A Review on Crop Yield Prediction using Learning Techniques

[1] Sandeep Kaur, [2] Gurvinder Singh, [3] Anil Kumar
[1]Research Scholar, [2]Associate Professor, [3]Assistant Professor
[1]Department of Computer Science, GNDU, Amritsar,
[2]Department of Computer Science, GNDU, Amritsar,
[3] Department of Computer Engineering and Technology, GNDU, Amritsar,
[1] sandeepcs.rsh@gndu.ac.in, [2] gurvinder.dcse@gndu.ac.in,[3] anil.dcse@gndu.ac.in

ABSTRACT

Food is regarded as a basic human requirement that is met through agriculture. Beyond meeting fundamental human requirements, agriculture is seen as a global source of employment in developing countries like India. Sustainable crop production is a persistent issue for farmers. Getting the best crop production has always been difficult for farmers since environmental circumstances are always changing. Land types, resource availability, and weather variability are the main causes of unpredictable crop yields. Therefore, scientists from all around the world are working to develop methods that can efficiently and accurately predict crop yields well in advance so that farmers may take the necessary steps to address upcoming issues. Crop production depends entirely on timely observation and advice. Farmers can reduce their losses if appropriate recommendations and information about the crop is provided. Machine learning is the prevailing technology that helps farmer to minimize agriculture losses. The study's primary goal is to explore different learning techniques used to predict crop yield. Reviews carried out in agriculture sector indicated a strong preference for deep learning methods and hybrid models for crop yield prediction.

Keywords: Machine learning, Deep learning, Crop Yield, Prediction

INTRODUCTION

About 58% of India's population relies on agriculture as their main source of income, making India one of the major players in the global agricultural industry[1]. In the modern world, as population grew, agriculture's significance and necessity also increases. A sustainable balance needs to be achieved through increased agricultural production [2]. Due to the world's growing population, there is a serious problem for humanity about the availability of food for everyone. Agriculture researchers are attempting to create sustainable farming practices that will improve the production of vital food crops while affecting the environment as little as possible. The majority of people on earth primarily rely on wheat, rice, and maize for nutrition, thus experts have put a lot of effort into figuring out how to increase their output in the face of growing food prices, climatic change, and resource depletion. It is crucial to increase wheat production because of the unanticipated environmental changes and the continuously rising demand for the grain[3].

Modern agriculture heavily relies on technology and concentrates on reaping large profits from a few chosen hybrid crops, which over time deteriorate the physical and biochemical properties of the soil. To maximize crop yields without sacrificing soil fertility, a number of coordinated

actions can be taken, paving the way for sustainable agriculture [4].The term crop yield refers to the amount of crop harvested per area of land. Despite being a crucial task, crop yield prediction is crucial for the nation's food security, which must be ensured despite the many difficulties associated with the rising population demand [5].Crop yield is an important activity in the field of agriculture. The various factors on which the yield depends include climate, seed variety, fertilizers, soil [6]. An accurate and timely forecast of crop yield can be of great assistance to a farmer, whose livelihood is entirely dependent on the expected yield of the crop. Also the government is able to make new policies and take decisions regarding planning import/export, price of crops if the yield is predicted accurately [7]. Numerous studies show that machine learning algorithms have comparative higher potential than traditional statistics. Machine learning is a branch of artificial intelligence that allows computers to be taught without explicit programming [8].

CROP YIELD PREDICTION MODEL

The prediction of crop yield is a major task in agriculture sector. Farmers are unable to predict the yield of crop and due to that they can suffer from loss .Yield prediction depends on the weather conditions and varies accordingly. Predicting crop yields is crucial for the production of food. The ability to estimate yields helps farmers make decisions. Crop production prediction is a difficult task because of numerous complex elements. It aids in locating the important characteristics that inevitably influence crop productivity. In the past, farmers' experience was used to estimate crop yields. Farmers today must produce an increasing number of crops since conditions and circumstances are changing quickly[9]. Various researchers have done lot of work in order to recommend the suitable crop so that yield production matches to the expectation. The recommendation model can be designed on the basis of machine learning that describes the best crop suitable to be grown[10]. This reduces the stress of the farmers which they bear during the whole season. The following are the steps to predict the yield of crop. Fig 1 depicts the flow of crop yield prediction.

