Forecasting Production Values using Fuzzy Logic Interval based Partitioning in Different Intervals

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Abstract—**Fuzzy time series models have been put forward for rice production from many researchers around the globe, but the prediction has not been very accurate. Frequency density or ratio based partitioning methods have been used to represent the partition of discourse. We observed that various prediction models used 7th interval based partitioning for their prediction models, so we wanted to find the reason for that and along with finding the explanation for that we have proposed a novel algorithm to make predictions easy. We have tried to provide an explanation for that. This paper has been put forth due to the motivation from previously published research works in prediction logics. In the current paper, we use a fuzzy time series model and provide a more accurate result than the methods already existent. To make such predictions, we have used interval based partitioning as the partition of discourse and actual production as the universe of discourse. Fuzzy models are used for prediction in many areas, like enrolments prediction, stock price analysis, weather forecasting, and rice production.**

Keywords*—*Mean Square Error; Fuzzy time series; Average Forecast Error Rate

I. Introduction

If there are doubts about the future, then forecasting process is a must. Forecasting process is used to predict outcomes in the future. Related data and figures are analysed carefully in order to make an accurate prediction and make optimal choices regarding the future. There are mainly two reasons for choosing time series forecasting. First, most of the data existing in the real world like economic, business, and financial area are in time series. Second, it is easy to evaluate time series data and many technologies are also available for evaluation of time series forecast. A fuzzy time series method is used and implemented to predict the production of rice with high precision, and also compare the result with other existing techniques. A major challenge to the human race in the coming time is to distribute food to the increasing size of the population; the population is anticipated to reach around 9,000 million in next 40 years. This situation can be detrimental since the world food production has not been able to meet the demand for food. Most of the work on time series has been carried out to solve problems like stock price prediction, sales and economic predictions, analysis of Budget, fluctuations and business analysis etc. Thus, there exists a persistent demand for forecasting techniques that offer optimal and precise results. These techniques must also be able to tackle and deal with the nonlinear, unusual and erratic behaviour and nature of crop production. Precision and accurate prediction of these real time systems have been a challenging task. Thus, there is a need for forecasting methods which are accurate and efficient and also can deal with all the uncertainty in the data for forecasting.

II. Related Work

Fuzzy time series prediction is a prudent avenue in the areas where information is inexplicit, unclear and approximate. Also, fuzzy time series can tackle circumstances which do not provide the study and analysis of trends nor the visualisation of patterns in time series. Profound research work has been accomplished on forecasting problems using this concept. Vikas [1] proposed different techniques for prediction of crop yields and used the artificial neural network to predict wheat yield. Adesh [2] did a comparative study of different techniques involving neural networks and fuzzy models. Askar [3] also tried to predict crop yield using time series models. Sachin [4-5] worked specifically on rice yield prediction using fuzzy time series model. Narendra [6] tried to predict Wheat yield. Pankaj [7] used adaptive neuro-fuzzy systems for crop yield forecasting Wheat Yield Prediction. W. Qiu, X. Liu and H. Li, [30] put forth a generalised method for forecasting based on fuzzy time series model. Fuzzy time series concepts and definitions were invented and presented by Song & Chissom. They also portrayed the concepts and notions of variant and invariant time series [8-9]. Initially, time series data of the university of Alabama was taken and enrolment forecasting was executed, and after some years they also [10] formulated an average auto correlation function as a measure of dependency. Later, Chen [11-12] depicted simplified arithmetic operations instead of using max- min composition operations that were previously accustomed by Song & Chissom and then, arranged forecasted model using high order fuzzy time series. Huarng [13-14], Hwang and Chen [15], Lee Wang and Chen [16], Li and Kozma [17], all created numerous fuzzy forecasting methods, each with a slight variation. Lee et al. administered a fuzzy candlestick pattern to enhance forecasting outcomes [19]. Later, a multivariate heuristic model was designed and implemented to obtain highly intricate and complex matrix computations [20]. Research Work was performed to ascertain the length of Intervals of fuzzy time series [21]. Event discretisation function based Forecasting models were put forth [22] and practiced to predict the average duration of stay of a patient [23]. Garg [24-25] developed a forecasting approach by administering the notion of OWA weights. This model proved to be an accomplishment as it downsized forecasting error to a certain extent. Afterwards, Garg [26-27] also put forward an optimised model based on genetic-fuzzy-OWA forecasting. Subsequently, the number of outpatient visits in the hospital was demonstrated by Garg [29]. As a matter of fact, the majority of these models was administered for prediction of all other problem domains except rice production. Keeping this fact in mind, this paper put forth a model to predict rice production for India on the premise of historical time series rice data. Real time data of Patnanagar farm, G.B. Pant University of Agriculture & Technology, India has been used by us, and this paper has applied the model to the afore-said data. Later, the final outcomes have been equated with already proposed models on identical rice data to validate its superiority.

