Maize Yield Prediction Considering Growth Stages using Fuzzy Logic Modelling

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***Abstract*— Over the last two decades yield prediction of agricultural products is performed by considering average weather data on a particular region and crop, on the other hand, that crop may have different weather requirements at different growth stages resulting in prediction to be less accurate and sometimes far off from real value. For example, Maize at the germination growth stage will need less rainfall than Maize at the silking growth stage. It is therefore useful to consider a specific crop and its weather requirements at different growth stages. This model of evaluating different growth stages provides better prediction accuracy. This paper presents an evaluation of Maize production by integrating temperature, humidity, rainfall of various growth stages, and sowing area as parameters. To present that, a simple and interactive Matlab simulink and fuzzy toolbox are provided.**

Keywords*— *Growth stage, germination stage, vegetative stage, tasseling stage, silking stage, grain stage, fuzzy logic, yield prediction.

I. INTRODUCTION

Crop yield prediction has received and will continue to receive major attention globally, as it helps in estimating the ratio of supply and continuously increasing demand for food, and other agriculture products like fodder, furniture and many more. Accurate yield prediction is therefore essential for policymakers to make timely import and export decisions to strengthen national agricultural products security. The impact of weather change and its unpredictable behaviour has a great influence on agricultural crops for their maintenance and production. Accurate forecasting of crop yield requires a basic understanding of the operational relationship among weather and geographic parameters with yield. To disclose such a relationship we need an approach towards the weather requirements of the crop which takes different growth stages in an account. In the paper, a fuzzy logic system is used on various crop parameters on different growth stages.

Growth stages are various periods in a crop's life cycle when parameters such as temperature, rainfall, humidity affect crop growth and development and hence the yield. In the paper, some of the growth stages of maize are combined and grouped into five major growth stages which are discussed below.

- The germination stage is the emergence stage of the crop after seed plantation [1].
- The vegetative stage is the major growth stage in which the plant reaches knee-length height. In this paper, all vegetative stages V1st to Vnth stages are grouped into a single stage which is named as vegetative stage [1].
- The tasseling stage is the pollen formation stage [1].
- The silking stage is the Cob formation stage. In this paper silking stage, the blister stage, the milk stage, dough stage are grouped into a single stage which is named as silking stage [1].
- The grain stage is the stage in which the kernel is dented and the black layer is formed. A maximum dry weight is achieved. In this paper dent stage and physiological maturity is grouped into a single-stage which is named as grain stage [1].

II. LITERATURE REVIEW

The previous works in which yield prediction of different crops utilizing various methods is viewed in this section.

S. Bang et al. [2] presented a fuzzy logic model for crop yield prediction using weather phenomena such as rainfall and temperature. They first predicted rainfall and temperature using SARIMA, ARMA, and ARMAX. The predicted outcomes of these three models are compared and the best model is taken out to predict rainfall and temperature. The predicted value of rainfall and temperature is used for the prediction of crop yield using a fuzzy inference system.

F. Jawad et al. [3] designed a system that is based on a neuro-fuzzy system (NFS). System that uses temperature, humidity and rainfall data as input for prediction of major crop (Boro and Potato) yield of Bangladesh. Input data is entered in a neuro fuzzy system for Boro and potato crops and according to resultant crop yield, it decides suitable crops to be cultivated for particular weather conditions. Using this system crop yield can be increased with less farming land and resources.

Shrestha R. et al. [4] suggested a system in which sunshine precipitation, temperature, soil type, altitude, and rainfall value is used as an input for the fuzzy logic system and, calculated the yield of certain crops such as rice, tea and wheat. Based on several climatic situations, the right crop is selected for cultivation for a particular period time.

A. C. Batista and Alfonso C. [5] developed a water irrigation model using a fuzzy logic controller. If irrigation is done more than the water requirement of the crop then access water is drained. During drainage, soil loses some amount of nutrients. This model suggests how much the water should be irrigated so that it consummate water requirement of crops as well as saves the loss of water and nutrients of the soil.

