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Crop Yield Prediction using Machine Learning and Deep Learning Techniques

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Abstract— Crop yield prediction has been designated as a major predictive analysis technique that increases the potential of the agricultural industry. The utilisation of such a measure has been important for the farmers to understand the yields of crops during the particular season from a data analytical point of view. Such an aspect has fallen under the concept of predictive analysis which allows the farmers, agricultures, and farming businessmen to make strategic decisions in terms of cultivation. The application of predictive analysis has been useful for understanding the specific set of crops to be sown during the season, and the types of fertilisers to be applied to the crops for an increased output. Risk analysis with the help of predictive modelling of crops helps in the improvement of the overall agriculture business and increases the potential of the farmers to improve their revenue collection. Once they have the potential of understanding the specific parameters of agriculture, the decision making for reducing the risks, increasing the overall gain from the crops, and such other aspects can be easily known. Predictive analysis allows the farmers to gain an expansive amount of knowledge regarding the weather conditions in the future, the quality of the soil for growing the crops, the nutrients required which are to be replenished for increasing the crop field, and several such parameters. Machine Learning or ML and Deep Learning or DL methods have been seen to be extremely important for data analysis and predictions. Several kinds of tools and techniques such as neural networking, Bi GRU, Maxout classifiers, and others have been applied within the agricultural industry. The study would lead to an extensive analysis of the different kinds of Machine Learning and Deep Learning techniques used for increasing the crop yields by prediction analysis. Such a measure would prove to be extremely important to make significant decisions regarding the importing and exporting of crops, and the pricing structure for the grains to be sold in the market. The distribution of crops and also making fruitful decisions regarding future crop plantations can also be inspected with the help of the ML and DL tools.

Keywords- Crop yield prediction, Machine learning, Deep learning, Neural networking, CNN, RNN, LSTM, Bi GRU, Maxout classifiers.

I. INTRODUCTION

The induction of improved food security and providing elaborate evidence regarding the optimum management of agriculture is significantly important to reducing food shortage on the global level. The need for prediction analysis regarding crop yield increases the potential of the farmers to perform management practices from the initial levels and help in making estimated decisions regarding the plantation of the crops [3]. Arrange of machine learning tools have been integrated within the agricultural industry for developing high quality prediction analysis of crop yield. Machine learning falls under the branch of Artificial Intelligence or AI which enables the digital systems to acquire informative knowledge from data without an extensive programming of the same [18]. With the help of ML, there is the ability of the computers to analyse humongous amounts of information and help to identify the patterns within the evidence to develop predictions [7].

The utilization of a wide number of tools has been seen to provide multidimensional and multifaceted data for the improvement of accuracy in terms of crop yield. The competition methods have helped in revealing the variability in the cropping which allows the farmers to have a more efficient monitoring system about the special and temporal aspects of the grounds [1]. The development of site-specific crop management systems has been encouraged with the usage of ML tools, which have increased the planning of fertilizers and nutrients towards the specific area of land. During times of extensive climate change, multi-dimensional factors of crop yields need to be taken into strict consideration for having effective environmental management and deduced using the different kinds of complex interactions of the crops with the environment [17].

With the help of optimizing power, a greater amount of agriculture and economic insights can be gained by the researchers on the farmers with the help of the different kinds of ML and DL tools [6].Visualization of the data has helped

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revolutionizing the agriculture industry and increased the ability of the farmers to set informative decisions regarding their crop yields [9]. Through improved accuracy of predictions, the workers have the potential to increase the overall efficiency of the season and allowing to enhance sustainability within the grounds.

