questions

Defining the correct way of research question is tedious process. In the agriculture sector, there was a numerous volume of issues are faced nowadays. Some of the challenges are crop suggestion, yield prediction, crop disease, fertilizer and pesticides recommendations, and irrigation levels. The questions were framed to identify the effective research articles which used deep learning techniques for prediction.

- **RQ1:** Whether the research objective is clearly mentioned.
- **RQ2:** Whether the appropriate data sources used for implementation.
- **RQ3:** Is necessary parameters considered for effective prediction.
- **RQ4:** Is effectively deep learning algorithms used.
- **RQ5:** Whether the suggested methodology gives better results.
- **RQ6**: Identification of effective results was made.

3.2 Data Collection via Systematic Literature Review

To address the above research questions, the study has followed an SLR for data collection. A valid search option is carried out in the following academic databases to identify the relevant and recent articles related to agriculture crop yield prediction using deep learning techniques. The research articles collected from the following live data sources.

a. IEEE Xplore.

b. Springer.

c. Elsevier

d. Google Scholar

By using valid search keywords and criteria as input to ensure that no relevant article is missed in our study related to mobile application development. In this study, only journals, conference proceedings, and articles related to prediction of crop yields using deep learning techniques as inclusion criteria and a paper published after 2019 as exclusion criteria. There are so many articles published related to our study [7]. We selected the following papers based on the inclusion and exclusion criteria. The study selected 20 research papers from various journals for the final study.

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Table 1 Utilization of Deep Learning Algorithms in Different Literatures

Paper ID	References & First Author	Year of Publication	Mode of Publication	Proposed Methodology/Algorithm Used	Findings
1.	Priti Prakash Jorvekar, Sharmila Kishor Wagh, Jayashree Rajesh Prasad	2023	IEEE Xplore	Deep Neural Networks, Long-Short Term Memory, Convolution Neural Networks	The evaluation metrics RMSE is used for prediction of the model and the LSTM gives better results
2.	Yadala Sucharitha, Pundru Chandra Shaker Reddy, T. N. Chitti	2023	Springer	Deep-Neural-Networks, Lasso, Shallow Neural Networks, and Regression Tree.	The Proposed DNN approach essentially outperformed
3.	Yogendra Narayan Prajapati, Swati Tomar, Pancham Singh, Anurag Gupta, Varun Kumar	2023	Springer	SVM, random forests, tree pruning, artificial neural networks, LSTM, RNN.	To estimate crop yields, the LSTM were used and performed well
4.	Kavita Jhajhariaa, Pratistha Mathura, Sanchit Jaina, Sukriti Nijhawana	2023	Elsevier	Random Forest, SVM, Gradient Descent, LSTM, Lasso Regression.	The RMSE value of RF and LSTM is low when compared to other models for maximize the yield
5.	Venkata Rama Rao Kolipaka, Anupama Namburu	2023	Google Scholar	ANN, CNN, RNN, LSTM.	The LSTM have been proven to be extremely important for crop yield prediction than ANN
6.	Attri, Ishana Awasthi, Lalit Kumar Sharma, Teek Parval Rathee, Priyanka	2023	Elsevier	CNN, RNN, AlexNet, and ResNet, LSTM.	CNN and LSTM is most used algorithm in various studies for prediction.

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7.	Li, Liangdan, Liu, Luo Peng, Yiping Su, Yingyue Hu, Yueming Zou, Runyan	2023	Elsevier	CNN, VGG-16, VGG-19 and ResNet-50 models used with web application.	ResNet-50 provides better performance in predicting in leaf decease's.
8.	Troncoso-García, AR Brito, IS Troncoso, A Martínez-Álvarez, F	2023	Elsevier	support vector machines, multi-layer perceptron, Lasso and decision tree compared with deep learning algorithm CNN, LSTM and RNN	LSTM gives better accuracy of predicting the forecasting data's.
9.	Sony M Kuriakose, Tripty Singh	2022	IEEE Xplore	LSTM and ML algorithms	The data is preprocessed by applying ML algorithm and the crop yield prediction is made by LSTM DL Networks
10.	Ohnmar Khin, Sung Keun Lee	2022	IEEE Xplore	Artificial Neural Networks (ANN)	Different classifier techniques were used along with ANN and concluded that ANN were performed good in predictions
11.	Shamli Bharti, Pardeep Kaur, Preeti Singh, Charu Madhu, Nidhi Garg	2022	IEEE Xplore	CNN, LSTM , RNN	Hybrid CNN-LSTM performed very well for wheat yield prediction
12.	K. Vignesh, A. Askarunisaand A. M. Abirami	2022	Google Scholar	SVM, RF, XG-Boost, MLP, Conv-iD, Deep Belief Network.	Deep Belief Network with Visual Geometry Group (VGG) Net classification