III. Proposed Method

A method for rice production forecasting by using actual production as the universe of discourse and interval based partitioning is proposed in this section. The related notions and definitions regarding this can be found by referring to previously published paper [29]. Another method for forecasting the value, which this paper has provided, would be clearly explained in the lines to come. The forecasting process follows the following steps:

Step 1: Firstly, clearly depict the Universe of Discourse U and Partition U into equally length intervals. Here, according to the data, 3219 is the least value and 4554 is the largest value.

First, the Universe Of Discourse , i.e. the interval within which all the given values of rice production would lie needs to be specified .Thus, in this case , the Universe Of Discourse would be [3200 , 4600]. The Historical Data is given year wise in Table 1.

TABLE I. Production Values of Rice

Year	**Production(Kg/hectare)**
1981	3552
1982	4177
1983	3372
1984	3455
1985	3702
1986	3670
1987	3865
1988	3592
1989	3222
1990	3750
1991	3851
1992	3231
1993	4170
1994	4554
1995	3872
1996	4439
1997	4266
1998	3219
1999	4305
2000	3928

Step 2: Depict the fuzzy sets Fi then apply fuzzification. Now divide Universe Of Discourse in 7, 9 and 11 equal intervals these are as following:

a) 7 equal intervals

B1: [3200-3400]
B2: [3400-3600]
B3: [3600-3800]
B4: [3800-4000]
B5: [4000-4200]
B6: [4200-4400]
B7: [4400-4600]

b) 9 equal intervals

C1: [3200-3355.55]
C2: [3355-3511.1]
C3: [3511.1-3666.65]
C4: [3666.65-3822.2]
C5: [3822.2-3977.75]
C6: [3977.75-4133.3]
C7: [4133.3-4288.85]
C8: [4288.85-4444.4]
C9: [4444.4-4600]

c) 11 equal intervals

D1: [3200-3327.27]
D2: [3327.27-3454.54]
D3: [3454.54-3581.81]
D4: [3581.81-3709.08]
D5: [3709.08-3836.35]
D6: [3836.35-3963.62]
D7: [3963.62-4096.89]
D8: [4096.89-4218.16]
D9: [4218.16-4345.43]
D10: [4345.43-4472.7]
D11: [4472.7-4600]

Step 3: Then apply Forecast and defuzzification on the output which have been forecasted.

Now a new method for forecasting the rice production is developed in this step. It's called the Mean Difference Method.

This method is explained as follow:

Consider that the need is to predict the value in the year 1985, and we're already given the actual data of the preceding years.

1981 – 3552 (Let this be x) and its fuzzy sets are B2, C3, D3.

1982 – 4177 (Let this be y) and its fuzzy sets are B5, C7, and D8.

1983 – 3372 (Let this be z) and its fuzzy sets are B1, C2, and D2.

1984 – 3455 (Let this be a) and its fuzzy sets are B2, C2, D3.

1985 - ?

(Let this be 'b'. We have to forecast value of b)

From subsequent tables, it can be inferred that b lies in interval B3, C4, D4.

(I). First, start with x, and from x, subtract the values of data following x. So, need is to compute (x-y), (x-z) individually and (x-a), and take the average of these 3 values as *avg1*.

(II) Similarly, from y, we subtract the values of the data following y in a discrete manner. Again, individually compute (y-z) and (y-a) and take an average of these two values. *Let's call this avg2*.

(III) There's only the value "a" following z. So compute (z-a). Let it be denoted by 'Z'.