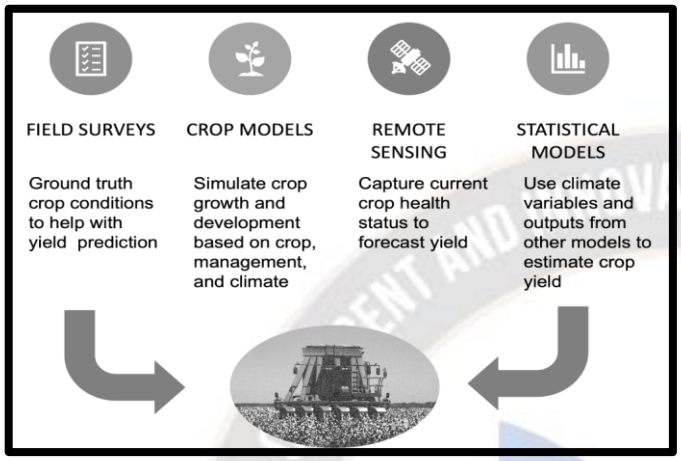

Figure 1. Different methods used in crop management practices [2]

As illustrated in figure 1, different kinds of tools such as field surveys, modelling of the crops, usage of remote sensing, and application of statistical models have been approached for increasing the potency of crop management measures. Through the development of profitable businesses, the global economic and agriculture sector would be significantly improved and innovative measures can be for the integrated into the future endeavours [2].In machine learning, a significant number of tools and techniques such as classifiers, neural networks, Bi GRU, LSTM, and optimization algorithms have been prevalent to make crop yield predictions [8]. Each of such techniques helps to make model decision-making and examine each of the factors that have a direct impact on the growth and development of the crops [4]. There has also been the application of data regression methods which increases the potential of effective crop yield predictive analysis.

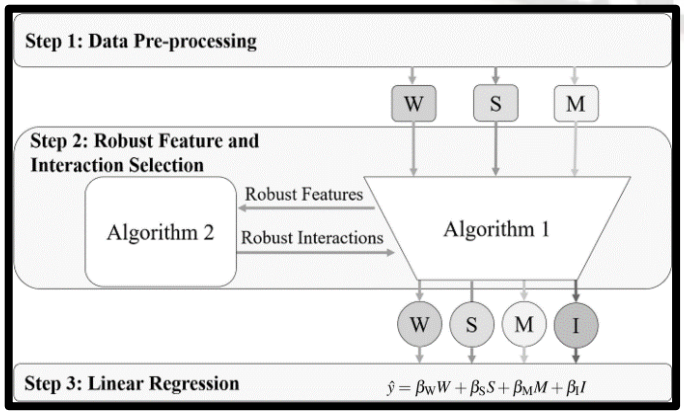

Figure 2. Three steps of regression analysis in crop yield predictions [5]

As mentioned in figure 2, three significant steps have been identified to play major roles in obtaining results of prediction analysis. The first step occurs where a prep processing of the data is performed followed by the selection of the robust features and the robust interactions between the two algorithms [5]. The third step is when regression analysis is enabled for the cropping prediction with the help of a multiple linear regression model [5]. Therefore, different kinds of machine learning tools and techniques can be applied within the predictive analysis to achieve the necessary outcomes of the project.

II. OBJECTIVES

The objectives constructed for the study are as follows:

RO1: To examine the inclusion of classifiers as a model of ML for predicting crop yield in agriculture

RO2: To assess the utilization of CNN and RNN in crop yield prediction

RO3: To inspect the application of Bi GRU in crop yield prediction

RO4: To scrutinize the importance of Maxout classifiers in crop yield prediction

RO5: To analyse the significance of LSTM in predicting crop yield

RO6: To examine the integration of optimization algorithms for testing crop yield

III. METHODOLOGY

The expansion of agricultural productivity has been directly linked to the increase in crop yield and the making of strategic crop management decisions [13]. Shifting from the traditional methods towards scientific decision making through automated techniques such as ML and DL has allowed the integration of computational models for improving the agricultural notions. Through the designing of efficient agriculture strategies, the policymakers of the agricultural industry and the farmers have the potential to ensure that food is safe and available to consumers for a long span of time in the future [20]. Such an aspect has been greatly beneficial in making informed decisions and picking tactical financial strategies to increase the overall potential of crop storage for both businessmen and customers [11]. The concept of crop yield refers to the numerical ratio present between the agricultural input and the agricultural output on a per unit area basis of cultivated land. Due to the fact that the increase in the crop yield relates to the increased productivity of agriculture, such a factor also acts as an indicator of agricultural efficiency.

