SHORT COMMUNICATION

Oryza Vol. 55 No. 1, 2018 (242-247)
DOI 10.5958/2249-5266.2018.00030.9

Economic yield prediction in six rice (*Oryza sativa* L.) genotypes by applying Mamdani rule based fuzzy model

Veena Pandey, Sanjay Kumar, Shailesh Chandra Shankhdhar and Deepti Shankhdhar*

G. B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

****Corresponding author e-mail: dshankhdhar@rediffmail.com***

Received : 29 March 2015 Accepted : 27 February 2018 Published : 21 March 2018

ABSTRACT

In the area of agricultural practices, yield prediction relies on human expertise but it is not always reliable due to many reasons. Fuzzy logic system is a mathematical method of rule-based decision making and can be used to predict the yield of crops very effectively. It plays an essential role in the remarkable human ability to make rational decisions in an environment of uncertainty which affects the yield of seasonal crops. In the present study, Mamdani fuzzy rule based system is developed for prediction of economic yield of six different rice genotypes, KRH-2, PA-6129, PHB-71, AK-DHAN, NDR-359, VARADHAN. The proposed Mamdani rule based model uses different values of total dry matter and number of effective tillers of all the genotypes as input variables. No remarkable difference was found in the prediction of economic yield of all the rice genotypes obtained by fuzzy rule based model and yield obtained by field grown crop. Out of six genotype fuzzy system also predicted that KRH-2 is best in terms of economic yield when grown in normal sowing conditions.

Key words: *Rice, prediction of yield, crop modelling & fuzzy model*

The awareness for the prediction of crop yield may be an important tool for sustainable and managed agriculture practices and important for policy decisions like import export, pricing marketing distribution etc. Various techniques are used by farmers but crop modelling has a lot of appeal over the years in this field (Day, 2001). Since the 1980s, crop modellers have been pointing their attention on rice productions and problems related to rice growers and producers (Confalonieri and Bocchi, 2005; Confalonieri et al., 2006a). Among the list of genotypes, It is very difficult for the growers to identify a genotype for maximum yield and standard quality because he could not control the environmental factors like soil type, changes in climate and availability of water and other typical features of rice systems (*e.g.,* weed and disease management, nutrient cycles) which make it a challenge to simulate rice growth via a generic crop simulator. However, prediction of crop yield has a great demand in order to acquire proper agricultural activities, enhanced crop yield and meet market values. Since the Fuzzy crop modelling system has relative importance of precision, is a wish to the rice growers as they can easily predict the most suitable genotype which could give maximum yield in particular environmental conditions. A farmer can also apply new techniques and precautions timely and can manage the budget for next crop.

L.A. Zadeh (Zadeh, 1965) introduced the concept of fuzzy set to handle the uncertainty in the system. In agricultural production system, even all the standard practices of cropping are adapted; the uncertainty lies in crop production due to some uncontrolled parameters. It can also be done on the basis of statistical methods like regression, correlation analysis etc. Accuracy about prediction is a great problem. Fuzzy system as used its inputs give more accurate results (Kumar and Kumar, 2012). In fuzzy logic everything, including truth, is a matter of degree. The greater expressive power of fuzzy logic derives from the fact that it contains as special cases not only the classical two valued and multi valued logical systems but also probability theory and probabilistic logic (Zareiforoush et al., 2012).

Fuzzy set theory allows computing using linguistic terms and can also provide a more powerful tool to model human reasoning than classical models. Fuzzy rule based models can better mimic the ways humans argue, are able to manipulate knowledge as well as quantitative and qualitative information. Moreover, FLMs allow decision-making in case of incomplete information, enable handling of difficult problems more efficiently than conventional methods, and can deal with interdependence between variables and conflicts of interest. Fuzzy logic models were successfully used in assessing irrigation performance by accounting the appreciation of individual farmers (Gowing et al., 1996).

Fuzzy set theory was developed to manage subjective human communication and interpretation of objective information. To do so, fuzzy logic models deal with variables having linguistic values (*i.e.,* human-interpretable) and their inference system is designed to deal with linguistic uncertainty, making them more appropriate to deal with farmers' decision-making. The essential part of a fuzzy system is a 'fuzzy rule base' consisting of 'if-then' propositions. Fuzzy systems can be developed in a data-driven way, in an expert-driven way (where experts are assumed to express their knowledge in a set of appropriate 'if-then' propositions), or in a combination of these ways.

