Review on Crop Prediction Using Deep Learning Techniques

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Abstract. Agriculture is the very important sector of each country, where the gross domestic pay relies on it. The outcome of the agriculture or crop management was completely based on the end yield and the market rate. The complete factor of the crop yield depends on timely monitoring and suggestion. Artificial intelligence gives a way to monitor the crop and to predict the yield in an automatized outcome. The study has been made on the deep learning and its hybrid techniques such as Artificial neural network, deep neural network and Recurrent neural network. It helped to identify how the technology of artificial intelligence helps to improve the crop yield. The research study clearly gives the idea and need of recurrent neural network and hybrid network in the field of agriculture. It also shows how it outperforms the other networks such as artificial neural network and convolutional neural network. The results were analyzed and the future perspectives were drawn with the obtained outcome.

1. Introduction
Agriculture is the one of the important sector in the country with respect to the economic and the sustainability. In today’s world as the importance and the need of agriculture was increasing with the increase in population. The production of agriculture has to be improved in order to have a sustainable balance. The sustainable production of the crop mainly depends on various factors such as environment, climate, soil, water, etc [1]. The outcome of the agriculture was measured by its crop yield. The crop yield mainly depends on the factors of agriculture. The process of agriculture was broadly classified into two categories such as pre sowing process and post sowing process. The stage of pre sowing process includes climate analysis for sowing period, soil nutrient analysis, formulating the texture of the soil, and appropriate crop based on soil type. In the stage of post sowing process it flows with the major part of the crop management which includes pest management, irrigation, and fertilizer management, and weed management, usage of tools and proper time of harvest. The each step in the pre and post sowing process plays a defined role in crop yield. If all steps are said to be in defined manner and well followed then the attainment of yield would be higher. In this advanced technology precision agriculture plays a major role where the optimized system of agriculture can be
made. This practice is prevailed in foreign countries where the agriculture is completely automatic with the drone surveillance and the monitoring of Internet of Things (IoT) [8].

2. Role Of Deep Learning In Agriculture
Deep learning is the integral part of Artificial Intelligence (AI), where it depicts the structure of the human brain and its process. The structure of the deep learning mainly termed as neural network which is processed with the hidden layers to improve the learning. We all have a doubt why is the need of AI in agriculture because it is completely a knowledge transformation and man work. The main reason is that the entire world is highly dependent on the biodiversity. The part of agriculture has a highest role in maintaining the biodiversity. The agricultural products and waste acts as a food for the living organisms of the world [3]. The balance of agriculture encounters any change or difficulty then the mankind and the life stock also experience a greatest change and difficulty in balancing the ecological cycle. The deep learning also extends its service in harvesting where AI collaborated machines were introduced and it was monitored using the drone systems, controlled by IoT. In such cases the extent of the field was automatically identified. The crop harvesting was done with the combination of machine learning techniques and IoT [8] [9].

3. Identification Of Plant Disease
In the segment of crop yield, identification of the disease is important because reduced plant disease will give the nature of good yield. Mostly at present and in early days the disease of the plant was identified by manual verification. As the knowledge transformation was reduced from generation to generation and new diseases were coming out due to environmental change. It was very difficult for the agriculture people to know all the information at the single point. It would be very useful if we had some automatic system in agriculture. In that point of view deep learning plays a major role in the identification of plants and the plant disease identification. The plant disease can be identified by using the method of deep learning called convolutional neural network (CNN), in which the images of the infected leaves are captured and then tested to find the disease of the plant. In this method the leaves of 25 plant species were at different stages were taken and then trained with around 80,000 images, so that the machine will get the clear view about the particular plant and then it would give the desired correct result. In the same part the diagnosis of the disease were done by the experts and then the required remedial measure were also given [4]. In the plant disease identification Region based Convolutional Neural Network(R-CNN) plays a major role where it identifies the accurate position of the diseased part and it helps for the high accurate diagnosis[5]. The plant disease can also be stopped before occurring if it was possible to identify the factors that cause diseases. Generally the factors that affect plants are climate and external factors like insects. It would be more helpful for the farmers that the diseases were identified at the time of intrusion of external factors that cause damage. The fungal, the bacterial infections were caused by the climatic changes, periodical pests and insects. The deep learning method of CNN helps to identify the various parts of plants and pests lying on it. It helps the farmers to locate the plant disease at the higher rate and reduced the crop damage [5] [6] [7].

