ANALYSIS AND DESIGN OF FUZZY MODEL FOR WHEAT PRODUCTION

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Abstract: In this paper investigates the predictive performance of fuzzy time series method for wheat production data set. Fuzzy time series deals with forecasting under the fuzzy environment that contains uncertainty, am- biguity, vagueness and imprecision of the data set. It is a time invariant method for modeling rather than classical method. There is no prerequisite like stationarity and normality. The aim of present work is to design and implement the competent of fuzzy time series model for forecasting of wheat production data set. The accuracy of the forecasting result is compared based on some residual methods.

KEY WORDS: sustainability, nitrogen, Mamdani, fuzzy system.

Introduction:

Wheat is the second most important food-grain of India and is the staple food of millions of Indians, particularly in the northern and north-western parts of the country. It is rich in proteins, vitamins, carbohydrates and provides balanced food. India is the fourth largest producer of wheat in the world after Russia, USA and China and accounts for 8.7 percent of the worlds total production of wheat. Conditions of growth for wheat are more exible than those of rice. In contrast to rice, wheat is a Rabi crop which is sown in the beginning of winter and is harvested in the beginning of summer. The time of sowing and harvesting di_ers in di_erent regions due to climatic changes. The sowing of wheat crop normally begins in the September-October in Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh and West Bengal; October-November in Bihar, Uttar Pradesh, Punjab, Haryana and Rajasthan Nov-December. in Himachal Pradesh and Jammu Kashmir.The harvesting is done in Jan - Feb in Karnataka, Andhra Pradesh, M.P., and in West Bengal; March-April in Punjab, Haryana, U.P and Rajasthan and in April-May in Himachal Pradesh the growing period is variable from one agro climatic zone to other that e_ects the vegetative and reproductive period leading to di_erences in potential yield. The important factors a_ecting the productivity are seeding time and methodology, crop establishment and climatic conditions during the growing season. Wheat is primarily a crop of mid-latitude grasslands and requires a cool climate with moderate rainfall. The ideal, wheat climate has winter temperature 10C to 15C and summer temperature varying from 21C to 26C. The temperature should be low at the time of sowing but as the harvesting time approaches higher temperatures are required for proper ripening of the crop.But sudden rise in temperature at the time of maturity is harmful. Wheat thrives well in areas receiving an annual rainfall of about 75 cm. Annual rainfall of 100 cm is the highest limit of wheat cultivation. A time series is a
sequence of observations collected at regular time intervals.Time series analysis comprises methods for analyzing time series data in order to extract meaningful statistics and other characteristics of the data. Time series forecasting is the use of a model to predict future values based on previously observed values time series model is used to discover the pattern and predict future values of real data. In the present work, we have implemented to forecast the wheat production in India.

MATERIAL AND METHODS

Experiment Description

The experiment was developed by Kummer (2013) which was conducted in pots arranged in a greenhouse at the Department of Soil and Environmental Resources belonging to the College of Agricultural Sciences at the Universidade Estadual Paulista "Julio de Mesquita Filho", FCA / UNESP, Botucatu / SP. Kummer (2013) classified the soil used in the experiment is originally as Dystrofic Oxsoil (Santos, 2013). Before the establishment of the experiment, in the same pots were cultivated two consecutive cycles of wheat and soybeans planted in May and November 2011, respectively, with application of composted sewage sludge (CSS) and irrigation with potable water (PW) and wastewater (WW), following the same experimental setup and the same research structure. Therefore this study started from the third application of composted sludge (Kummer, 2013).

The seeding took place in May 2012, which were sowed 30 seeds per pot of CD150 cultivar. At the time of seeding a template was used to provide the correct distribution in the pot. After emergence was performed plant thinning, leaving 24 plants per pot (KUMER, 2013).

A completely randomized design was adopted with two types of water (drinking water and wastewater) and 6 levels of nitrogen fertilization, totaling 12 treatments with 10 repetitions. Nitrogen fertilization was based on the N dose recommended (80 kg N ha-1) for the full development of the culture (Raij et al., 1997). In treatments with composted sewage sludge, fertilization levels were defined on the basis of partial, total or higher replacement of the recommended N rate by the equivalent of this element present in the composted sewage sludge.