Fuzzy logic may also be useful for descriptive systems, those that fall somewhere between hard systems and soft systems, such as biology and agriculture. Fuzzy logic approaches provide a suitable framework for modelling these systems due to their ability to handle "fragmentary, uncertain, qualitative and blended knowledge typically available for biological systems" (Konstantinov et al., 1992). Based on the growing evidence from the literature showing successful use of fuzzy logic for modelling, DSS(decision support system) & controls prediction of agricultural data , it appears that applications to biological and agricultural systems are inevitable (Zareiforoush et al, 2012).

In present investigation, developed fuzzy logic system is based on two input variable, total dry matter and number of effective tillers of six rice genotypes which provides a suitable frame work for prediction of economic yield.

The present investigation was carried out during *Kharif* 2011 at Norman Borolaug Crop Research Center, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar District (Uttarakhand). Geographically, the site lies in tarai plains about 30 km southwards of foothills of Shivalik range of the Himalayas at 29° N latitude, 79° 29'E longitude and at an altitude of 243.8 meter above the mean sea level. The seeds of six rice genotypes, namely, KRH-2, PA-6129, PHB-71, AK-DHAN, NDR-359, VARADHAN were obtained from the Directorate of Rice Research, Rajendranagar, Hyderabad and were grown under natural day-length and temperature conditions.

Field preparation and transplanting

Seeds were raised in nursery by dry bed method. The seeds beds were flooded on alternate days. The field was divided into three rows with proper randomization. Each row was divided into six plots of size 2.25 m^2 each and spacing of 1.5 x 0.5 m^2. Within each plot row spacing of 20x20 cm was maintained. Transplanting was done 21 days after sowing. A day before transplanting, the field was flooded with water and puddle on the following day. The field experiment was carried out with three replications of each in a split plot design. The plots were separated from each other with proper spacing (1.5 x 0.5 m^2). Date of nursery sowing and transplanting were 07-06-2011 and 28-06-2011 respectively.

Morphological and Physiological observations

The total plant dry matter per plant was calculated at maturity stage by uprooting the complete plant and then placing the plant sample in an oven at 65^{0}C for three days. The number of tillers was recorded by taking average number of shoots of three randomly selected plants from each row (replicate) at maturity stages. Grain yield (economic yield) from each replication was recorded in g/m^2 after harvesting and finally expressed in tones/hectare.

Mamdani Fuzzy Rule Based model

In the present study, fuzzy logic tool box of MATLAB^R

was used to develop Mamdani fuzzy inference system to predict economic yield using total dry matter and effective tillers as input variables. Development process of inference system includes following steps.

Step 1

Identification of input and output variables: In the present fuzzy rule based model, total dry matter and number of effective tillers were taken as inputs variables and yield was taken as output variable.

Step 2

Fuzzification of input and output variables: Triangular fuzzy sets ti (i=1 to 6), ei (i=1 to 6) and yi (i= 1 to 7) are used to fuzzify input variables (total dry matter and effective tillers) and output variable (economic yield) were used. These fuzzy sets are shown in following figures (fig. 1, 2 and 3).

Step 3

Knowledge base in the form of rule base: In the development of present rule based model 27 if- then rules are used. All the rules are given in following table.

Step 4

Inference: In this process, the membership grades are calculated and inferencing of different rules is done by using PRODUCT inference method. In this method, the output membership function is scaled by the rule premises computed degree of truth, to get different fuzzy subsets. Degree of truth (firing strength) of each rule is calculated by using following formula:

$$\alpha = \min\left[\mu_A(x), \mu_B(y)\right]$$

where, $\mu_A(x)$ is membership value of X in fuzzy set A and $\mu_B(y)$ is membership value of Y in fuzzy set B.

Step 5

Defuzzification: Defuzzification is the process of converting fuzzy output to numerical output. In other words, defuzzification interprets the membership degrees of the output fuzzy sets into a specific decision or real value. Centroid method of defuzzification is used in the present study.

$$\text{Output} = \left[\sum \alpha\mu_A(X_i)\right] / \sum \alpha_1$$

Above five steps were taken to predict the level of yield. Total dry matter (TDM) and number of effective tillers were the input variables and yield was the output variable used in membership functions. The membership grades were calculated and the inferencing of different rules was done by using Mamdani's method.