4. Climate And Soil Mapping For Crop Suggestion
India is a tropical country where the agriculture is completely based on climate and irrigation. All types of food and cash crops are majorly classified based on the soil type and the season. In the part of climate prediction it was mainly used to identify the sowing period and harvesting period of the crop. The remote sensing technology was implied on the satellite images to predict the climate of future using the deep learning techniques [10]. The rainfall prediction can also be done with the help of the satellite images. In our country monsoon plays a vital role and decides the role of agriculture of that particular year. The rainfall prediction helped the farmers to decide their crop based on the irrigation system they have in their field, which helps them to attain a fair yield. The geographical design of the satellite images would give the extent of soil type with respect to location. The satellite images can also be used with respect to the soil with the base of map reduce matrix to identify the soil type. In the combination of particular soil type and the climate it was possible to suggest the farmers with the crops they can plant. It also helped the farmers of particular group to maintain the certain type of crop.
rotation in their field [11, 12, 14]. In the process of crop suggestion fertilizer suggestion is also a major part which has been done by the analysis of soil nutrients. The analysis of the soil nutrients were done by macro and the micro nutrients of the soil. Based on the level of presence of macro and micro nutrients the fertilizer needed for the particular crop could be analyzed. The soil test results helped the officers to give the right suggestion of limited fertilizer and the defined crop [13, 15].

5. Crop Yield Prediction

In the ancient times people had the knowledge about predicting the weather conditions and based on that weather and the monsoon of that particular year they had selected the crop and they had a chance of predicting the yield before the period of harvest. As the years goes on the practice of agriculture and its knowledge transfer had been significantly reduced. The farmers also shifted their sight on machineries and automated system. In the case of agriculture the automated system can be implemented based on the AI, because agriculture could be done only with learning and knowledge. In AI it can be achieved through the technique of deep learning where it uses the concept of neural network which depicts the method of human brain. In the process of designing AI first and foremost thing was that machine has to learn the concept and be trained for the situations. Secondly it has to think and act as how human acts for that the machine learning and the deep learning can be encountered.

In crop yield prediction environmental factors plays a major role, which includes climatic conditions, temperature, rainfall, vegetative index, soil type, texture and nutrients. Based on the environmental factors the deep learning techniques will give the prediction value. The prediction can be of two types they are classification or regression. Classification can be to identify in which classes the crop growth falls. For example: Classes such as, well grown, medium grown and under grown. The another type is regression where it will give numerical estimated value. So that value of percentage for the estimated crop yield can be obtained.

In Deep learning various types of neural network and its combinations are used to find the classification and regression technique for crop yield.

5.1 Artificial Neural Network (ANN)

In crop yield prediction Artificial Neural Network was used with the regression technique to estimate the yield. Where the inputs and obtained labels were in terms of images and soil properties and environmental factors. The crop images were captured periodically and analyzed based on the level of periodic growth. The level of growth is measured to identify the correctness of growth with respect to height, disease and various development stages to predict the percentage of yield. The crop yield has also been predicted using the environmental factors such as temperature, rainfall and irrigation where based on which the sustainability of the crop can be decided. Based on the seasonal sustainability of the crop yield can be measured. ANN was trained with the data of environmental factors and crop images for the crops such as wheat, barley, sugar beet, potato and sunflower [16, 17]. The designed network has been tested and the obtained result was at the average estimation of 60-70%. The yield decision can be made more effectively by analyzing the multiple parameters of environmental factors. In order to obtain higher rate of crop yield environmental factors has to be analyzed using multiple linear regression (MLR). The environmental factors such as temperature, humidity, moisture is measured and analyzed periodically according to the crops to obtain the maximum accuracy of crop yield prediction 65%. [18] In the mentioned environmental factors it would be more difficult to have specific soil characteristics for each crop so it has been made more efficient with K-means Nearest Neighbor (KNN) to cluster the similar properties based on which the suggestions were given and the future yield was measured. In this two layered approach the yield estimation obtained was 67% [19].