Distribution of treatments in the experimental plots follows the principle of randomization and were defined as follows: N1 = without nitrogen fertilization; N2 = 50% mineral nitrogen fertilizer + 50% nitrogen fertilizer from composted sewage sludge – CSS (totaling 80 kg N ha-1); N3 = 100% of nitrogen fertilizer from the CSS (80 kg N ha-1 from sludge); N4 = 150% of nitrogen fertilizer from the CSS (120 kg N ha-1, via sludge); N5 = 200% of nitrogen fertilizer from the CSS (160 kg N ha-1 via sludge); N6 = 250% of nitrogen fertilizer from the CSS (200 kg N ha-1, via sludge).

The quantities of composted sewage sludge were calculated based on the nitrogen content in the organic material and mineralized fraction of N that was 30%, since the rates established by Resolution CONAMA no 375/2006 are based on North American values, specific to soils of temperate climate different from tropical conditions (Andrade et al., 2010). It was considered for 100 kg of sludge in dry basis we have 1.1 kg of N and 30% of this N will be mineralized in the first year.

All treatments received complementary chemical fertilizers with P2O5 and K2O (Raij et al., 1997) in order to standardize the soil in 150 mg dm-3 of P and 80 mg dm-3 of K.

The composted sewage sludge originated from the sewage treatment plant - STP from the city of Jundiaí-SP, and the wastewater was from the sewage treatment plant - STP of Botucatu-SP. Information on the characteristics of sewage sludge and wastewater is in Kummer (2013).

The water supply to the plants was carried out through drip irrigation, daily in order to restore the amount of water used by the plant due to the culture evapotranspiration, daily estimated from the evaporation of the water from a Class A tank, located in the center of the agricultural greenhouse.

The following parameters were evaluated from productivity components: dry mass of the aerial part, represented by the stem mass sum + mass of leaves excluding the spikes and roots (g pot-1); number of spikes per plant; spike length (cm); number of spikelet per spike; number of grains per spike; mass of grains per spike, corrected to 13% of moisture (g).

Method Used

In this section, we present the stepwise procedure of the proposed method for neural network forecasting model.

1. Define the input parameter (viz. those(X1, X2 , X3 …., Xn) metrological parameter which directly influencing the crop production).
2. Collect the enrollment data of year t and previous years (data for the metrological parameters and actual crop production).
3. Normalized the enrollment data so the every value must be in between 0 and 1.
4. Design the Artificial Neural Network (ANN) with the consideration of number of layers in ANN, number of hidden layer and number of neurons in a particular layer.
5. Select the best suited training algorithm for ANN.
6. Define the transfer function for the each layer as suited for the problem, for which we are designing the neural network.
7. Decide the number of epochs and goal for the training of ANN.
8. Select the programming tool to write the simulator for the proposed neural network.
9. Now train the ANN with the collected enrollment data of previous ‘ m ’ years for selected parameters (X1, X2 , X3 …., Xn) and (O(t-1), O(t-2), O(t-3),…….., O(t-m)) actual productions .
10. Once the ANN is trained for the set goal then apply the test patterns for the years t + 1, t + 2, t + 3 ……. t+p , for which we want to forecast the agricultural products. Output of ANN will be taken as the forecasted values for the corresponding years.
11. Do the Comparative study with fuzzy series forecasting models.
12. Do the error analysis with observed forecasted values and actual production values to validate the model.

Model-1

(1) If the production of the year i is Aj, and fuzzy logical relation is Aj□Ak and Ak has max membership in interval
Uk , then the forecasted production for the year i = l will be midpoint of Ak.

(2)If the fuzzified production of the year i is Aj, and there are fuzzy logical relationships in the fuzzy logical
relationship group as:

Aj □ Ak 1, Aj □ Ak1,.....Aj □Akp

Ak 1, Ak1 ,..... , Akp has max membership in the intervals

Uk1,Uk2,….., Ukp

respectively and m1 , m2 ,....mp are their respective midpoints , then the forecasted production for the year i+1
will be (m1 + m2+…..+mp)/p .