Daniel et al. [6] represented a model for the prediction of maize yield using a fuzzy inference system of the north-east region. Crop yield depends upon rainfall, which itself depends on climatic change such as temperature and humidity. For rainfall prediction, the author uses the Newton interpolation method and then a fuzzy logic model of temperature and humidity data. The predicted rainfall value is used for the prediction of maize yield using a fuzzy logic model.

A. H. Mohammed et al. [7] presented a fuzzy-based approach for providing suitable plantation date and used Hadoop map-reduce technology for a large dataset of agro-climatic data so that crop yield can be increased. Expected disease, water requirement, and harvesting date are also shown in the result. This approach helps to manage the cropplantation process concerning climate changes.

M. A. Jayaram et al. [8] developed a fuzzy inference system for crop yield prediction. The system uses physio-morphological features of Sorghum such as plant height, days of 50 percent flowering, panicle length, dead heart percentage, number of primaries, and panicle weight as input. In which input parameters one-to-one, two to one, three to one mapping is considered to find predicted values which are matched with actual values and get variation, accuracy and RMS value. It is reported that the combination of panicle weight, panicle length, and number of primaries have low variation, high accuracy and lowest RMS value which can be used for forecasting crop yield.

Malik A. et al. [9] have introduced a co-active neuro FIS (CANFIS) model for drought index prediction. In which different lead times of SPI were computed. CANFIS model contains features of ANN and FIS. CANFIS model was validated against two models: The Artificial intelligence model and the Regression model. RMS error and other performance evaluation metrics are calculated and found that the prediction of the CANFIS model is better than other models.

M. K. Singla et al. [10] represented a technique of short term load forecasting using a fuzzy logic model for rain prediction. In which temperature and speed of the wind are taken as input and forecasting load is taken as output and applied Mamdani approach for rainfall prediction. It has appeared that this model had been fruitfully used by power plants for useful operations like control and planning of power generation and establishing work plans for power plants.

Awanit K. & Shiv K. [11] predicted crop production using the K-means algorithm and fuzzy logic. The predicted values of both methods are compared. Rainfall and area in hectare used for production are input and crop production is the output. Based on previous year data, crop production of next year is predicted which can be useful for farmers so that they can be aware and take decisive action to manage themselves from its losses.

Garg & Agarwal [12] focused on the prediction of data values where second and third-degree relation is taken for fuzzy logic computations. In which four types of fuzzy intervals are taken and for each type of interval four degrees of the regression equation is taken for testing. For each case fuzzy logic relationship 2 and 3 are performed separately. MSE is calculated for forecasting values and finds out which interval is giving the least MSE and is the best suitable interval for forecasting crop prediction.

Manjula and Djodiltachoumy [13] proposed and implemented a system for prediction, of crop yield using previous data. For crop prediction they used data mining techniques in which association rules were created for past data and developed a prediction model that can be used for future prediction of crop yield.

III. PROBLEM STATEMENT

Agriculture in India is afflicted by both natural and man-made difficulties. A large population among farmers and villagers still believes in superstitions for farming. Some farmers rely on previous years' history and some are moving to use computer techniques. In computer techniques yield is predicted using average weather data but this technique has a limitation like weather data (example rainfall) may be poorly distributed, means rainfall in the starting phase may be very low and when crop matures that time rainfall can be heavy. This results in measuring average rainfall as good but this is not as per crop requirement so sometimes prediction using average weather data may fail. To remove these shortcomings in older technique, the new technique should be acquired in which growth stage-wise weather data is taken for yield prediction.

IV. OBJECTIVE

The objectives for the prediction of maize yield are given as:

- To collect historical agriculture, geographic and weather-related data of Chittorgarh district (temperature, rainfall, the humidity of all growth stages, sowing area,and maize yield)
- To develop a fuzzy model for maize yield prediction for forthcoming.
- To compare predicted maize yield of fuzzy inference system with actual maize yield.