- First step is to gather agriculture data from some reliable sources like website Kaggle.com or government of India.
- Pre processing is performed to eliminate the redundant piece of information present in the dataset.
- Features are extracted that are to be used in the classification processes.
- Next step is the splitting of dataset to train and test data
- Finally the results will be generated after the application of suitable algorithm.

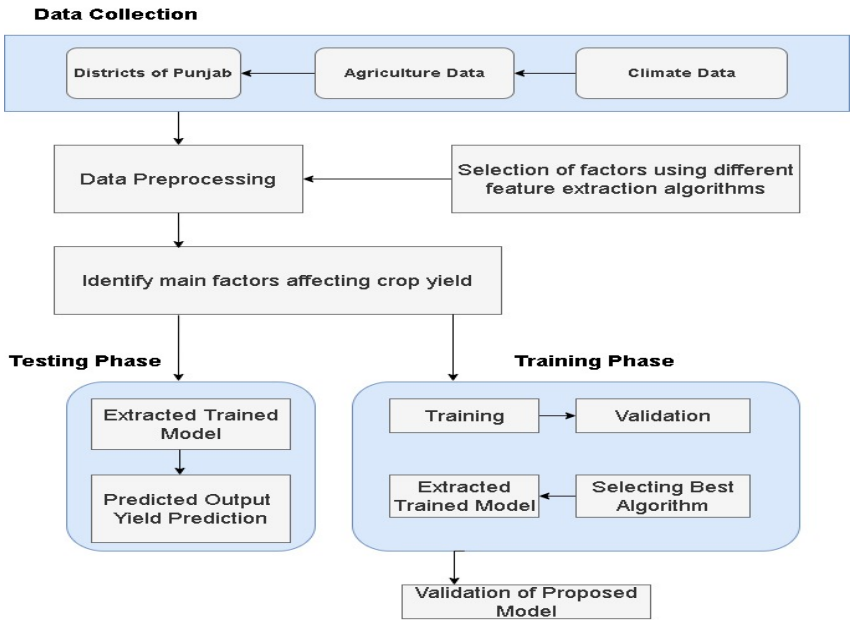

Figure -1. Flow diagram of crop yield prediction

LITERATURE REVIEW OF A FEW LEARNING TECHNIQUES

Food is considered as a basic need of human being which can be satisfied through farming. Agriculture not only fulfils humans' basic needs, but also considered as source of employment worldwide. Agriculture is considered as a backbone of economy and source of employment in the developing countries like India. Advancement in area of learning has helped improving gains in agriculture. Learning technique is the current technology which is benefiting farmers to minimize the losses in the farming by providing rich recommendations and insights about the crops. Crop management is the set of agricultural practices performed to improve the growth, development and yield of crops. It begins with a seedbed preparation, sowing of seeds and crop maintenance; and ends with crop harvest, storage and marketing.

Machine Learning [ML] algorithms are now widely used by enterprises and research communities for a variety of purposes since vast data sets and innovative algorithms are readily available through online resources [11].In this paper performance of different machine learning algorithms are discussed and analysed in crop yield prediction. A group of classification algorithms built on the Bayes' Theorem are known as naive Bayes classifiers. The authors of [12] suggested Naive Bayes to make recommendation of crops on the basis of climatic factors. The crop dataset is initially examined based on season and productivity. Farmers are able to forecast crop yields in recent years in this way. Related work on Random Forest is an author [13] who predicts crop yield by avoiding unintentional actions using real-time observations and weather forecasting so that farmers can receive periodic notifications about the future. Random forest algorithm is used to implement the work done by the author. Many authors have used this algorithms in their work.[14] Also suggest the proper fertilizer other than predicting the yield of crop.SVM Classifier is a supervised learning technique in machine learning whereby classified