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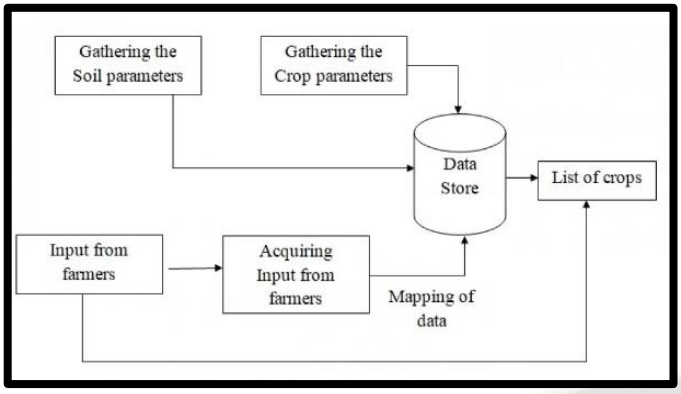

Figure 3. Flowchart showing the stepwise integration of input data for an effective forecast in crop yield [19]

A range of factors have been seen to have a direct impact on the productivity of agricultural ground such as the changes in the soil, the demands of the consumers, the presence of pests and pathogens, the climatic conditions, and several others [10]. Noted in figure 3, different factors and parameters are to be taken into consideration for bringing about a fruitful forecast of the data for the prediction modelling of crops. Therefore, the monitoring of the range of factors allows the farmers to develop strategic procedures for increasing the agricultural productivity of the nations. The usage of machine learning has refined the power of predicting crop yield and the presence of statistical models has helped the extrapolation of the available data from the past [16]. With the help of intelligent computational methods, the improvement of crop yield predictive analysis can be performed by the farmers and the researchers.

IV. ASSESSMENT OF CLASSIFIERS AS A MACHINE LEARNING MODEL

In the context of ML, a classifier is a specific algorithm that has the potential to automatically segregate data into various classes. Utilization of such a tool helps in the automation of the tasks regarding the distribution of the data into various categories based on certain traits and characteristics. Specifications are integrated during the development of such classifiers which allows the distribution of the data and the evidence based on their characteristics. Two specific kinds of classifiers can be identified within machine learning such as supervised and unsupervised classifiers [24]. With the help of unsupervised classifiers, the data which contain different anomalies are integrated within the unlabeled dataset.

On the other hand, in the case of supervised classifiers, there is the presence of shining data sets, which help the algorithm to determine the characteristics of the evidence through the analysis of the pre-developed categories. One of the major classification algorithms which have been seen to be utilized during the forecasting of crop production is the decision tree algorithm. With the help of such classification tools, the segregation of the data is performed based on the model decisions and the different results that can be predicted by the algorithm [30]. A significant input factor such as the temperature or the soil variant is taken to be the input data, which is then examined in different stages to make strategic decisions and reach the potential outcome. In such an algorithm, different inputs are fed into various lays which helps in diverging the outcome of crop yield.

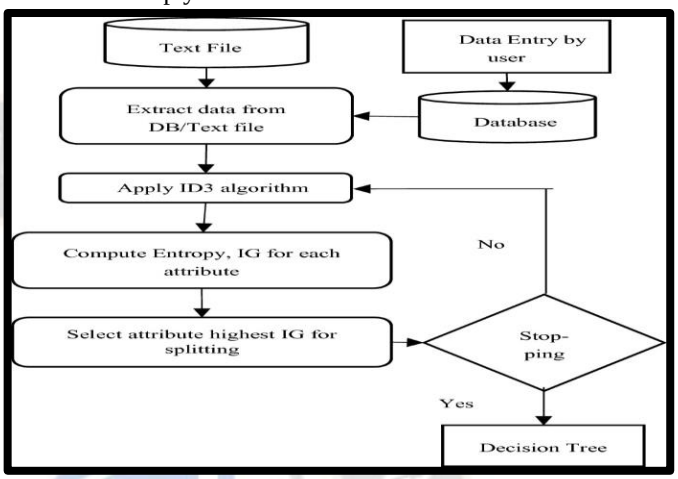

Figure 4. Decision tree model of assessing crop productivity [25]