V. PROPOSED METHOD

The system collects climatic data and geographic data of Chittorgarh district, from which data is cleaned and then pre-processed. After preprocessing data is grouped as per the growth stage and applied on model, where data is passed through growth stage prediction model and output of this model is passed to maize yield prediction model and receive predicted maize yield.

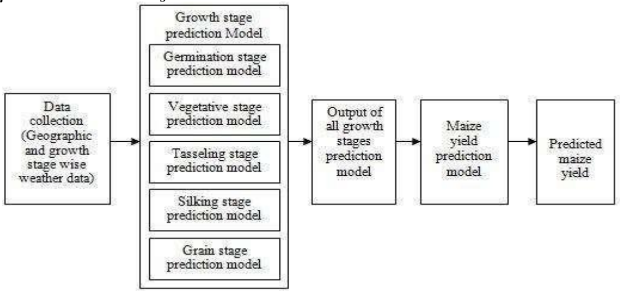


Fig. 1 Complete model for prediction of maize yield

The prediction model is divided into two sub models:

A. Growth Stage Prediction Model

This model is run for every growth stage of maize crops independently of each other. This prediction model takes rainfall, temperature, the humidity of the growth stage, and sowing area as input to a fuzzy logic model and computes the approximate result for that stage.

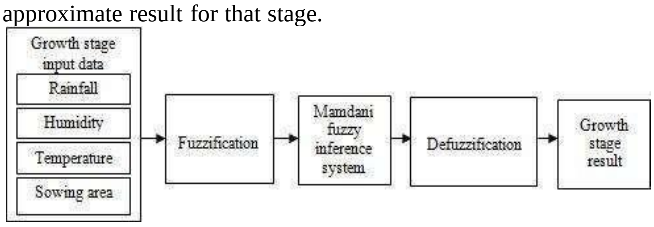


Fig. 2 Growth stage prediction model

B. Maize Yield Prediction Model

This prediction model takes the output of all growth stage prediction models and uses them to predict a final maize yield by using a fuzzy logic model.

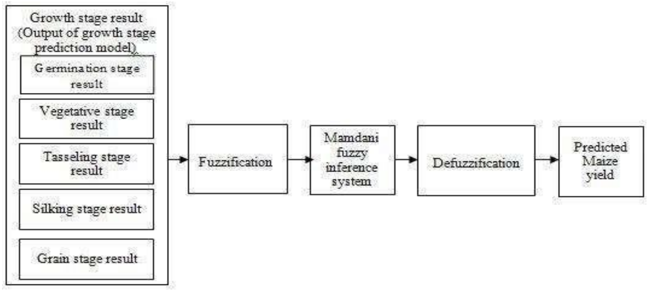


Fig. 3 Maize yield prediction model

VI. IMPLEMENTATION

Working of growth stage prediction model and maize yield prediction model consist of 3 steps.

A. Step 1

Formulate the list of input variable and output variable by utilizing statistical analysis.

1) *For Growth Stage Prediction Model:* In this modelfor each growth stage, 4 input the variables (rainfall, temperature, humidity and area (i.e. sowing area)) and 1 output the variable (growth stage result) are considered.

In the following figure input variable and output variable of the germination stage is shown, likewise all other stages input variable and output variables are formulated.

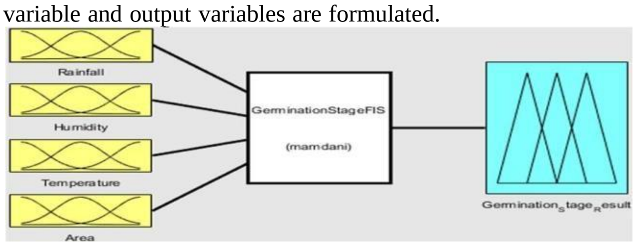


Fig. 4 Input output variables of germination stage

2) *For Maize Yield Prediction Model:* In this model, 5 input variables (germination stage result, vegetative stage result, tasseling stage result, silking stage result and grain stage result), and 1 output variable (Maize yield) are considered.