data from analysed data is used [15].SVM is used by other authors [16] [4] to give accurate prediction on the basis of different input parameters. It gives higher accuracy when combined with deep learning algorithms. Artificial neural networks were combined with the regression method in crop yield prediction to estimate the yield. Where the inputs and labels in terms of images, soil characteristics, and environmental factors came from [2] Pattern recognition, statistical estimation, and classification in machine learning have all utilised K-Nearest Neighbours.[17] Have used KNN to predict the yield of crops-tomato, potato and chilli.KNN gave higher accuracy as compared to Naive Bayes. Gradient-boosted decision trees are a machine learning method for improving a model's predictive power through subsequent learning steps. The author [18] used this method to resolve crop selection problem and thus helps in achieving maximum growth for the nation. Author [9] have used to predict the yield of four popular crops maize, potatoes, rice and wheat .One of the key regression algorithms, multiple linear regression simulates the linear relationship between a single continuous dependent variable and a number of independent variables. The author [3] examined MLR demonstrated larger amount of error due to nonlinear behaviour among climatic factors. LSTM can save the data for a very long time. It is utilised for time-series data processing, forecasting, and classification. The model can be stretched into a line of connected LSTM units when the input data has a series-structure [19]. Input, forget, and output gates make up the majority of the units' gating mechanism. [16] Evaluated that LSTM model gives higher accuracy when combined with other machine learning models.[20] presents an extensive survey of latest machine learning application in agriculture to alleviate the problems in the three areas of pre-harvesting, harvesting and post-harvesting. Application of machine learning in agriculture allows more efficient and precise farming with less human manpower with high quality production.The study indicated that there is need to follow the machine learning pipeline with standard experimental methods. Researches should create their own dataset and make this available to others through different platforms, so that others can use it for testing and validation of their own models.[17] Utilizing machine learning techniques, comparative analysis of soil parameters has been done to forecast agricultural production and fertility. Three crops—tomato, potato, and chilli—and a self-obtained dataset for each was used in the analysis. The K Nearest Neighbour algorithm, Naive Bayes algorithm, and Decision Trees classifier have all been used to forecast agricultural yield. KNN and Decision Trees outperform Naive Bayes in terms of accuracy by 14.453% and 18.935%, respectively. To increase the models' accuracy, the dataset can be expanded to include data for several seasons and crops. Additionally, it can be incorporated into apps and websites to educate citizens all throughout the nation. Farmers can use the suggested study to determine crop output under various soil and environmental conditions.

Sno.	Author/year	Methodology	Overview	Results	Gaps
1	R.Kumar et.al (2015) [18]	Gradient boosting decision tree	This paper proposed the Crop Selection Method to resolve the crop selection problem, maximise net yield rates across	The suggested approach determines a series of crops by using inputs such as crop, their sowing time,	• Fertiliser is not suggested to boost the crop's yield.

			seasons, and, Subsequently achieve maximum economic growth for the country.	plantation days, and expected yield rate for the season.	
2	S. M. Bharath et.al (2019) [14]	ANN, Random forest and Back propagation	Prediction of crop yield and also recommend proper fertilizer to the end user.	On comparing the error rate it was discovered that Random Forest algorithm had lower error rate than back propagation method.	• Discover disease at an early stage, can also help to increase the output.
3	S. S. Kale et.al (2019) [21]	ANN with 3 layer neural networks and Linear Regression	The study's primary goal is to predict various crops' yields using neural network regression modelling for 10 districts of Maharashtra state.	By utilising RELU activation function and gradient decesent, the proposed back propagation model aims to minimise MSE.	• The number of parameters needed to validate the model is insufficient. • In order to locate the greatest crop with a high success rate, additional Indian regions can also be researched.
4	S.Agarwal et.al (2020) [16]	Deep Learning, SVM, LSTM, And, RNN techniques to generate the results.	The proposed model is enhanced by applying deep learning techniques and along with the prediction of crop, clear information is achieved regarding the amounts of soil ingredients needed with their	The accuracy is 93% when using Random Forest and Artificial Neural Network (ANN) methods. While the accuracy is estimated to be 97% when using the Long-Short	• Other than SVM, the author did not take any other machine learning approach into account. • Crop disease detection is not mentioned...