As noted in figure 4, the text file containing the past data is integrated into the system, which is then processed through various layers for the extraction of the evidence and selection of various attributes for their examination. The processing of the information for the decision tree helps the researchers and the farmers to analyse the yield of the crop. For assessing the information with the help of the random forest method data cleansing is strictly important as it helps in identifying the missing gaps in the data set. Such values are to be filled to uplift the overall quality of the past data to make effective outcomes and decisions from the assessment [21]. With the help of the random forest network, the supervised classifier enables the classification and the regression of the issues, which helps in bringing forth an average decision-making based on the given output from the algorithm. Such a condition proves to be extremely important for the farmers to predict the kinds of crops to be grown along with their appropriate amount of fertilizers to be incorporated in the soil.

V. ANALYSIS OF BI-GRU IN CROP YIELD PREDICTION

GRU or Gated Recurrent Unit is a form of RNN that induces the Processing of different kinds of sequential information such as text variables, audio format, and time series information. The use of gated mechanisms of GRU is necessary for selectively passing and updating the information present in the hidden layers in DL [25]. Such a measure takes into consideration the extent of the flow of information through the

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network at every stage and time step. Two distinguished forms of gating mechanisms are present in GRU, named as reset gate and the update gate [16]. In the former case of the reset gate, the determination of the extent to which the previously hidden layer is to be omitted is inspected. On the other hand, in the case of the update gate, extends to which the new data input is used for updating the previous less identified. Hence, the integration of both the mechanisms of gating is considered during the passage of information and the updating of the hidden layers, with the integrated information.

In the case of Bidirectional GRU or Bi GRU, there is the application of two GRUs. One takes in information to move in the forward direction and the other integrates the data for the previous hidden layer. Such a form of RNN is seen to work in both directions and the model has the capacity to make the necessary decision regarding which direction needs to be started from. Transformation of the input data into the different forms of word vectors is allowed with the help of Bidirectional Encoder Representation from Transformers or BERT. Such a stage consists of the numerous amounts of information regarding the different parameters of the soil quality such as the acidic and the basic levels, the amount of water holding capacity, and the salinity of the soil. The second step is the formation of the regularisation constants, which consists of the different characteristics to be analysed from. The third step is necessary to examine the parts of speech from the input word vectors with the help of the designated attributes of the data [20]. The effective output hence relates to the juggling of information between the previous and the next player in Bi GRU. Such an aspect proves to be significantly important for improving the overall accuracy of the data set and also enabling the farmers to gain an improved Idea regarding the predicted soil capacity. In such a manner, strategic decision-making norms can be formulated within the agricultural industry to induce an improved working capacity of crop management [28].

VI. EXAMINATION OF CNN AND RNN IN CROP YIELD PREDICTION

CNN or Convolutional Neural Network and RNN or Recurrent Neural Network are two forms of artificial neural network that help in the examination of different types of data that are linked to each other based on their already identified attributes or factors [23]. One of the major advantages that has been identified in the application of such a process is the studying of the dependency between the environment and factors with that of the crops. Along with such, the examination of the genetic improvements within the seeds has also been studied with the help of the CNN-RNN model. Such a feature had taken into consideration the lack of genotype information and helped in the prediction of the future genetic improvement of seeds. The model of CNN-RNN has been seen to generate the capacity to predict the untested environments without tree requisite data information regarding the linear and nonlinear impacts of variables such as the weather and soil type [22].

