International Journal of Statistics and Applied Mathematics 2023; 8(3): 54-57

International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2023; 8(3): 54-57

https://www.mathsjournal.com
Received: 10-04-2023
Accepted: 11-05-2023

Elakkiya N
Research Scholar, Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

Bhattacharyya B
Associate Professor, Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

Corresponding Author:
Elakkiya N
Research Scholar, Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

Chen's model to understand the invariant fuzzy time series model through maize production in India

Elakkiya N and Bhattacharyya B

DOI: https://doi.org/10.22271/maths.2023.v8.i3a.980

Abstract
The present study has applied a time-invariant fuzzy time series model for maize Production in India. Most of the time series data is forecasted using AR and ARIMA models but the present study considered the Chen fuzzy time series model to understand fuzzy time series and endeavour to forecast. Generally, fuzzy models are based on uncertainty, non-probabilistic and linguistic variables. The maize production of India during 1951-2020 data was divided into seven subsets. The subsets are equal intervals. Chen's model has used arithmetic operations for fuzzy logic relations and forecasting. The accuracy of the model was measured by Root Mean Square Error (1949.93) and Mean Absolute Percentage Error (25.86). The Chen model will give impetus to the higher-order fuzzy time series model.

Keywords: Chen fuzzy time series model, subsets, fuzzy logic relations, and model accuracy

1. Introduction

Maize (*Zea mays*) is known as the queen of cereal crops and one of the most important crops for human consumption next to rice and wheat. India is ranked fourth in terms of area with 9.89 million ha and the productivity is about 3.19 t/ha. The major pattern of maize consumption is considered as feed, food and Industrial non-food products (mainly starch). Around 47% of maize produced in India is consumed by feed industries. From this, about 63% of the consumption is going to poultry and cattle feed. Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Bihar, Uttar Pradesh, Telangana, Gujarat and Tamil Nadu are contributing above 75% of production to the country. The traditional maize growing areas are Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh and non-traditional maize areas such as Karnataka and Andhra Pradesh. The crop is mainly grown in traditional areas as a subsistence crop to satisfy food needs. In comparison, maize is grown commercially in non-traditional areas, primarily to supply the expanding poultry industry's feed needs.

Zadeh [1965] [7] introduced the FS theory to deal with having uncertainty and impression, this becomes an amazing tool for many real-life problems involving vagueness and impression in the information. Soft computing techniques are more comfortable tools for forecasting over other statistical models in forecasting (Rana *et al.*, 2020a) [5]. Rana *et al.*, [2020b] [6] used nested interval-based fuzzy time series models to reduce the error in forecasting values significantly for fish production. The shape of the membership function was important in fuzzy time series model thus that triangular and trapezoidal membership with centroid defuzzification used by Basyigit *et al.*, [2014] [1]. Kumar *et al.*, [2010] [3] applied a fuzzy time series model to forecast wheat production. Kumar *et al.*, [2019] [4] build a mathematical prediction model that depends on the high-order fuzzy logical relationship to reduce the average forecasting error of the existing fuzzy time series forecasting method and increased the accuracy of prediction value in agricultural production.

2. Materials and Methods

Let's consider fuzzy set A, $A = \{u_i, \mu_{Ai}(u_i) | u_i \in \mathrm{U}\}$, where μ_{Ai} is called the membership function for the fuzzy set A. U is referred to as the universe of discourse with $U = \{u_1, u_2, u_3 \ldots\ldots\ldots, u_n\}$, where u_i are possible linguistic values of U, then a fuzzy set of linguistic variables A_i of U is defined by

$$A_i = \frac{\mu_{A1}(u_1)}{u_1} + \frac{\mu_{A2}(u_2)}{u_2} + \frac{\mu_{A3}(u_3)}{u_3} + \dots\dots\dots + \frac{\mu_{An}(u_n)}{u_n}$$