			expenses separately.	Term Memory (LSTM), Recurrent Neural Network (RNN), and Support Vector Machine (SVM) methods.	
5	D. Elavarasan and P. M. Durairaj Vincent (2020) [8]	RNN based DNN is used by the author.	In order to predict crop productivity, the suggested study develops a Deep Recurrent Q-Network model, a Recurrent Neural Network deep learning algorithm over the Q-Learning reinforcement learning method.	The effectiveness and accuracy tests show that the suggested Deep Recurrent Q-capability Networks are adaptable for yield prediction.	• The major problem with this approach is that parameters may slow learning down.
6	S. Sharma, S. Rai et.al (2020) [24]	Deep LSTM model is employed in the respective research.	Outlines a method for estimating crop yield from satellite imagery that uses deep learning techniques at block level of different states.	The proposed model performs better than current techniques by more than 50%.	• Better accuracy can be achieved by comparing different AI models. • To make the forecast more accurate, data from a standard source can be gathered.
7	B. Sharma et.al (2020) [4]	ANN and SVM methods are used.	It demonstrates how machine learning is used in agriculture to produce wheat crops.	This research presents a proposed model for identifying crop maturity stages from digital photos using image	• Crop maturity is not taken into account throughout the appraisal process, which results in decreased crop output.

				processing and machine learning approaches.	
8	P. S. Nishant et.al (2020) [26]	Advanced regression techniques like Kernel Ridge, Lasso and, Enet	The yield of all Indian crops is predicted using a web application that also uses stacking regression to improve the algorithm.	Root mean square error serves as the project's performance metric. For ENet, the application error was around 4%, for Lasso it was about 2%, for Kernel Ridge it was about 1%, and lastly after stacking it was less than 1%.	• The factors taken into account are insufficient for an accurate prediction. • Other ensemble methods, such as boosting, can be considered for improvement of the algorithms.
9	D. J. Reddy et.al (2021) [22]	ANN, CNN and, various machine learning methods.	This paper explores various ML techniques utilized in the field of crop yield estimation and provided a detailed analysis in terms of accuracy using the techniques.	The current study demonstrates a number of current models that effectively estimate crop yields while taking into account variables like temperature and weather.	• Enhancement to feature selection and fertiliser advice. • Using an AI technique, accuracy could be improved.
10	S. M. Pande et.al (2021) [23]	The researcher made use of ANN,SVM,MLR,RF, and, KNN to make prediction.	Provides a user friendly yield prediction system. Also suggest the best time to use fertilizer.	With a 95% accuracy rate, the Random Forest method proved to be the best for the provided data set.	• The proper time to utilise insecticides is not indicated.

11	Nishu Bali et.al (2021) [7]	The proposed study used ANN, LSTM, RNN, SVM and, KNN methods in the research.	Explore various machine and deep learning algorithms in crop yield prediction and also Explore efficiency of hybrid model.	The Neural Network method, or ANN, displays the best results. Deep learning, one of the more sophisticated machine learning approaches, has demonstrated strong potential for handling large volumes of data.	• Numerous authors overlooked the advice to use fertiliser to boost output. • Irrigation is another crucial aspect in crop production forecast that is seldom discussed.
12	N. Bali and A. Singla (2021) [3]	RNN and LSTM techniques are utilized.	To predict the yield of wheat crop in Ludhiana district of Punjab.	In comparison to ANN and Random Forest, Multivariate Linear Regression (MLR) has Demonstrated larger amounts of errors, notably MSE. The Random Forest model was discovered to provide the lowest levels of errors for all performance indicators among the three machine	• The proposed model only took into account the Ludhiana region. • Border areas in Punjab need to be examined in order to properly anticipate production and prevent losses for farmers.

				learning models.	
13	B. E et.al (2021) [6]	RF and Deep neural network are used by the author.	To increase the ability of Tamil Nadu state to anticipate the rice crop under diverse environmental circumstances	When compared to random forest and deep neural network, the RF-DNN strategy performs better in terms of the various performance indicators.	• To compare net yields and forecast wheat crop productivity for the key producing states. • Promote the use of the optimal fertiliser for the crop.
14	J. Pant, R. P. Pant et.al (2021) [9]	Gradient Boosting ,RF Regressor, SVM and, Decision tree Regressor	Predict the yield of four popular crops of India maize, potato, rice, wheat.	The decision tree regression model predicts agricultural yield with the maximum degree of accuracy. The forecast score of potatoes is the best of the four crops described in the study.	• To more accurately estimate the outcome, the crop yield analysis might be done on a state-by-state basis. • Additionally, only R square is utilised to compare algorithms; other performance metrics are not taken into account.
15	B. M. Nayana et.al (2022) [5]	The author used PCA MARS in his research.	Prediction of wheat for India and top wheat producing states with a comparison.	The results clearly showed that the MARS model fits the data better and is useful for analysing complex non-linear interactions.	• Only two characteristics were used to evaluate the study; therefore, other variables should be taken into account to increase its reliability.
16	S. Lingwal et.al (2022)	RaNN is proposed based on RF and	Determine and forecast crop	In comparison to other methods	• The model predicts Punjab's rice yield, but