With the usage of the RNN model, the capturing of the information related to the soil variations in the field can be recorded by the examiners and the farmers. The time dependency regarding the amount of crop yield over a specific amount of time can be applied using such a model as contrasting observations can be formulated from such an algorithm. Temporal dependencies have been seen to be present within the notes of such a system, which helps in bringing about a directed graph for understanding and examination of genetics of the crop models. With the conclusion of LSTM cells in the RNN, the reference neurons can capture the various dependencies of input data with the passive time. Once compared against other models of the time series, the utilisation of such LSTM cells proves to be resourceful, as they do not have the requisites to be specified, based on the nonlinear functions, which are to be estimated [31].

On the other hand, the application of CNN helps in the processing of multiple arrays within the data sets, which can be either one-dimensional, two-dimensional, or of three-dimensional. In the case of the one-dimensional dataset, the variables are in the form of signals and sequences [27]. On the other hand, in the case of the two-dimensional dataset, the information is in the form of images, and lastly, videos are present in the arena of three-dimensional information. With the help of the design parameters such as the filter of the information, the different kinds of crop production factors can be processed to preserve the information in the input space. Such a concept proves to be highly important during forecasting of the crops' parameters as sequence modelling applications can help in remembering and analyzing a significantly large volume of information. The usage of remotely sensed images has been seen to proliferate in the case of CNN RNN model usage, which increases the visual potential of examining the data. Such a situation is enabled with the usage of optimized feedback variables supplied from the ends of the satellite images and the products of meteorological inspections.

VII. INSPECTION OF MAXOUT CLASSIFIERS IN CROP YIELD PREDICTION

Maxout Network or Classifiers helps in the classification of images in the form of linear function which has the capability to return to the maximum value of the input variables. Such a form of classifier had been deliberately designed to be used in combination with dropout, which allows for the maximisation of the accuracy levels [24]. The utilisation of such a tool has been based on the consuming of the hidden units, which behave as a universal approximate measuring unit. The behaviour of the averaging or approximations of Maxout networks helps in providing effective training of the deeper networks. The

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application of such a tool has been seen to be useful in the predictive analysis of the crops and related agricultural aspects, as the averaging opportunity of the related variables has been stimulated. Such a condition has been seen to play a vital role in mediating the approximate valuation of the predictions, and necessary tactics can be considered based on the values. The integration of such a measure in the agricultural industry in the future would tend to be highly advantageous as the assessment of both the pros and the cons of the variables are issued with the Maxout classifiers.

VIII. IMPORTANCE OF LSTM IN PREDICTING CROP YIELD

LSTM or Long short-term memory approaches have been taken into consideration for evaluating the different kinds of agriculture products and their future with the help of prediction accuracy. Such a tool falls under the recurrent neural network or RNN, which helps in providing short-term memory to the NN and helps it to expand over an extensive number of stages. The study has recorded a range of optimization algorithms, which have been seen to be prevalent in deep learning measures such as Momentum, Adam, and Adagrad. The importance of such optimisation algorithms have been stated in the study which helps in dissecting the different problems of crop yield management and helps in bringing forth improved decision making. Each of the optimisation algorithms and their aligning benefits have been recorded in the study to have and elaborate examination of their importance in forecasting about crop growth and arrangement. Therefore, the study has provided an extensive examination of the different kinds of computational tools and techniques belonging to machine learning and deep learning for increasing the overall productivity of the agriculture business. Such an aspect has also been seen to bring forth an improvement in the working measures within the community of the farmers.