5.2 Convolutional Neural Network (CNN)

The technique of CNN is mainly used in deep learning to process with the crop images. In the convolution neural network the images were analysed pixel by pixel in a matrix format, then formed filter was termed as a convolution. Where crop images were captured at each stage and verified with the level of growth based on regression and calculation then the value for estimation for yield prediction would be calculated. In the southern region of Tamil Nadu seeds of seasonal crops were
considered and at most 85650 species were trained in CNN[20]. During the each stage of crop growth the crops were monitored and classified based on three classes good average and best. The result would be obtained based on the trained CNN model. The food crops were categorized and estimated with the percentage of 82%. Where the crops are categorized as crop type based on the climatic conditions. The crops are planted based on its seasonal division and monitored periodically using the image of fruits, vegetables and its leaves. By monitoring the image at each and every stage the disease in each part of the plant could be identified and treated effectively. The early ripen of crop could be identified which would give the proper alert time of harvest. This helped a long run in periodical harvest crops like apple, orange, bitter guard. The mean square was reduced much better and it was in the rage of 0.5 which is the optimum rage of regression. It gave the estimation percentage of 80% [21,22,23]. The technique of CNN can be further improved and made effective by making the analysis part under two layered approach (ie) two layered CNN where the climatic prediction and monitoring of the climate took place at the first layer of CNN based on the environmental factors. Where the second layer takes the process of monitoring the field of crop. In the encountered study the paddy field was monitored under the surveillance of camera. The various stages of paddy field images were trained and tested with the two layered CNN approach. The estimated yield prediction of the CNN was 86.5% and the actual rate of yield was 85.1%. as in comparison it performed well [24].

5.3 Deep Neural Network (DNN)
Deep Neural Network was a type of ANN, which uses multiple hidden layers along with the output layer. Mostly DNN was used in the place of multivariate attributes to link the complex terminals. In that process plant genotype and other plant growing properties are mapped with the climate to predict the crop yield. Where the genotype of the plant completely deals with the chemical compounds of the crop which makes the soul of the plant. The crop of maize and rice were taken and its genotype were mapped and trained with the DNN. It was completely of classification prediction which gave the estimation accuracy of 64%[25, 26]. In the next type of prediction using regression method where the atmospheric factors are compared and mapped with the sensor and the drone images. This network mainly worked on the process of identifying the climatic conditions and its effect on plants with the satellite images. Which helps to makes the precaution condition for crops and timely irrigation which increases the yield of the crop to a greater extent. The yield prediction with respect to this multivariate regression technique was around 64.5% accurate [27, 28]. In the phase of two layered DNN vegetative index of a particular locality has been analyzed along with the climate in the first layer and the crop monitoring takes place at the second layer. This decreases the mean square error and exists in the range of 0.6 with the estimation yield range of 67% [29].