Fuzzy logic is now a wide field of study and different tools have been developed over the last few years. In the present investigation, the Mamdani fuzzy rule based model is developed to predict the economic yield as output variable using total dry matter (TDM) and number of effective tillers as inputs variables. The yield calculated by using fuzzy logic and in field conditions (non-fuzzy) were compared and found minor difference which was not more than 9 percent in any case (Table 1).

Out of six genotypes maximum total dry matter was attained by genotype KRH-2 (79.8g/plant) and minimum by PHB-71 (66.7g/plant). Number of effective tillers at maturity were also maximum in KRH-2 (10.33) while minimum in PA-6129 (8.00). Both these parameters are very important and directly correlated to yield of crop. Initially the yield (economic)

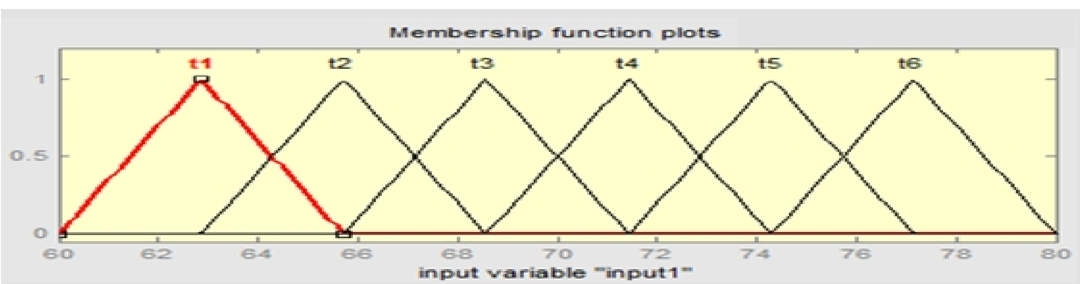

Fig. 1. Fuzzy sets for TDM (Total Dry Matter).

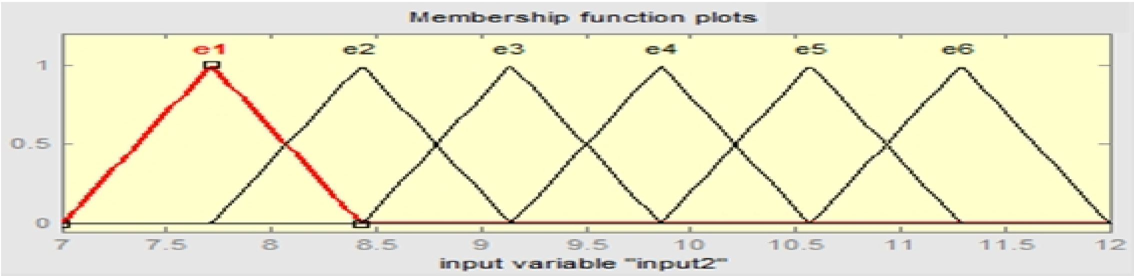

Fig. 2. Fuzzy sets for number of effective tillers.

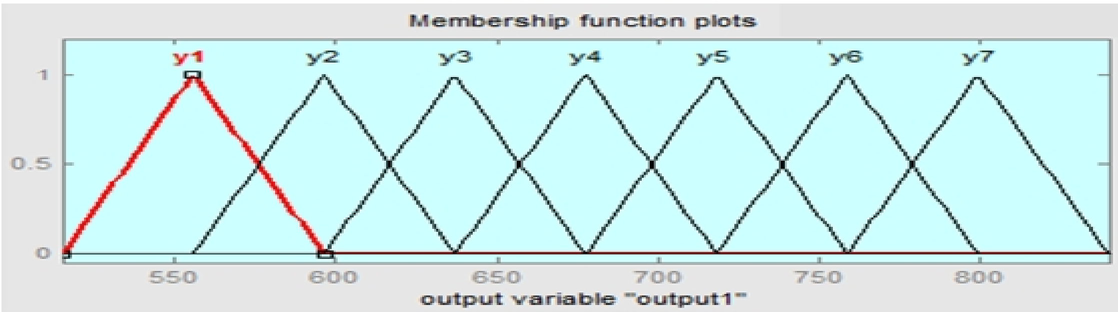

Fig. 3. Fuzzy sets for yield.

was recorded in g/m^2 and finally expressed in tones per hectare.