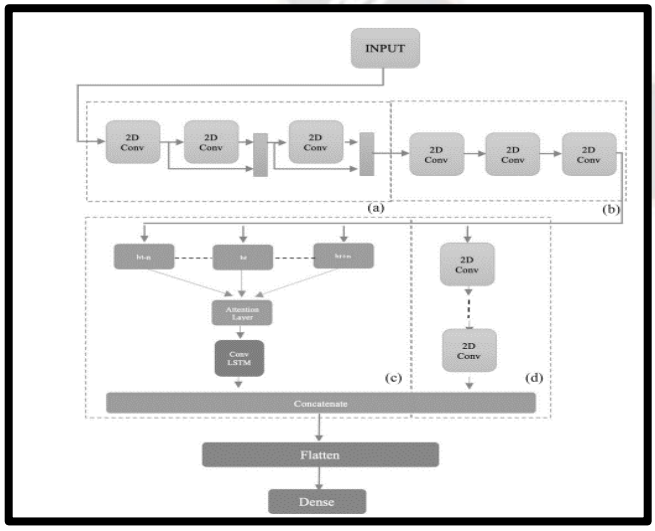

Figure 5. LSTM approach as Deep learning architecture for data examination in case of crop prediction modelling [19]

The introduction of such a step helps to make strategic decisions regarding the parameters as an extensive amount of long short-term memories are present within the algorithm. The inculcation of new advanced innovative measures has been induced with data from satellites such as the soil condition, the water intake capacity, the utilisation of fertilisers, and others for an optimal decision-making process [26]. The achievement of an effective accuracy rate during the periods of cultivation and the harvesting of the crops have been enabled with the aid of the LSTM mechanism. In such a scenario, three specific gates are used for controlling the flow of information between the input and the output of the cells. With the presence of selective release of information from the output gate, the LSTM network has the capacity to remain extremely useful for a significant amount of time [28]. The extraction of the features is enabled with the help of skip connection present in such a tool where the transition of memory between the different hidden layers of deep learning is associated with the preservation of information as illustrated in the above image, several layers have been seen to be skipped during the transmission of information from one layer to another [19]. With the help of such skip connection procedure, the gradation of the information can be done which allows the preservation of the information. In such a manner, during the forecasting of crop productivity, necessary information regarding the traits and the attributes of the information will not be lost or diluted during the transmission of information.

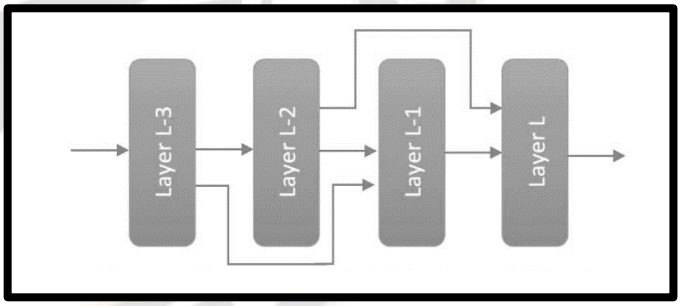

Figure 6. Skip connection in different layers of DL in LSTM approach [19]

IX. INCLUSION OF OPTIMIZATION ALGORITHMS FOR TESTING CROP YIELD

A range of optimization algorithms have been seen to be applied within the management practices as computational models for increasing the potential of crop yield forecasting [29]. The application of optimization algorithms is necessary to increase the efficiency of the models by training the algorithm with a pre-developed dataset. The major advantage of optimizing helps in the minimization of the loss function scene in the case of deep learning. With the ability of the algorithms to examine a humongous amount of data and understand the possible solutions regarding the information, the necessary solutions can be identified by the researchers. On the other hand, the aggregation of the large volume of data increases the

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overall responsiveness of the algorithm and helps to bring down the computational time. In such a manner, the identification of the results and forecasting of the crop yields have been seen to be easily performed with the help of the optimization algorithms [27]. The application of search tools have also been seen to have significance based on the different types of algorithms applied. For instance, Momentum, Adam, and Adagrad have been identified as major optimizing algorithms, which affect speed of the training model. Such an aspect has been seen to vital impact on the time efficacy of the tools and overall effects the decision making process of the farmers.