	[25]	ANN.	productivity in the Indian state of Punjab using a variety of environmental parameters.	used on the same agricultural dataset, the suggested hybrid RaNN model provides greater prediction accuracy with a 98% correlation between the actual production and the anticipated output.	Punjab is a key wheat-producing state, thus it needs to be looked at. • Additionally, as Python is quicker than R and better suited for machine learning and deep learning, it can be implemented in that language..

Table (1) -Comparative Analysis of different algorithms used for crop yield prediction

ANN: Artificial Neural Network; SVM: Support Vector Machine; KNN: K Nearest Neighbour; RF: Random: Forest; CNN: Convolution Neural Network; LSTM: Long Short term memory; RNN: Recurrent Neural Network; MLR: Multiple linear Regression; PCA: Principal Component analysis; MARS: Multivariate Adaptive Regression Splines; DNN: Deep Neural Network; RELU: Rectified Linear Units;

DISCUSSION

Datasets from various sources were used in all of the researchers' experimental setups. Various types of data, including those related to agriculture, the climate, soil quality, fertiliser use, and pesticide use, are used to predict crop yield. These datasets each contain a unique set of attributes or features. Table 2 describes the datasets used by the researchers . After the data is gathered, various tasks are carried out to prepare it for use, including pre-processing, cleaning, merging, and selection. On the dataset, various classification techniques are used to extract features. Numerous researchers have used various input parameters in their implementation, leading to variations in prediction accuracy. Table 1 describes the various methods used by the authors for predicting the yield of crops. Deep Learning (DL), a branch of machine learning, has recently been applied to the problem of predicting crop yields and is seen to hold great promise. We also found a number of deep learning-based researches in this investigation. The automatic feature extraction and improved performance of DL techniques are just two more encouraging features. Due to DL algorithms' higher performance in other problem domains, we anticipate that more study will be done on the use of DL techniques in crop production prediction in the near future. Much more information regarding the model's accuracy can be revealed once more data has been obtained for training and testing. The models can only be helpful for decision-making throughout the growing season if apps are created that the farmer can use. Predictions will be more accurate when precise parameters for that particular location are measured and added.

Authors	Year	Methodology	Dataset source	Performance metrics
[21]	2019	The author practiced ANN with 3 layer neural network and Linear Regression	Maharashtra state data is taken from kaggle.com website.	ANN-82%
[8]	2020	RNN,DNN is used and comparison is done with other machine learning models	Climate data is taken from Indian Meteorological Department	ANN -90.5% RF – 70.7% GB-81.2%
[23]	2021	ANN,SVM,MLR,RF, KNN are utilised in the study.	The sources of dataset areData.gov.in,Kaggle.com and, indianwaterportal.com	ANN-86% SVM-75% MLR-60% RF-95% KNN-90%
[9]	2021	Gradient boosting, RF Regression, SVM and, Decision tree Regression are employed by the author.	Agriculture data is extracted from FAO (Food and Agriculture Organization) repository. Climate data is collected from world data bank.	GB-89% RF-68% Decision tree-96%
[6]	2021	RF and Deep neural network are applied in the research work.	Tamil Nadu state data is used and it is taken from websiteKaggle.com	RF-86.9% DNN-72.5% RF+DNN-92.1%
[16]	2021	Deep learning, SVM, LSTM and, RNN are the methods given by the author.	Website Kaggle.com is used for data collection.	ANN+ RF-93% LSTM+RNN+SVM-97%