(IV) Now, compute *Favg*.

$$Favg = \left(avg1 + avg2 + \text{'}Z\text{'}\right) / 3.$$

In this case:

$$Favg = 291.25.$$

Similarly, the following values of Favg were calculated for the years of which is used to predict the values. These Favg values are used in the next steps to predict the values of rice production. Using Table 1 Favg is summarised as below in Table 2:

TABLE II. CALCULATED FAVG VALUES

Prediction for the year X	**Favg value**
X=1981	-
X=1982	-
X=1983	-
X=1984	291.25
X=1985	188.16
X=1986	22.325
X=1987	13.62
X=1988	-73.79
X=1989	14.24
X=1990	153.96
X=1991	19.46
X=1992	-31.88
X=1993	-181.93
X=1994	-93.53
X=1995	-234.89
X=!996	-138.37
X=1997	-245.29
X=1998	-240.27
X=1999	-39.84
X=2000	-132.46

Step 4: Calculation of Forecasted Values:

Now, we have calculated the Favg value, we would predict the value of rice production at a particular year using this.

METHOD: $Favg = \left(avg1 + avg2 + \text{‘}Z\text{’}\right) / 3.$

If we want to predict value at Year = X, first note Favg value at year = X-1. We need to make a fuzzy set mapping with production value as shown in Table 3.

Now, consider year X, note in which Fuzzy Interval it lies. Let L and R be the lower bound and the Upper Bound of that Fuzzy interval respectively. Then, we calculate the mid-point ‘C’ of this interval as follows:

$$C = \left(L + R\right) / 2$$

The mid-values of the 7, 9, and 11 intervals are calculated in the Tables 4, 5 and 6.

TABLE III. FUZZY SET MAPPING WITH PRODUCTION VALUE

Year	Production	Fuzzy Set 7 Interval	Fuzzy Set 9 Interval	Fuzzy Set 11 Interval
1981	3552	B2	C3	D3
1982	4177	B5	C7	D8
1983	3372	B1	C2	D2
1984	3455	B2	C2	D3
1985	3702	B3	C4	D4
1986	3670	B3	C4	D4
1987	3865	B4	C5	D6
1988	3592	B2	C3	D4
1989	3222	B1	C1	D1
1990	3750	B3	C4	D5
1991	3851	B4	C5	D6
1992	3231	B1	C1	D1
1993	4170	B5	C7	D8
1994	4554	B7	C9	D11
1995	3872	B4	C5	D6
1996	4439	B7	C8	D10
1997	4266	B6	C7	D9
1998	3219	B1	C1	D1
1999	4305	B6	C8	D9
2000	3928	B4	C5	D6

TABLE IV. MIDPOINTS IN 7 INTERVALS

INTERVAL	Mid Points (C)
[3200-3400]	3300
[3400-3600]	3500
[3600-3800]	3700
[3800-4000]	3900
[4000-4200]	4100
[4200-4400]	4300
[4400-4600]	4500

TABLE V. MIDPOINTS IN 9 INTERVALS

INTERVAL	Mid Points (C)
[3200-3355.5]	3277.77
[3355.5-3511.1]	3433.32
[3511.1-3666.65]	3588.87
[3666.65-3822.2]	3744.42
[3822.2-3977.2]	3899.97
[3977.75-4133.3]	4055.52
[4133.3-4288.85]	4211.07
[4288.85-4444.4]	4366.62
[4444.4-4600]	4600

TABLE VI. MIDPOINTS IN 11 INTERVALS

INTERVAL	Mid Points (C)
[3200-3327.27]	3263.63
[3327.27-3454.54]	3390.9
[3454.54-3581.81]	3518.17
[3581.81-3709.08]	3645
[3709.08-3836.35]	3772.75
[3836.35-3963.62]	3899.98
[3963.62-4090.89]	4027.25
[4090.89-4218.16]	4154.22
[4218.16-4345.93]	4281.79
[4345.43-4472.7]	4409.06
[4472.7-4600]	4536.33

Now, to this value of C, we add Favg value. Thus,

$$\text{Forecasted Value } \left(at\ X\right) = C\ \left(of\ X - 1\right) + Favg\ \left(of\ the\ year\ X\right)$$

The year-wise Forecasted Value using different intervals is shown in Table 7.