In the case of Momentum, one of the major benefits have been seen in the strategic notions of assisting the optimizer to continue in the same direction even with the change in the gradient. With the help of such a measure, the optimization algorithm has a potential to update the data set or the parameter with the present problems, which further has an accelerated motion on the optimization process. With inclusion of several updates, the capacity of the algorithm to examine the different varieties of attributes regarding crop yield can expand. Such a concept has been used for measuring the increase within the potential of the machine learning system to make accurate decisions by examining a further larger amount of data within the system [10]. With the usage of Big Data and the Machine Learning algorithms, the already presented and defined set of training examples helps the further development of the attributes and brings into limelight the further enriched set of information. Such a measure increases the overall potency of the dataset, and a highly accurate result can be approached.

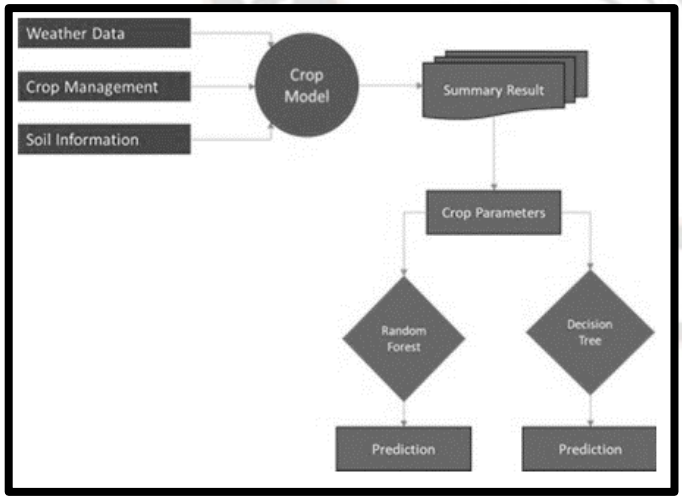

Figure 7. Inclusion of data factors in crop model for modelled prediction [4]

On the other hand, the application of the optimization algorithms of Adam or adaptive moment estimation has been useful to determine the updated skill of parameters with the application of exponentially decaying mean value of the gradients. Adam also applies the momentum-optimizing algorithm to increase their optimization levels in a more functional manner without the loss of data. Such a tool behaves to increase the accuracy of conducting strategic detections. Through the defining of the rules and identification of the different patterns within the large data sets, optimization algorithms have the ability to identify the amount of irrigation required, focus on the properties of the soil, and help in recognizing the dosage of fertilizers. With the optimization of the past data with momentum, the predictive variables can be further proliferated with an extensive amount of data and their respective traits.

X. PROBLEM STATEMENT

The forecasting regarding the different factors of crop growth and productivity has been linked to the quality of data, which is integrated into the computational models for their examination [9]. Certain limitations have been identified within such procedures, which decreases the accuracy of prediction analysis and causes slight mismanagements within the crop management techniques.

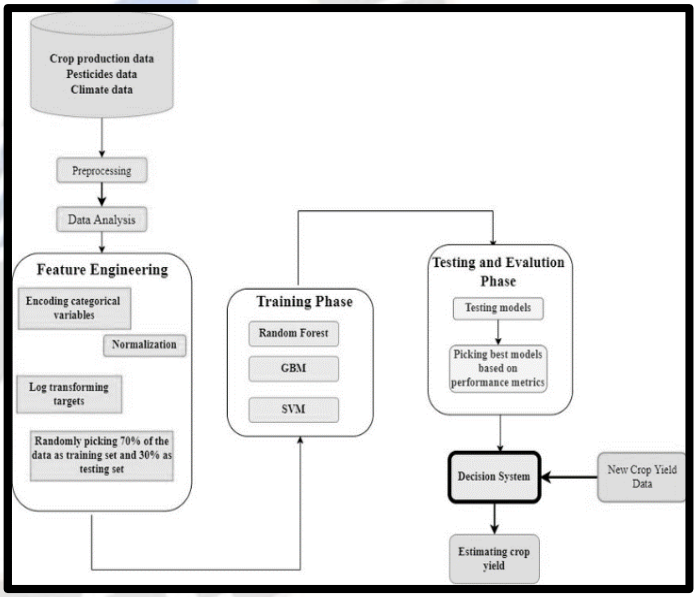

Figure 8. Complicated procedures in forecasting crop yield data by Random Forest method [26]