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					method were correctly predicts crop output with good accuracy
13.	Alexandros Oikonomidisa, Cagatay Catalb, and Ayalew Kassahun	2022	Springer	XGBoost, Convolutional Neural Networks, Deep Neural Networks, Recurrent Neural Networks and Long Short Term Memory.	The hybrid CNN-DNN model outperforms other models, having an RMSE is low for crop yield prediction
14.	Parjanya Prashant, Kaustubh Ponkshe, Chirag Garg, Ishan Pendse, Prathamesh Muley	2021	IEEE Xplore	An ensemble neural network model using Long Short-Term Memory (LSTMs) and one-dimensional Convolutional Neural Networks (CNNs).	Accuracy in predicting crop yields is higher by using LSTM and CNN when compared to other models like FFNN, XGB,RF and Linear Regression
15.	Akash Mondal, Saikat Banerjee	2021	IEEE Xplore	Feed forward neural network, Rectified Linear Activation Unit, backward and forward propagation techniques.	The experimental result shows that Feed forward neural network model performance is quite satisfactory.
16.	Sonal Agarwal and Sandhya Tarar	2021	Google Scholar	DT, ANN, RF, SVM, LSTM, RNN.	The LSTM model predicts best crops
17.	J. Sun, L, Di, Z. Sun, Y. Shen, and Z. Lai,	2019	Springer	Convolutional Neural Network, Long Short-Term Memory.	The Results of the experiment indicate that the prediction performance of the proposed

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					CNN-LSTM model can outperform the pure CNN or LSTM model
18.	Saeed Khaki and Lizhi Wang	2019	Google Scholar	Lasso, shallow neural networks, regression tree, DNN.	The DNN model gives good prediction accuracy
19.	Tanhim Islam, Tanjir Alam Chisty, Amitabha Chakrabarty	2018	IEEE Xplore	Artificial Neural Network, support vector machine, Logistic Regression, and random forest.	ANN performed well for agricultural crop selection and yield prediction among ML algorithms

Findings and Results

The proposed SLR methodology is used to identify the appropriate agricultural research articles that are used with deep learning algorithms [11]. Table 1 describes the different methodologies and techniques related to deep learning models. The SLR was carried out in 20 research papers which is used deep learning algorithms like CNN, RNN, LSTM and etc. Figure 1 shows the appropriate article selection in different live data sources like IEEE, Springer, Elsevier and Google Scholar.

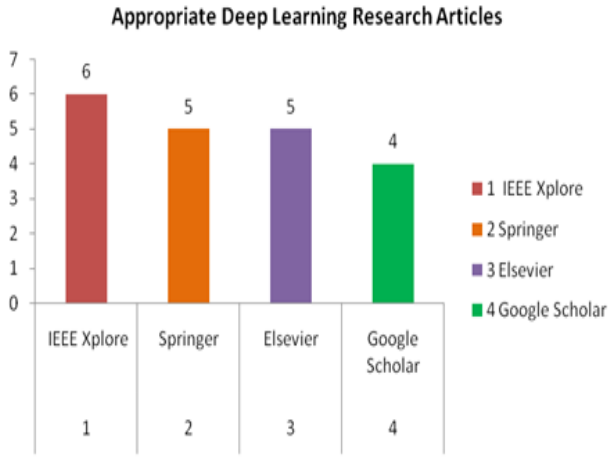

Figure 1 Data Collection in Live Data Source

The articals utilized the deep learning methods with agriculture datasets were carried out for the proposed SLR. The SLR reults were identified in Table 2, It shows the LSTM model is frequently used for crop prediction with sequntial data set. It was used in 11 papers out of 20 and CNN and RNN is used in 4 papers. The remaining algorithms were used in less papers.