(3)If the fuzzified production of a year i is *Aj*, and no logical relationship is found in logical relationship groups, whose current state of production is Aj ,where the maximum membership value of Aj occurs at interval U*j* and the midpoint of Uj is mj then the forecasted production of year i+1 is mj.

Model-2

Similar procedures of defuzzification as in model-1 with additional concept of repeated relations and according
weighted mean is computed keeping in view of their frequencies.

Model-3

A combined approach is proposed to have the defuzzification of the fuzzy output into crisp output. The rules are as follows;

(1) If fuzzy output set has only one max, then choose the mid point of the interval corresponding to that max as
forecasted production.

(2) If the fuzzy output has only one consecutive max, then choose the midpoint of the corresponding conjunct
interval as the forecasted value.

(3) If more than one non consecutive max and that lies in min set and in max set then choice will depend on the
previous year production. If previous year production is closer to min set then select the min set and vice-versa.

(4) If the rule 3 is not applied and other type of non consecutive max appear in fuzzy output then compute the
weight function wf for selection First weight function :

Wf1= Max [min (Ui, Ui-1) + min (Ui, Ui+1)]

The set with higher Wf1 will be selected.

If first weight function is equal, compute the second weight function

Wf2 = Min [min (Ui ,Ui-2) + min (Ui ,Ui+2)]

The set with lower Wf2 will be selected.

(5) If there occurs a consecutive max followed by another relative consecutive max, compute the weighted mean of the means of two streams of max and relative max.

(6) Otherwise compute the forecasted value by computing the average of all max intervals.

RESULTS AND DISCUSSIONS

The Production of wheat (in million tons) in India is considered for the model building for 57 observations from the years 1958 to 2015 are used for _tting the both fuzzy time series and ARIMA model. The main objective is to identify the more accurate model for forecasting agricultural production.

ARIMA Model. The production and yield of wheat in India have observed a many fold increase during past 57 years (Fig.1). Increase in wheat productivity represented an increase of year. However, cultivated area merely doubled during this period. Highest production as well as yield of wheat was recorded during 2019-2020. Increase in production of wheat in this, Improved plant protection measures, e_cient irrigation facility, etc. As close observation of the production and yield of last ten years showed that overall negative trend was registered over these years. Possible cause of such disparity in production might be abnormal climate change, excessive chemical use in recent years etc.

Estimation of ARIMA model involves transformation of the forecasting vari- ables into a stationary series. The most usual method is to check stationary series through the graph or time plot of data (Mandal, 2005). Fig. 1 revealed that the data is non-stationary. Non-stationary in mean is corrected through suitabledi_erencing of the function auto.arima () in the forecast library of the language worked out that di_erence of order 1 was su_cient to achieve stationarity in mean for all the cases. Model diagnostics variable production is presented in a lower value of RMSE (root mean square error) and MAE (mean absolute error) de-ne that identi_ed models were accurate enough to forecast above variables. The production results are here under.