As recorded in the overhead figure, a significant number of procedures occur with DL for the assessment of the input data for crop productivity forecasting. Due to the fact that predictive analysis is one of the most innovative and advanced scientific tools, a large number of highly skilled and experienced employees are not present in the agriculture industry [15]. For instance in the case of neural networks, one of the major limitations is the decreased ability to perform highly accurate data prediction as the selection and sorting of the data is highly complicated [12]. Having skilled and supervised workers and researchers to examine the quality of the data and analyse the results is of extreme importance. Therefore, the presence of

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complicated architecture of the models behaves as a chief issue present within the application of such in the industrial background.

DL techniques have a significant shortcoming of the inability to capture the present non- linear associations occurring between the factors of input and output. During the stage of sorting, the understanding of the non- linear relationships between the input and output variables is of acute importance for developing an efficient forecast. However, due to such a lacking within the deep learning method of multiple linear regression analysis, a decreased accuracy of data prediction is identified within the tool [19]. With the recognition of the different limitations in each of the models, a buffer zone of uncertainty needs to be created within the management system of agriculture where strategic measures to reduce risk can be entangled. In such a manner, the policy makers and the farmers would have an initial management practice system to reduce the unforeseen risks occurring within crop production and reduced crop yield [14]. Therefore, the recognition of the limitations prove to be significantly important for increasing the overall potential of the tools in future and inducing heightened accuracy.

The study has provided an in- depth assessment of the different classifiers of machine learning required in crop yield management such as logistic regression and random forest. It has been recorded that random forest has provided a greater amount of accuracy than the other measures, which helps the farmers to invest on suitable crops as per the weather conditions. The study has also identified that the utilisation of LSTM has proven to be useful for laying an assessment of the factor of temperature, which has a dramatic impact on the increase of crop yield. In terms of optimization algorithms in DL, they have been required for allowing the inclusion of necessary adjustments within the model parameters. Such an aspect has been identified to be extremely significant in the minimization of the loss function and increases the overall accuracy of the computational models.

XI. CONCLUSION

Hence, the study provided and overall examination of the different kinds of machine learning and deep learning tools integrated into the agricultural industry for forecasting regarding crop yield. With the help of a neural network, the genotype and environmental analysis of different crops can be examined which helps in understanding the functional relationship between the aligning factors and crop productivity. The study has also identified CNN and RNN framework for crop yield prediction as efficient, which allows the application of developing data management practices. With the capturing of the time dependencies regarding the different elements of the environment, yield prediction in an untested agriculture land can be forecasted by the farmers. Therefore, an expensive area can be brought under consideration by the agricultural industry with the help of data protection analysis.

Along with such, the study has also inspected the parameters of weather conditions with the help of machine learning tools, which increases the potential of the farmers to judge whether a particular piece of land during the respective season is habitable for the growth of crops. The development of knowledgeable management practices by the farmers to have a successful crop field has turned to be difficult due to the complicated environment and complex introductions between the crops and the natural environment. The study has focused on the different hidden layers of deep learning to have improved prediction analysis than artificial neural networks. The usage of Bi- GRU as a type of RNN has been seen to be resourceful in the processing of sequential data belonging to the text form, speech or time series evidence. The gated mechanisms utilised in such an aspect has been seen to be necessary for controlling the amount of information going in or coming out of the network system. The study has elaborated on the selective updates of each of the hidden layers in the Deep Learning, enabling it to increase the potential of sequential modelling. Therefore, the application of DL tools such as LSTM, CNN and RNN have been proven to be extremely important.

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