In the following figure input variable and output variable of the maize yield prediction model is shown:

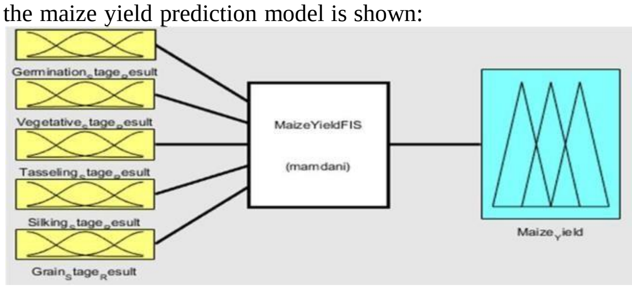


Fig. 5 Input output variables of maize yield prediction model

B. Step 2

Resolve fuzzy membership value for each input and, the output variable, and define the number of membership functions

1) *For Growth Stage Prediction Model:* In this model input variables Rainfall, temperature and humidity are classified into 3 fuzzy sets as low, medium and high while Area is classified as small, medium and large. The output variable growth stage result is classified in 3 fuzzy sets as bad and average and good.

For each membership value, trapezoidal membership function is defined.

In the following figure membership function of the area, input variable of the germination stage is defined; likewise, all other stages membership functions of all input variables and output variables are defined.

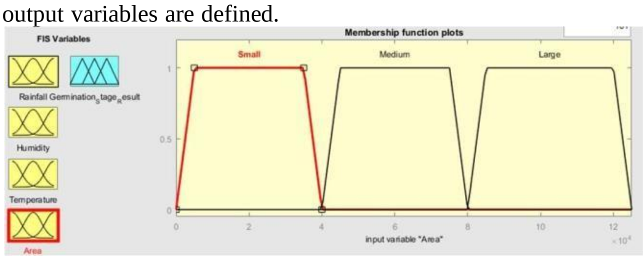


Fig. 6 Membership function of germination stage prediction model

2) *For Maize Yield Prediction Model:* In this model germination stage result, vegetative stage result, tasseling stage result, silking stage result, and grain stage result are taken as input variables and classified into 3 fuzzy sets such as bad, average, and good. Maize yield will be our output variable, and is classified into 5 fuzzy sets such as very poor, poor, good, very good and excellent.

For each membership value trapezoidal membership function is defined.

In the following figure membership function of the input variable vegetative Stage Result is defined, likewise, membership functions of all input variables and output variables are defined.

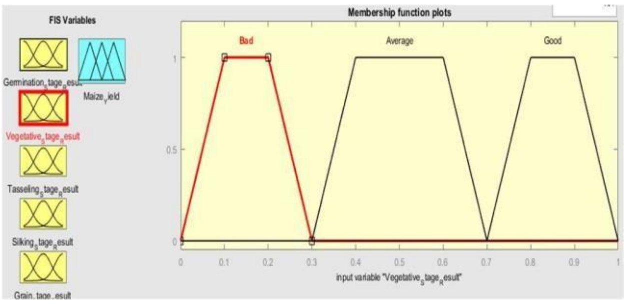


Fig. 7 Membership function of maize yield prediction model

C. Step 3

Assign rules (take fuzzified inputs and apply to the predecessor using fuzzy operators (OR or AND) of the fuzzy rules and then apply that evaluation to the resultant membership function).

1) *For Growth Stage Prediction Model:* In this model for each growth stage rules are made using rainfall, temperature, and the humidity and area (i.e. sowing area) as predecessor, and growth stage result as resultant membership functions. For example, one set of a rule is given below:

Rules

- If (germination stage rainfall is medium) and (germination stage temperature is medium) and (germination stage humidity is medium) and (area is large) then (germination stage result is good)
- If (vegetative stage rainfall is medium) and (vegetative stage temperature is medium) and (vegetative stage humidity is high) and (the area is large) then (vegetative stage result is good)
- If (tasseling stage rainfall is low) and (tasseling stage temperature is medium) and (tasseling stage humidity is medium) and (the area is large) then (tasseling stage result is average)
- If (silking stage rainfall is medium) and (silking stage temperature is medium) and (silking stage humidity is medium) and (the area is large) then (silking stage result is good)
- If (grain stage rainfall is medium) and (grain stage temperature is medium) and (grain stage humidity is medium) and (the area is large) then (grain stage resultis average).