5.4 Long – Short Term Memory (LSTM)
LSTM is one among the type of Recurrent Neural Network( RNN), where the RNN holds the process of feed forward network with back propagation loop. LSTM adds the advantage in RNN that it holds the value of the previous output for a short period of time. It acts as a small part of memory in a network which helps in the part of feedback analysis. It mostly used for the complex variables and combinational inputs. In the conducted case study the following crops such as tomato, soya bean and corn has been taken. The crops were monitored based on the vegetative index, whether and climatic data along with all environmental factors where mapped. These attribute variables are monitored time to time and the time series data were analyzed using LSTM. It gives the estimated crop yield of around 86.3% [30, 31, 32]. Two layered LSTM was used to process the genotype of the 25 species plants at a layer1 and the environmental factors at the layer 2 which gives the more effective process and the clear suggestions with the accuracy of 89% [33]. Depth adaptive LSTM is the combinational network with deep neural network where the image is processed along with the environmental factors. The image depth of the plant was analyzed so that the chemical composition of the plant can be analyzed with the most accurate level of 89% [34, 35]. Then the process of LSTM was done with environmental factors with the time series data to get the better yield estimation. The direct one dimensional data can be directly fed in to the 1 dimensional convolutional network and then processed. The training time of the network will be low because of the data type so the processing
time and the storage space is also effective. The attainment of estimated crop yield is of 85% from the suggested one [36].

5.5 Hybrid Network

Hybrid network is a network which contains a neural network composed along with the machine learning techniques. In crop management the crop has to be monitored using the wireless sensor network to monitor temperature and humidity to predict the rainfall which would help in irrigation system[43, 44]. In which the input data were trained using the self mapping system which measures and predict at the range of accuracy 89% [40, 41]. The climatic condition and the rainfall prediction were further improvised with multi-temporal data and satellite images. It has been classified using the Bayesian classifier and analysed using the multilayer feed forward network which predicts the rainfall to the maximum of 87.7% [38, 39, 42]. The prediction of rainfall helped to choose the type of crop for particular vegetation and soil type of particular season. The meta heuristic algorithm and the crop model help the agriculture work to predict the crop yield at the level of 85% [37,45]. The reinforcement learning along with Q-learning gives the way along with the external parameters of environmental factors and it increases the prediction value to the higher rate of 90% [46].

| Neural network or algorithm | Method | Input Parameters Considered | Crop/ Crop type | Region & References |
|-----------------------------|--------|-----------------------------|-----------------|---------------------|
| ANN                         | Regression | Crop species, irrigation level, crop images, climatic and soil properties. | wheat, barley, sugar beet, Potato, sunflower | Iran, India [16,17] |
| ANN+ MLR                    | Regression | soil resistance to penetration, soil organic matter, soil microbial biomass values and tillage system | Potato | India [18] |
| ANN-KNN                     | Regression | Soil Characteristics: ph, micro nutrients, macro nutrients | Seasonal crops | India [19] |
| CNN                         | Classification | Seed structure , shape, colour | 10 verities of seeds Barley, wheat, bitter guard, apple, orange. | India [20] |
| CNN                         | Regression | Climate and crop type, crop images- leaf and fruit images. | Paddy | India [21,22, 23] |
| Two layered CNN             | Classification | Soil nutrient Properties: nitrogen, potassium, phosphorus and healthy paddy field image | 2500 verities of maize, rice Wheat, Soya bean, Corn | India [25, 26] |
| DNN                         | Classification | Growth properties, genotype of plant and climate | Tomato, Soya bean, corn | Brazil, India, Belgium [30, 31, 32] |
| DNN                         | Regression | Temperature, length of the growing season, sensor and drone images of crop. | Corn | India [29] |
| Two layered DNN             | Regression | vegetative Index, climate data | Tomato, Soya bean, corn | Brazil, India, Belgium [30, 31, 32] |
| LSTM                        | Regression | Soil and environmental characteristics, vegetative index, weather and climatic data. | | |