TABLE VII. FORECASTED VALUES FOR ALL INTERVALS

Year	**Production (A_i)**	**Forecasted value (7 intervals)**	**Forecasted value (9 intervals)**	**Forecasted value (11 intervals)**
1981	3552	-	-	-
1982	4177	-	-	-
1983	3372	-	-	-
1984	3455	3791.25	3724.57	3809.42
1985	3702	3888.16	3932.58	3733.6
1986	3670	3722.325	3766.745	3667.765
1987	3865	3913.61	3913.58	3913.59
1988	3592	3426.21	3515.08	3571.65
1989	3222	3314.24	3292.01	3277.96
1990	3750	3853.96	3898.38	3926.67
1991	3851	3919.46	3919.43	3919.44
1992	3231	3268.12	3245.89	3231.75
1993	4170	4281.93	4393.3	4336.15
1994	4554	4406.47	4428.25	4442.8
1995	3872	3665.11	3665.08	3665.09
1996	4439	4361.63	4228.25	4547.43
1997	4266	4054.71	3965.78	4527.08
1998	3219	3059.73	3037.5	3023.36
1999	4305	4260.16	4326.78	4241.95
2000	3928	3767.54	3767.51	3767.52

IV. PERFOMANCE EVALUATION AND COMPARITIVE STUDY

A. Performance evaluation:

Two parameters have been used to compare the outcomes of proposed method with existing methods. These are as follows

a) AFER (Average Forecasting Error Rate)

$$AFER = (\sum_{n}^{i=1} \left(\left| A_i - F_i \right| / A_{i)} \right) / n * 100\%$$

b) MSE (Mean Square Error)

$$MSE = \left(\sum_{n}^{i=1} \left(A_i - F_i \right)^2 \right) / n$$

Where A_i denotes real time production and F_i denote the predicted value of year i, respectively in [20] Fuzzy time series method.

The MSE and AFER are the values calculated for the interval 7, 9, and 11 as is shown in the Tables 8, 9 and 10.

TABLE VIII. MSE AND AFER VALUES IN 7 INTERVALS

Year	**A_i**	**F_i**	**MSE** $(A_i - F_i)^2$	**AFER** $\vert A_i - F_i \vert / A_i$
1981	3552	-	-	-
1982	4177	-	-	-
1983	3372	-	-	-
1984	3455	3791.25	113064.0625	0.097322
1985	3702	3888.16	34655.546	0.05028
1986	3670	3722.325	2737.9056	0.01425
1987	3865	3913.61	2362.9321	0.0125
1988	3592	3426.21	27486.324	0.04616
1989	3222	3314.24	8508.217	0.02862
1990	3750	3853.96	10807.6816	0.0277
1991	3851	3919.46	4686.7716	0.0177
1992	3231	3268.12	1377.894	0.0114
1993	4170	4281.93	12528.324	0.02684
1994	4554	4406.47	21765.1009	0.03239
1995	3872	3665.11	42803.4723	0.05343
1996	4439	4361.63	5986.1168	0.01743
1997	4266	4054.71	44646.46409	0.04952
1998	3219	3059.73	25366.93289	0.049478
1999	4305	4260.16	2010.6256	0.010415
2000	3928	3767.54	25747.4116	0.048531
			MSE = 22737.576	AFER = 3.45051%

Here it can be observed that the MSE for all the forecasted values in 7^{th} interval based partitioning has been calculated in Table 8. MSE gives us the deviation error from the actual value to the predicted value. The deviation in the form of a graphical representation has been shown in Figure 1 to give a better visibility. As it can be seen that the proposed algorithm gives values very near to the values that are the actual production values. Similarly, it is done for intervals 9^{th} and 11^{th} as shown in Tables 9 & 10 and Figures 2 & 3.