2) *For Maize Yield Prediction Model:* In this model rules are made using germination stage result, vegetative stage result, tasseling stage result, silking stage result, and grain stage result as predecessor and maize yield as resultant membership functions. For example, one set of the rule is given below:

- If (germination stage result is good) and (vegetative stage result is good) and (tasseling stage result is average) and (silking stage result is good) and (grain stage result is average) then (maize yield is very good).

VII. Result

The predicted output of a particular year is shown using the rule viewer, and surface viewer of growth stage prediction model, and maize yield prediction model.

A. Rule Viewer and Surface Viewer of Growth Stage Prediction Model

For all growth stage prediction models rule viewer and surface viewer is shown in which rainfall, temperature, humidity and area of the year 2018 is entered as input and growth stage result is received as output.

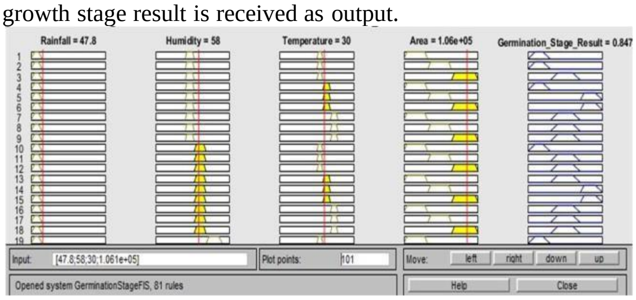


Fig. 8 Rule viewer of germination stage prediction model

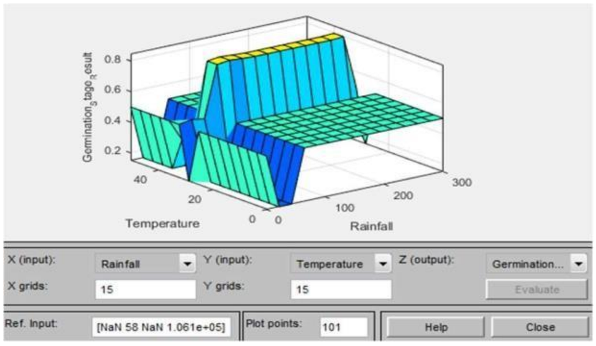