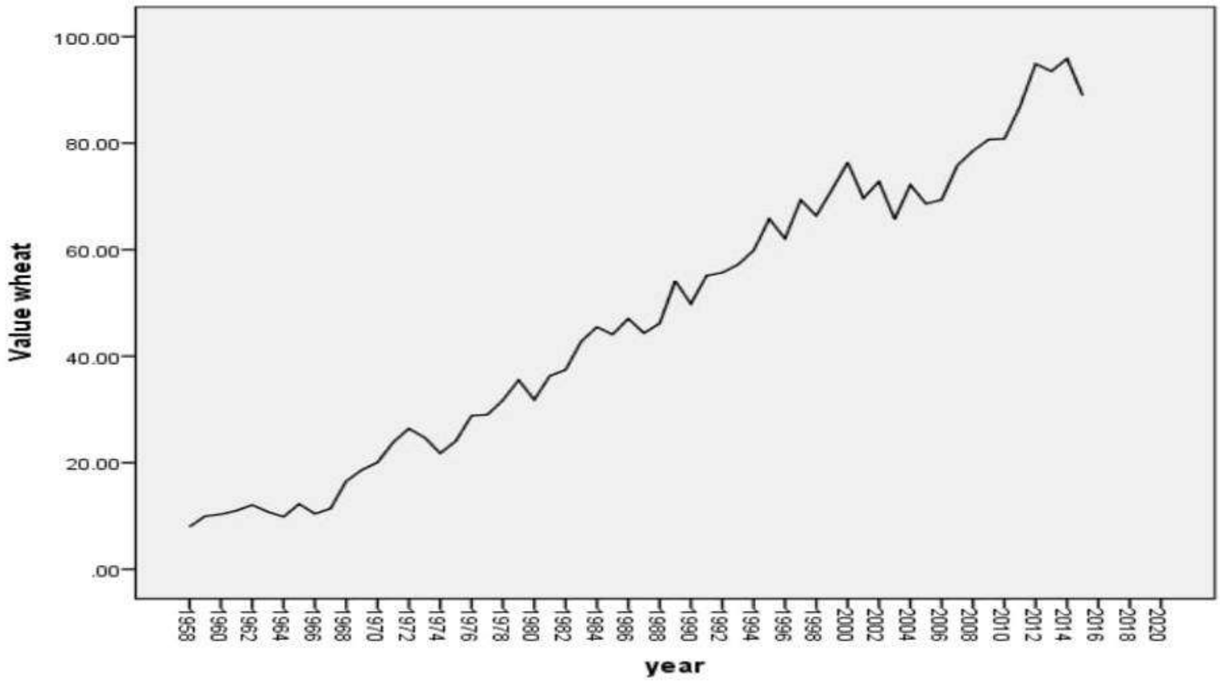

Figure 1. non-stationary series of wheat production

Using ARIMA (1, 1, 1) the 5 year advance production and their 95 per cent con_dence interval are calculated and presented in Table 1. The production results in wheat production indicated trends in production in the coming years. On the basis of model output an increase in the production from 88.77 million tons in 2010-11 to 103.87 million tons in 2015-16 and 110.47 million tons in 2020 is expected (Table 5). The minimum production with 95 per cent con_dence showed that wheat production may decrease in the coming years and will reach 86.97 million tons during 2020 which is at par with the current production level. This may occur due to adverse e_ect of temperature rise, government attention to the crop and decrease in cultivable land. However, maximum production registered a signi_cant increase in production levels which may reach upto 110.47 million tons by 2020, like wheat production in India. Figure represent the forecasting value of wheat production.