[3]	2021	RNN and LSTM is used. Comparison is performed with machine learning models like ANN,MLR and, RF	Yield data is extracted from statistical abstract of Punjab and Weather data is gathered from meteorological department of Punjab.	RNN with LSTM RMSE-147.12 MAE-60.50 MSE-21644.59 ANN RMSE-732.14 MAE-623.13 MSE-536027.56 RF RMSE-540.88 MAE-449.36 MSE-292549.09 MLR RMSE-915.64 MAE-796.07 MSE-838398.33
[25]	2022	RaNN is proposed based on RF and ANN. Performance is compared with other machine learning models SVM, RF, MLR and, Boosting Regression.	Agriculture data from Punjab ENVIS Centre and, Climate data from Indian meteorological Department Pune	MLR-61.91% RF-89.22% SVM-69.13% ANN-81.07% RaNN-98.880%

Table (2) - Dataset and Performance Measures used

Performance metrics are used in the evaluation of previous results by various authors. Different types of measurements are taken into account for comparison. A few of them are Accuracy, F1 score, recall, RMSE, MAE, MSE, R-square.

SNO	Algorithm	Accuracy
1	Multiple Linear Regression	60%
2	Deep Neural Network	72.5%
3	Support Vector Machine	75%
4	Random Forest	80.15%
5	Gradient Boosting	85.1%
6	Artificial Neural Network	86.16%
7	K Nearest Neighbour	90%
8	Random Forest with Deep Neural Network	92.1%
9	Artificial Neural Network with Random Forest	93%
10	Decision Tree	96%
11	Long Short Term Memory with Recurrent Neural Network and Support Vector Machine	97%

Table (3) - Comparison of algorithms used in previous research

Table 3 displays the average accuracy of different algorithms used by the previous researchers. Hybrid algorithms give more accurate result as compared to others. Fig 2 depicts the comparison of different algorithms in terms of accuracy. It concludes that the combination of LSTM, RNN and SVM gives the higher accuracy as compared to other algorithms

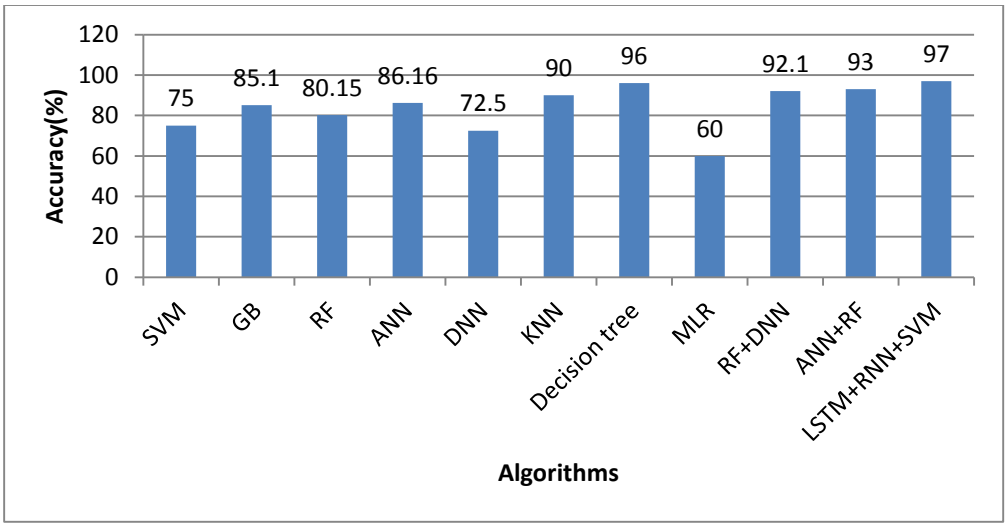

Figure-2.Performance analysis of various algorithms

CONCLUSION AND FUTURE WORK

This review compares and contrasts many cutting-edge ML and deep learning algorithms from 2018 onwards to predict the yield of crops depending on the dataset availability. The existing models utilised SVM, KNN, ANN, MLR, RF, and some deep learning techniques for better predictions and accuracy. All have considered different input parameters in their study, such as temperature, humidity, rainfall, area and, season . The most used features are temperature rainfall, humidity. Not usually the same type of data is used as the most popular characteristics. For instance, temperature is measured as the average temperature but additional parameters like the highest temperature and minimum temperature are also applied. Fertilizers and soil parameters can also be considered. The choice of features depend on the requirement of the problem and also affect the evaluation of the model. It was evident from this study that artificial intelligence is growing rapidly in the agricultural sector. Therefore, the researchers can focus on real-time datasets and a variety of crops for their research. Because the agriculture data primarily rely on real-world data, the work needs to be more focused on RNN. In future the research can be conducted for a particular crop like wheat for a particular geographical location. Hybrid aproach can be followed to make better and accurate predictions regarding crop yield. Detection of disease can be done stage wise to increase the yield. More research can be carried by increasing the number of parameters like pesticide use, fertilizers, and soil properties. Recommendation of suitable fertilizer can also help to increase the yield. It is past due for the agriculture industry to go digital so that not only the government but also the society may benefit from it. It will just take one small step from us to implement a digital agriculture system that will allow for the optimum crop selection and yield prediction.