Fig. 9 Surface viewer of germination stage prediction model

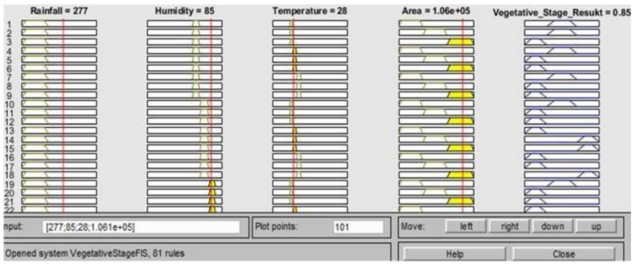


Fig. 10 Rule viewer of vegetative stage prediction model

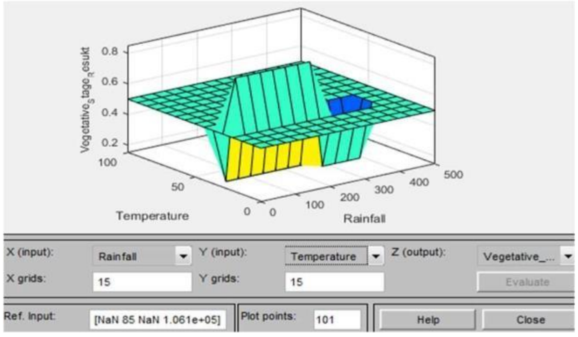


Fig. 11 Surface viewer of vegetative stage prediction model

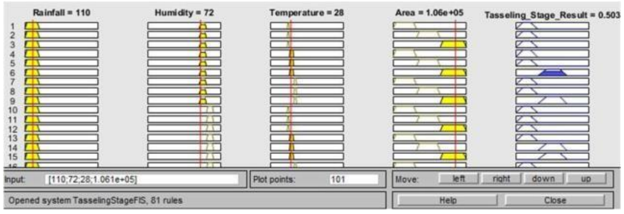


Fig. 12 Rule viewer of tasseling stage prediction model

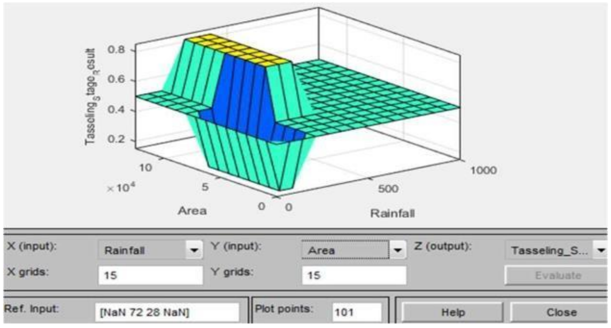


Fig. 13 Surface viewer of tasseling stage prediction model

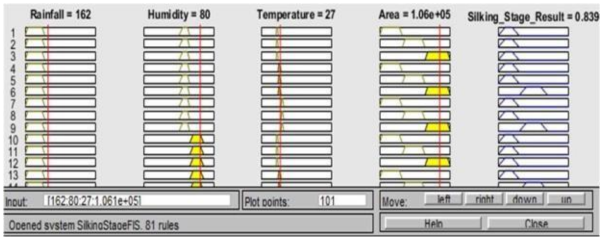


Fig. 14 Rule viewer of silking stage prediction model

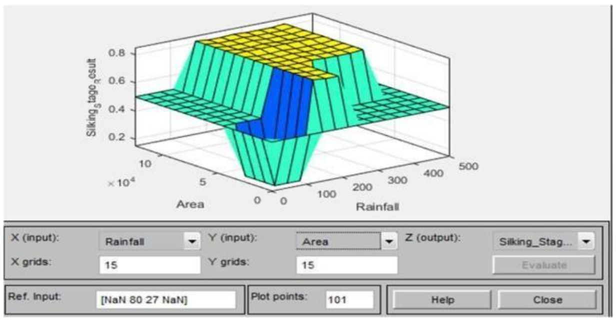


Fig. 15 Surface viewer of silking stage prediction model

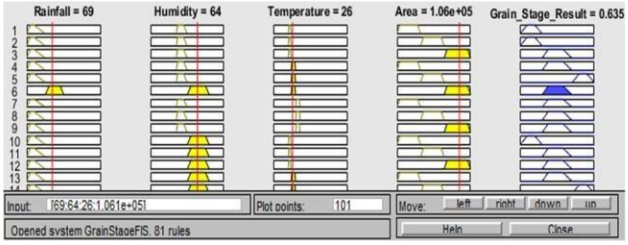


Fig. 16 Rule viewer of grain stage prediction model

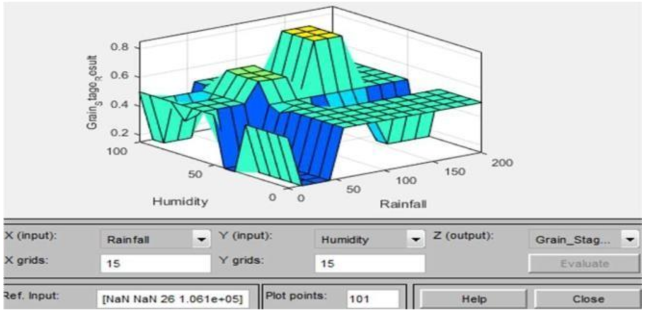


Fig. 17 Surface viewer of grain stage prediction model

B. Rule Viewer and Surface Viewer of Maize Yield Prediction Model

The predicted value of Maize yield is shown using rule viewer and surface viewer in which output of all growth stage prediction models are passed as input for maize yield prediction model, and predicted maize yield (kg/ha) is received.