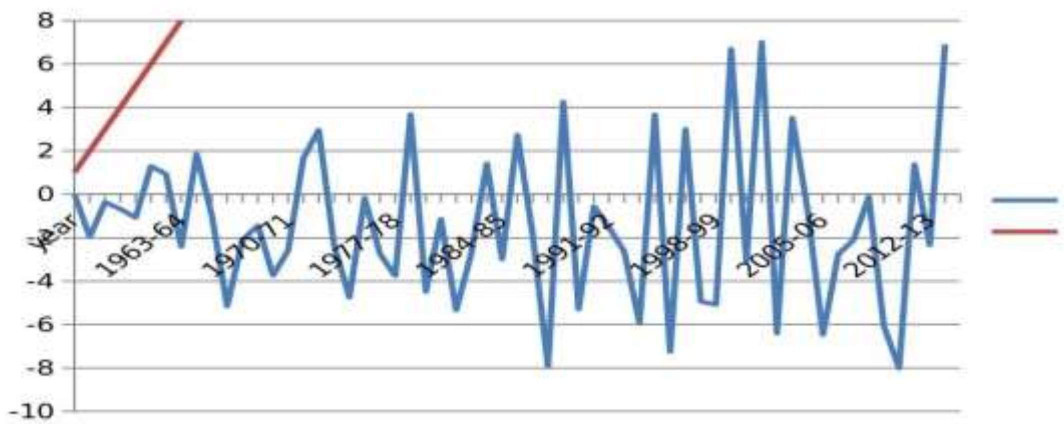

Figure 2. stationary series of wheat production

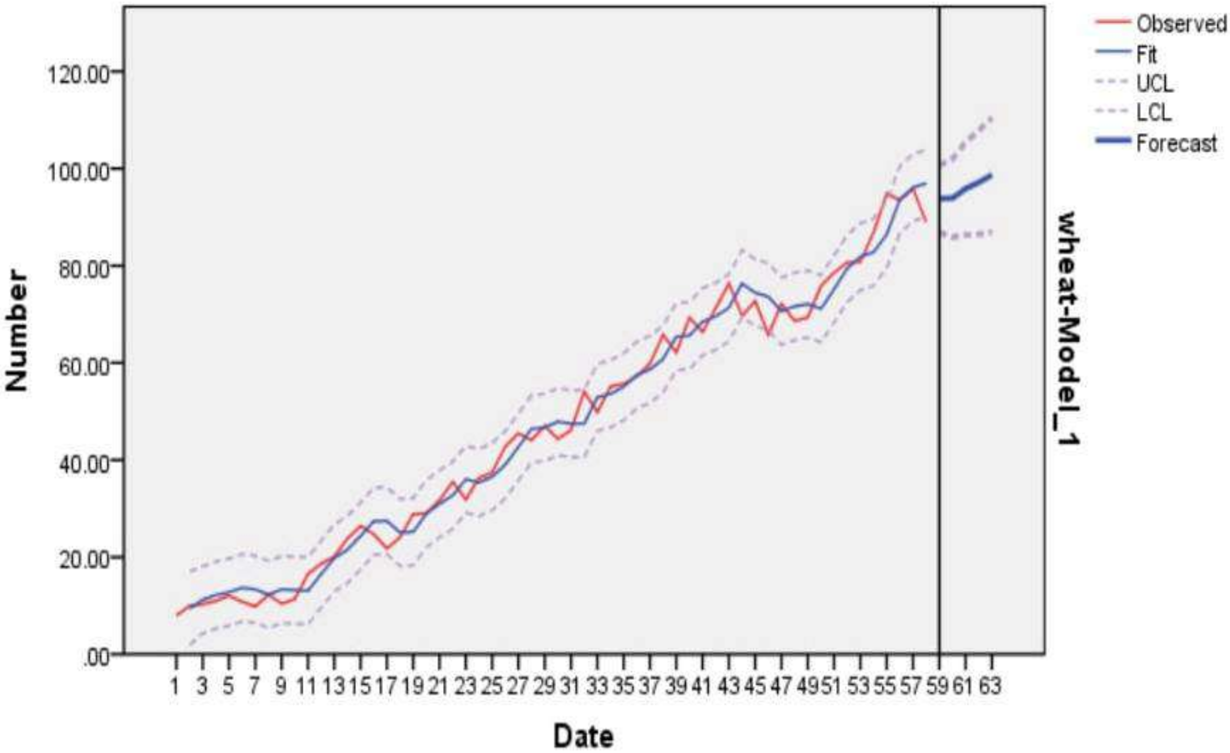

Figure 3. Forecasting of wheat production

Table 1. Prediction of wheat production

Year	Production	Difference	Prediction	LCL	UCL	Noise Residual
2010	80.8	0.12	81.87	74.97	88.77	-1.07
2011	86.87	6.07	82.8	75.9	89.7	4.07
2012	94.88	8.01	86.46	79.56	93.36	8.42
2013	93.51	-1.37	93.65	86.75	100.55	-0.14
2014	95.85	2.34	96.09	89.19	102.99	-0.24
2015	88.94	-6.91	96.97	90.07	103.87	-8.03
2016			93.81	86.91	100.71	
2017			93.92	85.9	101.95	
2018			95.91	86.36	105.47	
2019			97.17	86.49	107.84	
2020			98.71	86.94	110.47	

Table 2. Forecasting of wheat production

Model		59	60	61	62	63
wheat-Model_1	Forecast	93.81	93.92	95.91	97.17	98.71
	UCL	100.71	101.95	105.47	107.84	110.47
	LCL	86.91	85.90	86.36	86.49	86.94

Computation of Fuzzy Time Series model.