REFERENCES

[1] “Agriculture in India: Industry Overview, Market Size, Role in Development...| IBEF.” https://www.ibef.org/industry/agriculture-india (accessed Oct. 05, 2022).

[2] M. K. Dharani, R. Thamilselvan, P. Natesan, P. C. D. Kalaivaani, and S. Santhoshkumar, "Review on Crop Prediction Using Deep Learning Techniques," *J. Phys. Conf. Ser.*, vol. 1767, no. 1, 2021, doi: 10.1088/1742-6596/1767/1/012026.

[3] N. Bali and A. Singla, "Deep Learning Based Wheat Crop Yield Prediction Model in Punjab Region of North India," *Appl. Artif. Intell.*, vol. 35, no. 15, pp. 1304–1328, 2021, doi: 10.1080/08839514.2021.1976091.

[4] B. Sharma, J. K. P. S. Yadav, and S. Yadav, "Predict Crop Production in India Using Machine Learning Technique: A Survey," *ICRITO 2020 - IEEE 8th Int. Conf. Reliab. Infocom Technol. Optim. (Trends Futur. Dir.*, no. 978, pp. 993–997, 2020, doi: 10.1109/ICRITO48877.2020.9197953.

[5] B. M. Nayana, K. R. Kumar, and C. Chesneau, "Wheat Yield Prediction in India Using Principal Component Analysis-Multivariate Adaptive Regression Splines (PCA-MARS)," *AgriEngineering*, vol. 4, no. 2, pp. 461–474, 2022, doi: 10.3390/agriengineering4020030.

[6] B. E and G. A, "Rice Crop Yield Prediction Using Random Forest and Deep Neural Network - An Integrated Approach," *SSRN Electron. J.*, no. Icsmdi, 2021, doi: 10.2139/ssrn.3852547.

[7] N. Bali and A. Singla, "Emerging Trends in Machine Learning to Predict Crop Yield and Study Its Influential Factors: A Survey," *Arch. Comput. Methods Eng.*, vol. 29, no. 1, pp. 95–112, 2022, doi: 10.1007/s11831-021-09569-8.

[8] D. Elavarasan and P. M. Durairaj Vincent, "Crop Yield Prediction Using Deep Reinforcement Learning Model for Sustainable Agrarian Applications," *IEEE Access*, vol. 8, pp. 86886–86901, 2020, doi: 10.1109/ACCESS.2020.2992480.

[9] J. Pant, R. P. Pant, M. Kumar Singh, D. Pratap Singh, and H. Pant, "Analysis of agricultural crop yield prediction using statistical techniques of machine learning," *Mater. Today Proc.*, vol. 46, no. xxxx, pp. 10922–10926, 2021, doi: 10.1016/j.matpr.2021.01.948.

[10] M. K. D. P, N. Malyadri, M. S. Srikanth, and A. B. J, "recommendation model for Crop and Fertilizer," vol. 8, no. 5, pp. 10531–10539, 2021.

[11] A. Sharma, A. Jain, P. Gupta, and V. Chowdary, "Machine Learning Applications for Precision Agriculture: A Comprehensive Review," *IEEE Access*, vol. 9, pp. 4843–4873, 2021, doi: 10.1109/ACCESS.2020.3048415.

[12] S. Vaishnavi, M. Shobana, R. Sabitha, and S. Karthik, "Agricultural Crop Recommendations based on Productivity and Season," *2021 7th Int. Conf. Adv. Comput. Commun. Syst. ICACCS 2021*, pp. 883–886, 2021, doi: 10.1109/ICACCS51430.2021.9441736.