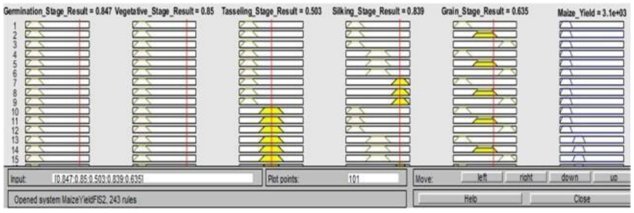


Fig. 18 Rule viewer of maize yield prediction model

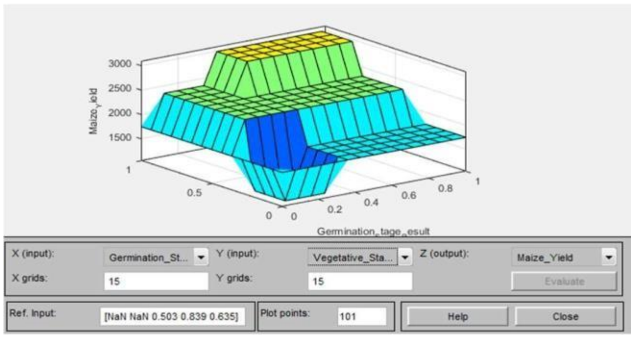
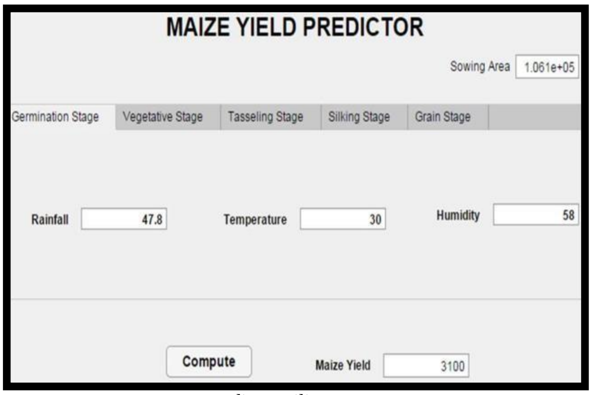


Fig. 19 Surface viewer of maize yield prediction model

Predicted result for the year of 2018 using maize yield predictor utility in which rainfall, humidity, and temperature are entered for each growth stage and sowingarea is taken commonly for all growth stages. On calculate predicted maize yield (kg/hectare) is shown in the output field.



predictorutility

Predicted yield and actual yield of Chittorgarh district for the year from 2015 to 2019 with percentage error is shown in the following table, here percentage error is calculated using formula ((actual yield – predicted yield)*100/actual yield).

TABLE I

PREDICTED AND ACTUAL MAIZE YIELD WITH PERCENTAGE

Sr. No	Year	Predicted yield(kg/ha)	Actual yield(kg/ha)	% Error
1	2015	2100	2172	3.4
2	2016	1520	1455	4.4
3	2017	2940	3006	2.1
4	2018	3100	3050	1.6
5	2019	2690	2780	3.2

Year (from 2015 to 2019) as x axis and yield (in kg/ha) as y axis is taken in the given bar chart

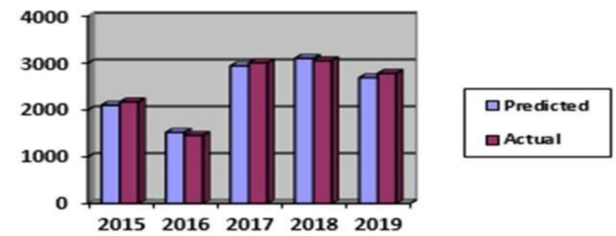


Fig. 21 Bar chart for predicted yield and actual yield of Maize

VIII. CONCLUSION

This paper implemented a fuzzy model to predict the yield of maize crop. Based on the result, it can be concluded that the accuracy of crop yield prediction made by considering weather data of various growth stages is better than considering average weather data of a particular season. Various growth stages have different weather requirements and significant impact by weather change for a particular growth stage which gives a negative impact on the upcoming growth stages. The implemented fuzzy logic technique can be seen as an efficient way to estimate and evaluate maize yield prediction for those years also in which weather data is poorly distributed as per crop requirement.