Each element is mapped to [0, 1] in fuzzy sets by a membership function.
Let Y(t) (t =…..,0, 1, 2, 3,…..) be a subset of R, be the universe of discourse on which fuzzy sets $[f_i(t): i = 1, 2, \dots]$ are defined and F(t) is the collection of fuzzy sets, then F(t) is defined as fuzzy time series on Y(t). At different times, the values of F(t) can be different, *F*(*t*) is a function of time and similarly, the universe of discourse *Y*(*t*) may be different at different times. If there exists a fuzzy relationship $R(t, t-1)$, such that

$$F(t) = F(t-1) o R(t, t-1)$$

Where *o* is an operator, then F(t) is said to be caused by *F* (*t* − *1*). The relationship between *F*(*t*) and *F* (*t* − *1*) can be denoted by $F(t-1) \to F(t)$. Suppose $F(t-1) = A_i$ and $F(t) = A_j$, a fuzzy logical relationship is defined as

$$A_i \to A_{j1}$$

$$A_i \to A_{j2}$$

where A_i is named as the left-hand side of the fuzzy logical relationship and A_j on the right-hand side. Fuzzy logical relationships can be further grouped into fuzzy logical relationship groups according to the same left-hand sides of the fuzzy logical relationships.

$$A_i \to A_{j1}, A_{j2} \dots,$$

Suppose *F*(*t*) *is* a fuzzy time series and $R(t_1, t_1 - 1)$ be a first-order model of *F*(*t*) such that $R(t_1, t_1 - 1) = R(t_2, t_2 - 1)$ for $t_1 \neq t_2$, the *F*(*t*) is called the time-invariant fuzzy time series. But if $R(t_1, t_1 - 1)$ is time-dependent i.e., $R(t_1, t_1 - 1) \neq R(t_2, t_2 - 1)$ for $t_1 \neq t_2$, then *F*(*t*) is called time-variant fuzzy time series. If *F*(*t*) is caused by more fuzzy sets, $F(t-n), F(t-n+1), \dots, F(t-1)$, the fuzzy relationship is represented by

$$A_{i1}, A_{i2}, A_{i3} \dots\dots, A_{in} \to A_j$$

where $F(t-n) = A_{i1}$, $F(t-n+1) = A_{i2}, \dots$, $F(t-1) = A_{in}$. This relationship is called the n^{th}-order fuzzy time series model Rana *et al*., [2020b] [6].

2.1 Fuzzification and defuzzification
The process of generating membership values for a fuzzy variable using membership functions is termed fuzzification. (i.e., translation from u to $\mu_A(u)$. The process of transforming a fuzzy output of a fuzzy inference system into a crisp output is known as defuzzification. The input for the defuzzification process is a fuzzy set and the output is a single number.

2.2 Membership functions
A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse.

$$\mu_{Ai} : U \to [0, 1]$$

Where $\mu_A(u) = 1$ if *u* is totally in fuzzy set A;
$\mu_A(u) = 1$ if *u* is not in fuzzy set A; $0 < \mu_A(u) < 1$ if *u* is partly in fuzzy set A;
In this study time-invariant fuzzy time series model especially Chen model is used for maize production data in India for the 1951 to 2020 data set. The steps involved in the invariant fuzzy time series model are

1) Defined the universe of discourse and the intervals,
2) Partition of the intervals,
3) Defined the fuzzy sets,
4) Fuzzified the data,
5) Established fuzzy relationships,
6) Forecasted and defuzzified the forecasting results.

In the Chen Model, the arithmetic operation is applied for establishing fuzzy relationships and forecasting Joshi *et al*., [2013] [2].