Step 1: De_ne the universe of discourse to accommodate the time series data. It needs the minimum and maximum production and set as D min and D max. Thus universe of discourse U is de_ned as [Dmin { D1, Dmax - D2], here D1, and D2 are two proper positive numbers. In the present case of production forecasting universe of discourse computed is U = [7.99 { 95.85]

step 2: Partition the universes of discourse into 20 equal length intervals U1, U2,...., U20:

step 3: Calculate the number of intervals (fuzzy numbers) as follow. Intervals Fuzzy Numbers
U1 =[5, 10], U11=[55, 60] A1= (0, 5, 10, 15)
U2=[10, 15], U12=[60, 65] A2= (5, 10, 15, 20)
…….U9=[45, 50], U19=[95, 100] A19= (85, 90, 95, 100)
U10=[50, 55], U20=[100,105] A20= (90, 95, 100, 105)
step 4: Fuzzify the productions, for example, the wheat production in year 1958 is 7.99, which is located at the range of U2 = [10; 15]: Thus, the corresponding fuzzy number of year 1958 is assigned as Ai. Table 1 lists the corresponding fuzzy number for the wheat production of each year.

step 5: According to table 3, we can derive the fuzzy logical relationships as shown in table 4. Notice that the repeated relationships are counted only once.

step 6: Based on the same fuzzy numbers on the left hand side of the fuzzy logical relationships in table 4, 18 fuzzy logical relationship groups are generated as shown in table 5
.
step 7: According to tables 5 and 6, we can calculate the forecasted wheat productions. For instance, the forecasted wheat productions of years 1959 and 1961 can be illustrated below: Forecasting 1958: The fuzzi_ed wheat production of year 1958 in table 3 is A1, and from table 6

we can _nd that there are three fuzzy logical relationships in group 1. A2!A2, A2!A3, A2!A3.
According to Rule 2,the forecasted wheat productions of year 1958 is A1.Thus, FV 1958 = (9:27; 11:17; 11:17) = 10:53 Forecasting 1959: According to table 6, we can _nd that there
are _ve fuzzy logical relationships in group 2. A3!A3, A3!A3, A3!A2, A3!A3, A3!A4. The forecasted wheat production of year 1959 is A6. Thus, FV 1959 = (11:17; 11:17; 11:17; 9:27; 17:60) = 12:76 Forecasting 1960: Because the fuzzi_ed wheat production of 1960 in table 5 is A1, and from table 6, we can _nd that there are two logical relationships in group 3. A4!A4, A4!A5 According to Rule 3, the forecasted wheat production of year 1960 is computed as follows:

$$F|_{V1960} = \frac{A_4 + A_5}{2} = \frac{17.60 + 22.91}{2} = 20.22$$

In _gure, established that observed value and estimated value of wheat production based on fuzzy time series model.