IX. FUTURE SCOPE

Some important points in future work should be considered for the crop prediction model which includes the timing of planting by considering shifts of planting dates depend on the climate condition in the fuzzy logic model. The developed model can be expanded by taking into account the fuzzy inference system of all vegetative and reproductive growth stages separately. The soil pH concentration, soil types, and water evaporation are some of the factors which can be added to improve and optimize the more accurate result.

REFERENCES

[1] Jourdan Bell, “CORN GROWTH STAGES AND DEVELOPMENT”,Texas A&M AgriLife Extension and Research Agronomist, Amarillo,2017

[2] S. Bang, R. Bishnoi, A. S. Chauhan, A. K. Dixit and I. Chawla, "Fuzzy Logic based Crop Yield Prediction using Temperature and Rainfall parameters predicted through ARMA, SARIMA, and ARMAX models," 2019 Twelfth International Conference on Contemporary Computing (IC3), Noida, India, 2019, pp. 1-6.

[3] F. Jawad et al., "Analysis of Optimum Crop Cultivation using Fuzzy System," 2016 IEEE/ACIS 15th International Conference on Computerand Information Science (ICIS), Okayama, 2016, pp. 1-6.

[4] S. Roy, D. Dey, M. Saha, K. Chatterjee and S. Banerjee, "Implementation of Fuzzy Logic Control in Predictive Analysis and Real Time Monitoring of Optimum Crop Cultivation: Fuzzy Logic Control In Optimum Crop Cultivation," 2020 10th International Conference on Cloud Computing, Data Science & Engineering (Confluence), Noida, India, 2020, pp. 6-11.

[5] Carrasquilla-Batista and A. Chacon-Rodrıguez, "Proposal of a fuzzy logic controller for the improvement of irrigation scheduling decision- making in greenhouse horticulture," 2017 1st Conference on PhD Research in Microelectronics and Electronics Latin America (PRIME-LA), Bariloche, 2017, pp. 1-4

[6] K. Daniel, P. Sharma and R. Srivastava, "Fuzzy Based Prediction Model Using Rainfall Parameter for North eat India Maize production," 2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), Gorakhpur, 2018, pp. 1-6.

[7] Mohammed, A.H., Gadallah, A.M., Hefny, H.A. et al., “Fuzzy based approach for discovering crops plantation knowledge from huge agro- climatic data respecting climate changes,” Computing 100, 689–713, 2018.

[8] M. A. Jayaram & Netra Marad, “Fuzzy Inference Systems for Crop Yield Prediction,” Journal of Intelligent Systems 21,2012,, pp363–372

[9] Malik A, Kumar A, Salih SQ, Kim S, Kim NW, Yaseen ZM, et al. “Drought index prediction using advanced fuzzy logic model: Regional case study over Kumaon in India.” PLoS ONE 15(5): e0233280, 2020.

[10] Manish Kumar Singla, Harkamal Deep Kaur, Parag Nijhawan, “Rain Prediction using Fuzzy Logic,” International Journal of Engineering and Advanced Technology (IJEAT) ,October 2019, ISSN: 2249 – 8958, Volume-9 Issue-1

[11] Awanit Kumar, Shiv Kumar, “Prediction of Production of Crops using K-mean & Fuzzy Logic,” International Journal of Computer Science and Mobile Computing, Vol. 4, Issue. 8, August 2015, 44 – 56

[12] Bindu Garg, Shubham Aggarwal, Jatin Sokhal, “Crop yield forecasting using fuzzy logic and regression model,” Elsevier - Computers and Electrical Engineering, Volume 67, April 2018, Pages 383-403.

[13] Manjula,S. Djodiltachoumy, “A Model for Prediction of Crop Yield,” International Journal of Computational Intelligence and Informatics, Vol. 6: No. 4, March 2017