2.3 Forecasting accuracy measures
Mean Absolute percentage Error (MAPE) = 1/n ∑ [| Actual Value – Forecasted Value |) / Actual Value] * 100.

$$e_i = (Actual\ value - forecasted\ value)$$

Root means squared error (RMSE)= $(\text{mean}|e_i^2|)^{1/2}$

3. Results and Discussion

Table 1: Subset of maize production data in India using the Chen model

Subset	Lower limit	Upper limit	Mid value	Number
Very poor yield	1719	5585	3652	19
Poor yield	5585	9451	7518	23
Below average yield	9451	13317	11384	11
Average	13317	17183	15250	5
Above average	17183	21049	19116	2
High yield	21049	24915	22982	6
Very high yield	24915	28781	26848	4

In the Table 1 showed that the whole 70 years of mazie production data have been divided into seven subsets. The intervals of each subset had been equal. Therefore, the fuzzy set is called an equal interval fuzzy set. The mid-value of each set is calculated by adding both lower and upper limit values and dividing by two. The last column indicated the number of observations belonging to the corresponding sets.

Table 2: Relative groups of fuzzy logic

$A_1 \to A_1, A_2$	$A_2 \to A_1, A_2, A_3$
$A_3 \to A_2, A_3, A_4$	$A_4 \to A_4, A_5, A_6$
$A_5 \to A_4, A_5$	$A_6 \to A_6, A_7$
$A_7 \to A_7$	

From the 19 fuzzy logic relations: $A_1 \to A_1$, $A_1 \to A_2$, $A_2 \to A_2$, $A_2 \to A_3$, $A_3 \to A_3$, $A_3 \to A_4$, $A_4 \to A_4$, $A_4 \to A_5$, $A_4 \to A_6$, $A_5 \to A_5$, $A_6 \to A_6$, $A_7 \to A_7$, $A_2 \to A_1$, $A_3 \to A_2$, $A_2 \to A_3$, $A_4 \to A_3$, $A_5 \to A_4$, $A_6 \to A_4$, $A_7 \to A_6$ formed the fuzzy logic relative groups using $\cup_{i=1}^{19} R_i$; where R is fuzzy time-invariant relation.In Table 3, the forecast value has been presented. There are obtained from the following steps

If $A_i \to A_j$ is the only fuzzy logic relation in Table 2 then next year's forecast will be m_k i.e. mid-value of A_j. The forecasted value of the year 2018-2020 would be the mid-value of subset A_7 because these years had $A_7 \to A_7$ fuzzy logic relation.

If relation groups were $A_1 \to A_1$, A_2 then the forecast value would be the mean of the corresponding mid-value. Therefore forecast value of relation $A_1 \to A_1$, $A_1 \to A_2$ has been (3652+7518)/2 = 5585. Similarly, for the fuzzy logic relation group $A_2 \to A_1$, A_2, A_3 the forecast has been (3652+7518+ 11384)/3. The accuracy of the forecast is measured by Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE).