[13] A. H. Tidake, Y. K. Sharma, and V. S. Deshpande, "Design Efficient Model to Increase Crop Yield Using Deep Learning," *Proceeding - 1st Int. Conf. Innov. Trends Adv. Eng. Technol. ICITAET 2019*, no. Dl, pp. 221–226, 2019, doi:

10.1109/ICITAET47105.2019.9170227.

[14] S. M. Bharath, S. Manoj, P. Adhappa, P. L. Patagar, and R. Bhaskar, "Crop Yield Prediction with Efficient Use of Fertilizers," *Lect. Notes Electr. Eng.*, vol. 783, pp. 937–943, 2022, doi: 10.1007/978-981-16-3690-5_87.

[15] U. Shruthi, V. Nagaveni, and B. K. Raghavendra, "A Review on Machine Learning Classification Techniques for Plant Disease Detection," *2019 5th Int. Conf. Adv. Comput. Commun. Syst. ICACCS 2019*, pp. 281–284, Mar. 2019, doi: 10.1109/ICACCS.2019.8728415.

[16] S. Agarwal and S. Tarar, "A hybrid approach for crop yield prediction using machine learning and deep learning algorithms," *J. Phys. Conf. Ser.*, vol. 1714, no. 1, 2021, doi: 10.1088/1742-6596/1714/1/012012.

[17] P. Malik, S. Sengupta, and J. S. Jadon, "Comparative Analysis of Soil Properties to Predict Fertility and Crop Yield using Machine Learning Algorithms," *Proc. Conflu. 2021 11th Int. Conf. Cloud Comput. Data Sci. Eng.*, pp. 1004–1007, 2021, doi: 10.1109/Confluence51648.2021.9377147.

[18] R. Kumar, M. P. Singh, P. Kumar, and J. P. Singh, "(Paper 7 Tafur)," no. May, pp. 138–145, 2015.

[19] S. Godara and D. Toshniwal, "Deep Learning-based query-count forecasting using farmers' helpline data," *Comput. Electron. Agric.*, vol. 196, no. February, 2022, doi: 10.1016/j.compag.2022.106875.

[20] V. Meshram, K. Patil, V. Meshram, D. Hanchate, and S. D. Ramkteke, "Machine learning in agriculture domain: A state-of-art survey," *Artif. Intell. Life Sci.*, vol. 1, no. September, p. 100010, 2021, doi: 10.1016/j.ailsci.2021.100010.

[21] S. S. Kale and P. S. Patil, "A Machine Learning Approach to Predict Crop Yield and Success Rate," *2019 IEEE Pune Sect. Int. Conf. PuneCon 2019*, pp. 1–5, 2019, doi: 10.1109/PuneCon46936.2019.9105741.

[22] D. J. Reddy and M. R. Kumar, "Crop yield prediction using machine learning algorithm," *Proc. - 5th Int. Conf. Intell. Comput. Control Syst. ICICCS 2021*, pp. 1466–1470, May 2021, doi: 10.1109/ICICCS51141.2021.9432236.

[23] S. M. Pande, P. K. Ramesh, A. Anmol, B. R. Aishwarya, K. Rohilla, and K. Shaurya, "Crop Recommender System Using Machine Learning Approach," *Proc. - 5th Int. Conf. Comput. Methodol. Commun. ICCMC 2021*, pp. 1066–1071, Apr. 2021, doi: 10.1109/ICCMC51019.2021.9418351.

[24] S. Sharma, S. Rai, and N. C. Krishnan, "Wheat Crop Yield Prediction Using Deep LSTM Model," 2020, [Online]. Available: http://arxiv.org/abs/2011.01498.

[25] S. Lingwal, K. K. Bhatia, and M. Singh, "A novel machine learning approach for rice yield estimation," *Journal of Experimental and Theoretical Artificial Intelligence*. 2022, doi: 10.1080/0952813X.2022.2062458.

[26] P. S. Nishant, P. Sai Venkat, B. L. Avinash, and B. Jabber, "Crop yield prediction based on indian agriculture using machine learning," *2020 Int. Conf. Emerg. Technol. INCET 2020*, no. October, 2020, doi: 10.1109/INCET49848.2020.9154036.