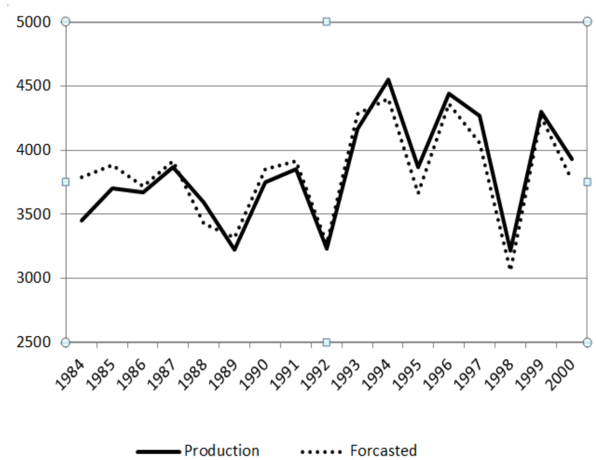

Fig. 1. Forecasted Vs. Production - 7 intervals

TABLE IX. MSE AND AFER VALUES IN 9 INTERVALS

Year	A_i	F_i	MSE $(A_i - F_i)^2$	AFER $\lvert A_i - F_i \rvert / A_i$
1981	3552	-	-	-
1982	4177	-	-	-
1983	3372	-	-	-
1984	3455	3724.57	72667.984	0.071013
1985	3702	3932.58	53167.1367	0.06267
1986	3670	3766.74	9359.5950	0.02654
1987	3865	3913.58	2360.0163	0.01257
1988	3592	3515.08	5916.6864	0.02144
1989	3222	3292.01	4901.400	0.02104
1990	3750	3898.38	22016.624	0.03638
1991	3851	3919.43	4682.664	0.01777
1992	3231	3245.89	221.71209	0.00486
1993	4170	4393.3	49862.89	0.05352
1994	4554	4428.25	15813.0625	0.02118
1995	3872	3665.08	42815.8864	0.05343
1996	4439	4228.25	44415.5625	0.04744
1997	4266	3965.78	90132.0483	0.07065
1998	3219	3037.5	32942.25	0.0562
1999	4305	4326.78	474.368	0.00505
2000	3928	3767.51	25757.0400	0.408579
			MSE = 28088.6429	AFER = 3.759311%

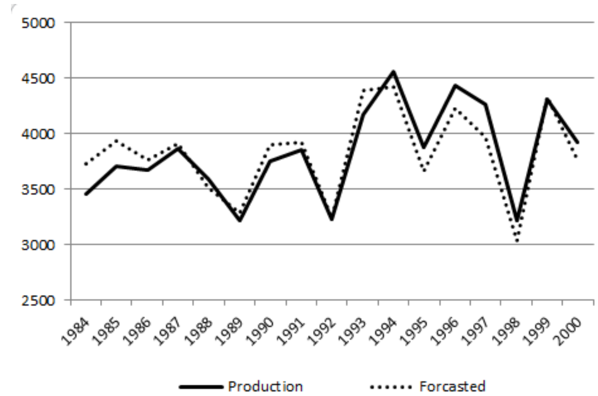

Fig. 2. Forecasted Vs. Production - 9 intervals

TABLE X. MSE AND AFER VALUES IN 11 INTERVALS

Year	A_i	F_i	MSE $(A_i - F_i)^2$	AFER $\lvert A_i - F_i \rvert / A_i$
1981	3552	-	-	-
1982	4177	-	-	-
1983	3372	-	-	-
1984	3455	3809.42	125613.5364	0.10258
1985	3702	3733.6	998.56	0.00853
1986	3670	3667.765	4.995225	0.00006
1987	3865	3913.59	2360.9881	0.01257
1988	3592	3571.65	414.1225	0.00566
1989	3222	3277.96	3131.5216	0.01736
1990	3750	3926.67	31212.0336	0.047112
1991	3851	3919.44	4682.0336	0.01777
1992	3231	3231.75	0.5625	0.00002
1993	4170	4336.15	27605.8225	0.03984
1994	4554	4442.8	12365.44	0.02441
1995	3872	3665.09	42811.7464	0.053437
1996	4439	4547.43	11757.065	0.024418

1997	4266	4527.08	68.162.7664	0.0612002
1998	3219	3023.36	38275.0096	0.0607766
1999	4305	4241.95	3975.3025	0.0142001
2000	3928	3767.52	25753.8304	0.0408553
			MSE = 23478.0938	AFER = 3.1297204%