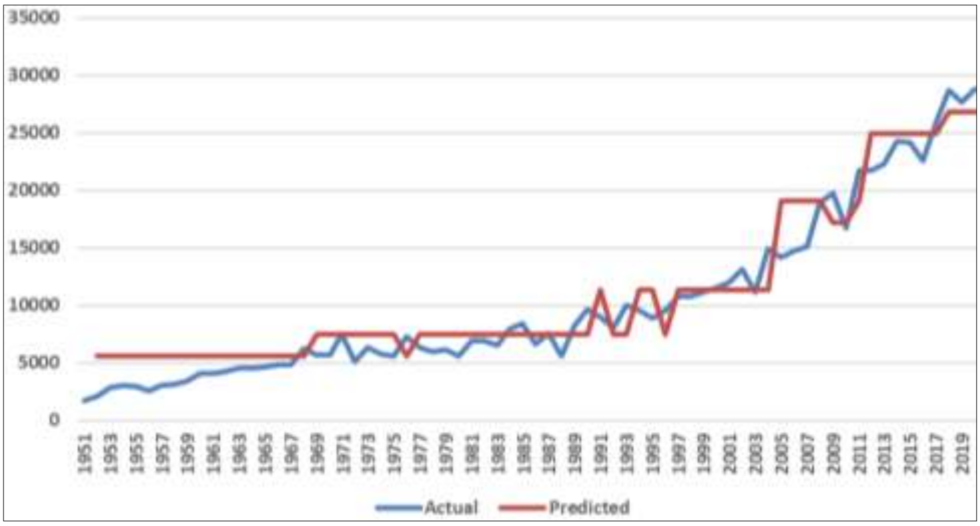

Fig 1: Plot of Actual Vs Forecasted Mazie Production in India

Table 3: Actual Vs Forecasted Value of Maize Production with an accuracy value

Year	Actual Mazie Production	Predicted Value	Year	Actual Mazie Production	Predicted Value
1951	1729	NA	1986	6643	7518
1952	2076	5585	1987	7593	7518
1953	2870	5585	1988	5629	7518
1954	3039	5585	1989	8229	7518
1955	2975	5585	1990	9651	7518
1956	2602	5585	1991	8962	11384
1957	3078	5585	1992	8064	7518
1958	3150	5585	1993	9994	7518
1959	3463	5585	1994	9601	11384
1960	4073	5585	1995	8884	11384
1961	4080	5585	1996	9534	7518
1962	4312	5585	1997	10770	11384
1963	4607	5585	1998	10819	11384
1964	4561	5585	1999	11148	11384
1965	4664	5585	2000	11510	11384
1966	4823	5585	2001	12043	11384
1967	4894	5585	2002	13160	11384
1968	6270	5585	2003	11152	11384
1969	5701	7518	2004	14984	11384
1970	5674	7518	2005	14172	19116
1971	7486	7518	2006	14709	19116
1972	5101	7518	2007	15097	19116
1973	6388	7518	2008	18955	19116
1974	5803	7518	2009	19731	17183
1975	5559	7518	2010	16720	17183
1976	7256	5585	2011	21726	19116
1977	6361	7518	2012	21759	24915
1978	5973	7518	2013	22258	24915
1979	6199	7518	2014	24260	24915
1980	5603	7518	2015	24172	24915
1981	6957	7518	2016	22567	24915
1982	6897	7518	2017	25900	24915
1983	6549	7518	2018	28753	26848
1984	7922	7518	2019	27715	26848
1985	8442	7518	2020	28766	26848
MAPE	25.86				
RMSE	1949.93				

4. Conclusion

This study attempted a fuzzy time series model for maize production data in India. The whole data was divided into seven fuzzy sets and from the 19 fuzzy logic relation seven fuzzy logic groups were obtained using union operator relationship. Chen's model has used arithmetic operations for forecasting. The actual and forecasted value is figured in Figure 1. Chen's fuzzy time series model is fitted, and its accuracy has been measured with Root Mean Square Error (1949.93) and Mean Absolute Percentage Error (25.86). The Chen model will give impetus to the higher-order fuzzy time series model for forecasting Kumar *et al*., [2019] [4].

5. References

1. Basyigit, Ihsan A, Ulu C, Guzelkaya M. A new fuzzy time series model using triangular and trapezoidal membership functions, Proceedings of International work-conference on Time Series; c2014. p. 634-644.
2. Joshi BP, Kumar S. A computational method for fuzzy time series forecasting based on different parameters, International Journal of Modeling, Simulation and Scientific Computing. 2013;4(1):1250023-34.
3. Kumar N, Ahuja S, Kumar V, Kumar A. Fuzzy time series forecasting of wheat production, International Journal on Computer Science and Engineering. 2010;2(3):635-640.
4. Kumar S, Manas KS. A higher order fuzzy logic model with the genetic algorithm used to predict rice production in India, International Journal of Innovative Technology and Exploring Engineering. 2019;8(12):771-775.
5. Rana AK. Comparative study on fuzzy models for crop production forecasting, Mathematics and Statistics. 2020a;8(4):451-457.
6. Rana AK. Fish production forecasting in India using nested interval based fuzzy time series model, International Journal of Recent Technology and Engineering. 2020b;8(6):5534-37.
7. Zadeh L. Fuzzy Sets, Information and Control. 1965;8:338-353.