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Table 2 Data collection in Live Data Source

S.No.	Deep Learning Algorithms	Paper ID	Total papers used the same algorithms
1	CNN	P7, P14, P15, P18	4
2	ANN	P6, P11, P20	3
3	LSTM	P1, P2, P4, P5, P6, P7, P9, P10, P15, P17, P18	11
4	DNN	P3, P14, P16, P19	4
5	CNN - RetNet50	P8	1
6	Hybrid CNN-ANN	P12	1
7	VGG	P13	1

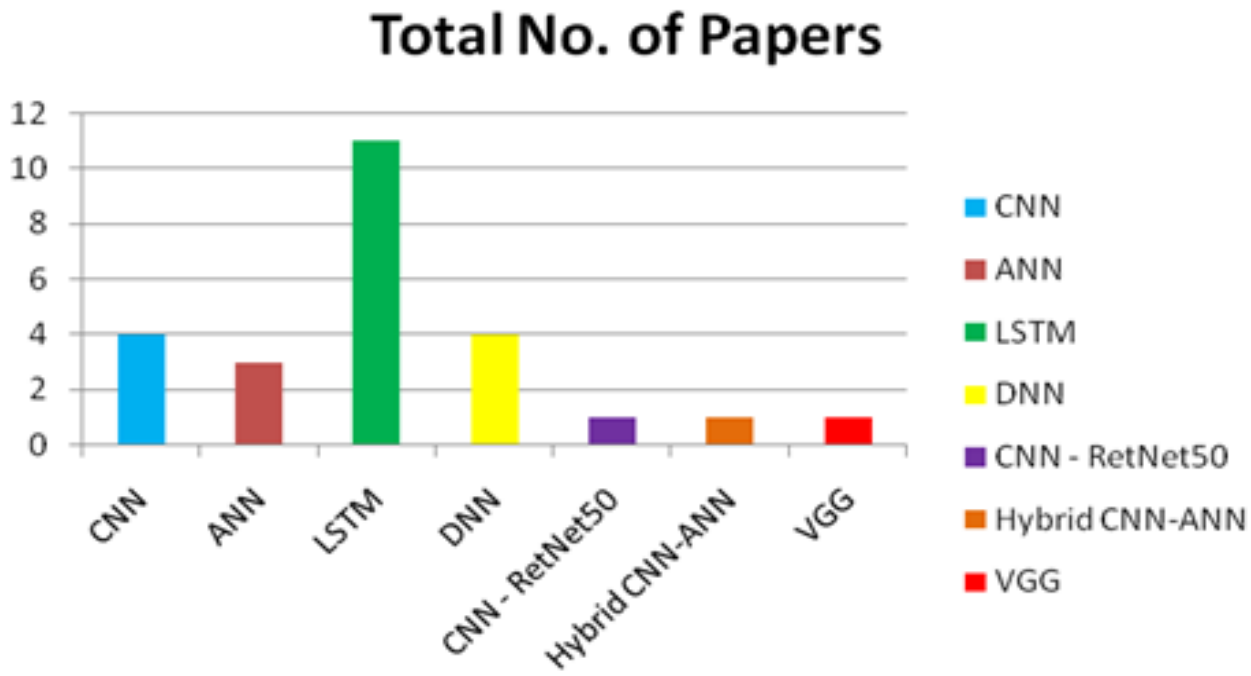

Figure 2 Algorithms Used in Different Articles

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Based on the Table 2 analysis and the systematic literature review, the deep learning algorithm LSTM is used frequently in many papers. The analysis shows in Figure 2. Seven algorithms are used in 20 papers. In that LSTM is mostly used and produced better results among all the algorithms.

Conclusion

The deep learning algorithms are more efficient compared with machine learning algorithms for better prediction of agricultural data. The algorithm's accuracy and efficiency are very important to achieve better results. The analysis of agricultural data is very helpful to farmers to predict their crop yields. Hence, there was much research and the researchers were predicting the yields of the various crops with different data. This research is mainly focused on identifying a better deep learning algorithm that is used to predict crop yield. Based on the findings and results of this research, the deep learning-based LSTM model was used in 11 papers out of 20. The other models were used for less than 5%. Hence, this SLR identified that the LSTM-based deep learning models give better predictions with agricultural data sets. The same was used in many papers. Further, the LSTM model was compared with different data sets, and its accuracy will be measured [12-15].

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