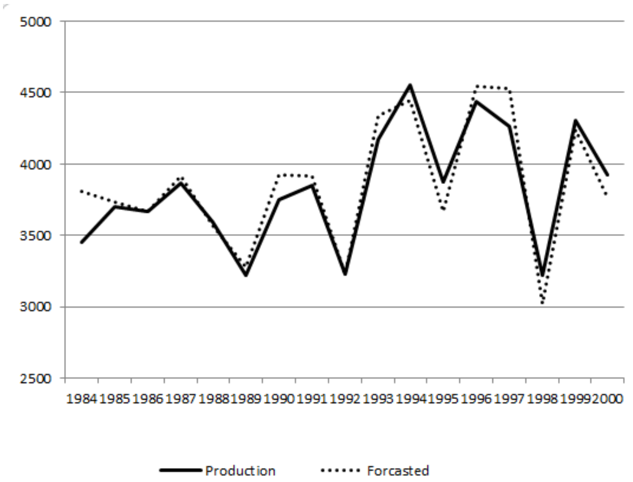

Fig. 3. Forecasted Vs. Production - 11 intervals

B. *Results and discussion:*

The MSE and AFER as calculated above in the Tables 8-10 have been analysed. This paper shows work on different intervals such as 7th, 9th and 11th intervals. The majority of papers that have been published recently have worked on one of these intervals. The focus of this paper was to propose a novel algorithm and see its prediction variation on all these intervals. The results have shown that prediction works best for 7th intervals among all other intervals. All the results are shown in the form of easy to understand bar graphs so as to reduce the complexity of this research and present it in a more easy to understand fashion. The MSE of all the intervals has been compared in Figure 4. The comparison has been made with other existing methods proposed by Chen and Song & Chissom in Table 11 to prove that this algorithm is efficient. As it can be seen in Figure 5, the proposed algorithm was able to achieve significantly lower MSE as compared to other methods. The model not only gives a lower MSE but also explains why researchers who make fuzzy logic predictions choose the 7th interval for their line of work. All other intervals do not give better results than 7th interval partitioning. There could be the reason that with increasing the number of intervals, the data becomes overly congested. Due to this, relevant data between the intervals do not get included in the prediction algorithm and affects the prediction results. If we keep the intervals lower than 7th interval then the data get overly disseminated. So 7th interval partitioning seems to be the overall best fit for fuzzy logic based prediction models.

Fig. 4. MSE 7, 9 and 11 intervals

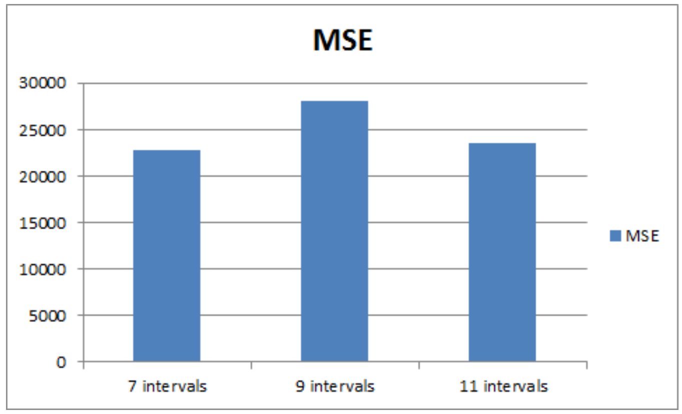

TABLE XI. COMPARISON TO PROVE EFFICIENCY

Method	**MSE**	**AFER**
Proposed Method	22737.5	3.45051%
CHEN	132162.9	7.934613%
Song & Chissom	131715.9	7.748644%

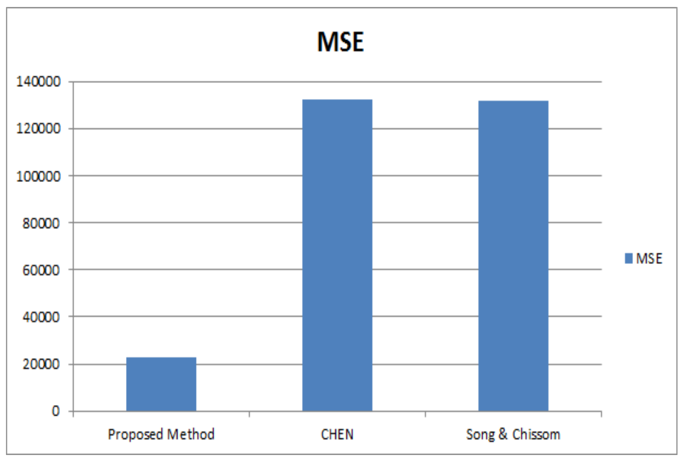

Fig. 5. MSE comparison among three models.

V. CONCLUSION AND FUTURE SCOPE

A new fuzzy time series strategy based upon the mean difference of the production of rice to predict the yield of rice in that particular year has been put forward by us. First, the set of data is divided into 7,9,11 intervals and for every year Favg value is calculated, using these Favg values the forecasted value of rice production in any year is calculated. After that, the results have been validated using the precision, accuracy and robustness of the proposed model by comparing it with other existing methods. It was noticed that the new method is optimal and produces the highest precision having a minimal mean square error and average forecasting error rate than those of the given prediction models. Therefore, the established fuzzy approach can be viewed as an inerrant and efficient way to assess, evaluate and approximate rice production. Keeping the future scope of this work in mind, the proposed model can be extended to deal with multidimensional time series data and augmented with more advanced algorithms. Proposed model can be extended by working on more intervals. Frequency based partitioning can also be applied to intervals to get better refinement in distribution.

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