Table 1. Crop Prediction Deep Learning Network
| Method                          | Task                  | Data sources                                                                 |
|--------------------------------|-----------------------|------------------------------------------------------------------------------|
| 2 Layered LSTM                 | Regression            | genotype of plant and climate of 25 species of plants                       |
| DA(depth adaptive)-LSTM         | Regression            | environmental factors of Tomato                                             |
| deep CNN-LSTM                  | Regression            | satellite image of crop of Soya bean                                         |
| DEEP Q-NETWORK(Reinforcement + Q learning) | Regression | Environmental factors - climate data based on crop of Soya bean            |
| LSTM, Conv-1d                  | Classification        | Time series data of vegetative index for Economic Crops                      |
| ML(Linear Deterministic Algorithm) | Regression           | periodical growth value of maize                                             |
| Multi task machine learning    | Regression            | topographical, spectral data, climate data of cotton                        |
| Multilayer perceptron          | Regression            | weather parameters of wheat                                                  |
| Neural network                 | Classification        | crop type, soil type, rain fall rate, temperature, humidity, crop cost, etc.|
| Self Organising Map(SOM), Latent Dirichlet Allocation(LDA) | Regression        | climate data for cultivable crops                                           |
| Semi parametric Neural network (SNN) + Bayesian hyper parameter optimization support vector machine, random forest, and neural network | Classification | Vegetative Index, solar chlorophyll level of wheat                          |
| WSN                            | Classification        | climate, vibration of footsteps (seismic sensor)                            |
| Crop model + ML                | Regression            | yield data, Weather data, Soil Management data                              |

6. Results And Discussion

The study on the crop yield prediction has been made and then the results were being categorized into three categories and are tabulated [Table1]. The categories were completely based on the five networks such as ANN, CNN, DNN, RNN, hybrid network. Each network are analyzed with three perspective such as regression, classification and two layered approach. The ANN and DNN of the feed forward has been analyzed and they both gave the average performance of prediction 60–70%. The most processing of agriculture was done with image and timely monitoring CNN out performs both DNN and ANN and gives the accuracy of around 80-85%. The only drawback of CNN in this study was that it had its predictions only on the trained data but not with the real time previous data. In order to improvise the yield prediction further and to avoid loss at the time of yield some work was carried out using RNN. In the RNN the combination of LSTM is used which enables the added feature of data storage. It includes the feedback loop which the CNN fails which produces the average estimation of 83 – 89% with the most accurate level as compared to other three networks.
In the case of hybrid network it is the process with two or more different network so it has been analyzed separately and the percentage of yield prediction was analyzed and then compared. In the hybrid network three different types of classifications were made which includes multivariate regression at different stages with different algorithms based on the need which gives the accuracy of yield range of about 85%. Since it gave the similar result of RNN it has been worked with the combination of classification and regression at the different layers of network. It gives the improvement with the yield accuracy of 87.7%. The process was also worked with the reinforcement learning multiple network which gives the range of accurate crop yield of about 90% in which the actual attainment of yield is about 89%. With the above study it was very clear that the RNN and hybrid network outperforms the other entire network and achieves the accuracy of maximum 90%.

**Figure 1.** Evaluation of ANN, DNN, CNN, RNN

**Figure 2:** Evaluation of Hybrid Network
7. Conclusion And Future Work
The study was done on the crop yield prediction method using the deep learning techniques. The methods used were ANN, CNN, RNN-LSTM, Hybrid network have been analysed and found the following observations. In the ANN the result obtained was completely using the feed forward network, obtained results shows the performance around 60-70%. This result was observed for both single and double layered network. CNN out performs ANN with its pictorial matrix evaluation which gives the accuracy of estimation of around 87% [figure-1]. It is also worked with the single and two tire networks. RNN – with LSTM and the hybrid network out performs other network with the estimation accuracy of 89%. The hybrid network holds the combination of network along with the additional algorithm to give the most accuracy of 90% [figure-2]. The RNN with LSTM holds the major advantage of storage and feedback loop. The result of it will be better than the hybrid network and RNN since it can able to process time series input and can able to store the previous output for future use.

As with this study it was clear that agriculture was completely moving towards the field of artificial intelligence. So the researchers can concentrate their research on verities of crops and real time dataset. The work has to be more focused on RNN because the agriculture data mostly rely on real time, time series data. RNN with hybrid network can also provide a new inference to artificial intelligence in agriculture.

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