Table 3. Fuzzy numbers of the wheat production

Year	Production	Fuzzy No	Estimate value	Year	Production	Fuzzy No	Estimate value
1957-58	7.99	A2	9.27	1986-87	44.32	A9	43.73
1958-59	9.96	A2	9.27	1987-88	46.17	A10	47.14
1959-60	10.32	A3	11.17	1988-89	54.11	A11	54.11
1960-61	11	A3	11.17	1989-90	49.85	A10	43.14
1961-62	12.07	A3	11.17	1990-91	55.14	A12	56.97
1962-63	10.78	A3	11.17	1991-92	55.69	A12	56.97
1963-64	9.85	A2	9.27	1992-93	57.21	A12	56.97
1964-65	12.26	A3	11.17	1993-94	59.84	A12	56.97
1965-66	10.4	A3	11.17	1994-95	65.77	A14	67.84
1966-67	11.39	A3	11.17	1995-96	62.1	A13	62.10
1967-68	16.54	A4	17.60	1996-97	69.35	A14	67.84
1968-69	18.65	A4	17.60	1997-98	66.35	A14	67.84
1969-70	20.09	A5	22.91	1998-99	71.29	A15	72.07
1970-71	23.83	A5	22.91	1999-00	76.37	A16	76.92
1971-72	26.41	A6	28.09	2000-01	69.68	A14	67.84
1972-73	24.74	A5	22.91	2001-02	72.77	A15	72.07
1973-74	21.78	A5	22.91	2002-03	65.76	A14	67.84
1974-75	24.1	A5	22.91	2003-04	72.16	A15	72.07
1975-76	28.84	A6	28.09	2004-05	68.64	A14	67.84
1976-77	29.01	A6	28.09	2005-06	69.35	A14	67.84
1977-78	31.75	A7	31.79	2006-07	75.81	A16	76.92
1978-79	35.51	A8	36.42	2007-08	78.57	A16	76.92
1979-80	31.83	A7	31.79	2008-09	80.68	A17	80.74
1980-81	36.31	A8	36.42	2009-10	80.8	A17	80.74
1981-82	37.45	A8	36.42	2010-11	86.87	A18	87.91
1982-83	42.79	A9	43.73	2011-12	94.88	A19	94.20
1983-84	45.48	A10	47.14	2012-13	93.51	A19	94.20
1984-85	44.07	A9	43.73	2013-14	95.85	A20	95.85
1985-86	47.05	A10	47.14	2014-15	88.94	A18	87.91

TABLE 4. Fuzzy Logic Relationship Group

A2→A2	A2→A3	A3→A3	A3→A3	A3→A2	A2→A3	A3→A3
A3→A4	A4→A4	A4→A5	A5→A5	A5→A6	A6→A5	A5→A5
A5→A5	A5→A6	A6→A6	A6→A7	A7→A8	A8→A7	A7→A8
A8→A9	A9→A10	A10→A9	A9→A10	A10→A9	A9→A10	A10→A11
A11→A10	A10→A12	A12→A12	A12→A12	A12→A12	A12→A14	A14→A13
A13→A14	A14→A14	A14→A15	A15→A16	A16→A14	A14→A15	A15→A14
A14→A15	A15→A14	A14→A14	A14→A16	A16→A16	A16→A17	A17→A17
A17→A18	A17→A18	A18→A19	A19→19	A19→A20	A20→A18	

TABLE 5. Fuzzy logical relationships groups

Group	Fuzzy logical Relationship
1	A2→A2 ,A2→A3,A2→A3
2	A3→A3,A3→A3,A3→A2,A3→A3,A3→A4
3	A4→A4,A4→A5
4	A5→A5,A5→A6,A5→A5,A5→A5,A5→A6
5	A6→A5,A6→A6,A6→A7
6	A7→A8, A7→A8
7	A8→A7,A8→A9
8	A9→A10, A9→A10, A9→A10
9	A10→A9,A10→A9,A10→A11,A10→A12
10	A11→A10
11	A12→A12,A12→A12,A12→A12,A12→A14
12	A14→A13,A14→A14,A14→A15, A14→A15, A14→A15, A14→A14, A14→A16
13	A15→A14,A15→A14,A15→A16
14	A16→A16,A16→A17
15	A17→A17,A17→A18,A17→A18
16	A18→A19
17	A19→A19,A19→20
18	A20→A18

TABLE 6. Estimated production and forecasting of Wheat Production

Year	Production	Fuzzy No	Estimate	Error	Year	Production	Fuzzy No	Estimate	Error
1957-58	7.99	A2	9.27	0.00	1986-87	44.32	A9	43.73	0.02
1958-59	9.96	A2	9.27	0.12	1987-88	46.17	A10	47.14	0.04
1959-60	10.32	A3	11.17	0.14	1988-89	54.11	A11	54.11	0.00
1960-61	11	A3	11.17	0.03	1989-90	49.85	A10	43.14	0.23
1961-62	12.07	A3	11.17	0.13	1990-91	55.14	A12	56.97	0.06
1962-63	10.78	A3	11.17	0.06	1991-92	55.69	A12	56.97	0.04
1963-64	9.85	A2	9.27	0.10	1992-93	57.21	A12	56.97	0.01
1964-65	12.26	A3	11.17	0.15	1993-94	59.84	A12	56.97	0.08
1965-66	10.4	A3	11.17	0.13	1994-95	65.77	A14	67.84	0.05
1966-67	11.39	A3	11.17	0.03	1995-96	62.1	A13	62.10	0.00
1967-68	16.54	A4	17.60	0.11	1996-97	69.35	A14	67.84	0.04
1968-69	18.65	A4	17.60	0.10	1997-98	66.35	A14	67.84	0.04
1969-70	20.09	A5	22.91	0.24	1998-99	71.29	A15	72.07	0.02
1970-71	23.83	A5	22.91	0.07	1999-00	76.37	A16	76.92	0.02
1971-72	26.41	A6	28.09	0.11	2000-01	69.68	A14	67.84	0.01
1972-73	24.74	A5	22.91	0.13	2001-02	72.77	A15	72.07	0.05
1973-74	21.78	A5	22.91	0.09	2002-03	65.76	A14	67.84	0.02
1974-75	24.1	A5	22.91	0.09	2003-04	72.16	A15	72.07	0.05
1975-76	28.84	A6	28.09	0.05	2004-05	68.64	A14	67.84	0.00
1976-77	29.01	A6	28.09	0.05	2005-06	69.35	A14	67.84	0.02
1977-78	31.75	A7	31.79	0.00	2006-07	75.81	A16	76.92	0.04
1978-79	35.51	A8	36.42	0.04	2007-08	78.57	A16	76.92	0.03
1979-80	31.83	A7	31.79	0.00	2008-09	80.68	A17	80.74	0.04
1980-81	36.31	A8	36.42	0.01	2009-10	80.8	A17	80.74	0.00
1981-82	37.45	A8	36.42	0.05	2010-11	86.87	A18	87.91	0.00
1982-83	42.79	A9	43.73	0.04	2011-12	94.88	A19	94.20	0.02
1983-84	45.48	A10	47.14	0.06	2012-13	93.51	A19	94.20	0.01
1984-85	44.07	A9	43.73	0.01	2013-14	95.85	A20	95.85	0.01
1985-86	47.05	A10	47.14	0.00	2014-15	88.94	A18	87.91	0.00

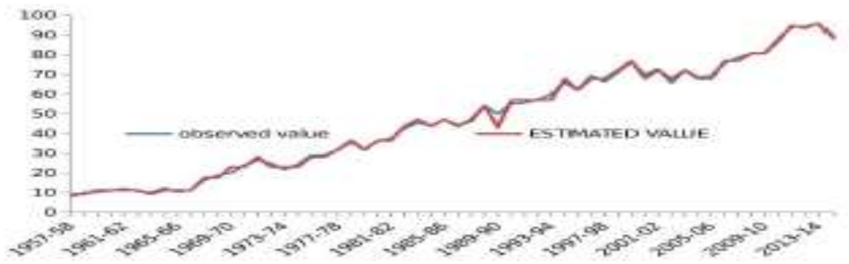

FIGURE 4. wheat production based on fuzzy time series modeling

TABLE 7. Characteristics of Performance Parameters

	RMSE	MAE
ARIMA Model	3.44	2.63
FUZZY Model	1.43	1.01

CONCLUSIONS

It can be concluded that the fuzzy model developed is possible to observe the wheat crop behavior when submitted to different nitrogen levels and types of water.

The availability of nitrogen from sewage sludge application contributes to greater development of production components. It should be noted that there was no greater weight of 100 grains, but the highest number of grains per spike, as occurred greater length of the spike. This fact was caused by the release of nitrogen along the cycle and did not occurring volatilization and / or leaching.

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