Under field trials economic yield was found maximum in KRH-2 (8.22 tons/ha) and minimum in PA-6129 (5.16 tons/ha) among all the genotypes which was directly correlated to total dry matter and number of effective tillers. Due to high number of effective tillers, genotype PHB-71 was also performed well in terms of economic yield (7.35 tons/ha).

The comparative results for output (economic yield) obtained by fuzzy method and field observations (non-fuzzy) showed non-significant difference in all the genotypes *i.e.,* less than nine percent (table 1). In KRH-2 the difference in yield was only 7.9% however, in PA-6129 it was 8.8% when compared between field observations and prediction of yield by Mamdani fuzzy model. This little difference in yield may be because of the genotypic variations and facts that the environmental conditions of field are uncontrolled and ever changing and each genotype has its own physiological requirements. Moreover, Fuzzy logic gives the predicted ideal results for controlled condition. It clearly predicted that out of six genotypes KRH 2 could be recommended for cultivation in above proposed environmental conditions.

Fuzzy sets are used to represent the imprecise nature of information and convert this into simple mathematical expressions in various ways that can be manipulated to make mathematical inferences. It is now a wide field of study that has seen the development of different tools over the last 10 years (Petermeier et al., 2002). A fuzzy decision support system (DSS) was also developed to take decisions related to quality sorting of tomatoes. The outputs of fuzzy decision support system predicting quality and the days of shelf life were highly accurate when compared with the data provided by an

		Input 2 Number of Effective Tillers													
Input 1		e1			e2				e3			e4		e5	e6
TDM	t1	-	-	-	-	-	-								
(Total	t2	y1	y2	y1	y2	y3	y4	y3	y4	y5	y3	y4	y5	-	-
Dry	t3	y1	y2	y1	y2	y3	y4	y3	y4	y5	y3	y4	y5	-	-
Matter)	t4	-			-				-			-		-	-
	t5	-			-				y5		y4	y5		-	-
	t6	-			-			y4	y5	y4	y5	y6	y5	y6	-

Table 1. Yield (tones per hectare) obtained by using Fuzzy (mathematical model) and field trial (non fuzzy) method. Values given in parenthesis showed percent difference in fuzzy based and non fuzzy based economic yield of six rice varieties.

Variety	Total Dry Matter (TDM) (g/hill)	Number of Effective Tillers	Economic Yield (tones/ha)		
			Fuzzy	Non Fuzzy	(% difference)
KRH-2	79.8	10.3	7.57	8.22	(7.9)
PA-6129	67.8	8.0	5.66	5.16	(8.8)
PHB-71	66.8	9.7	6.85	7.35	(6.8)
AK-DHAN	67.5	9.2	6.85	6.50	(5.1)
NDR-359	75.0	9.2	7.27	7.08	(2.6)
VARAHAN	68.1	8.8	6.17	6.77	(8.8)

expert (Verma, 1995).

In an investigation, using several parameters like soil moisture content, above ground biomass, and storage organs biomass as inputs and remote sensing information's like Normalized Difference Vegetation Index (NDVI) in Adaptive Neuro-Fuzzy Inference System, crop yield of wheat was also predicted (Stathakis et al., 2006).

It was also proposed in a study that newly developed Evolving Fuzzy Neural Network model predicted weekly fluctuations of the yield of tomato in a green house with an average accuracy of 90%. Environmental variables like temperature, carbon dioxide concentration and humidity inside the green house were used as inputs for the model. By using such mathematical models we can avoid the problems related to overproduction and over demand in the market and can manage it timely (Qaddoum, 2013).

Various fuzzy based models have been developed to study nutrient and nutrient stress management in plant system. A tolerance based fuzzy goal programming (FGP) and a FGP based genetic algorithm (GA) model was developed for nutrient management decision making for rice crop planning in India. The results of the study showed that the proposed FGP based GA approach were very efficient in selecting the course of action that will increase the yield of rice while maintaining soil fertility (Sharma and Jana, 2009). A generalized dynamic fuzzy neural network (GDFNN) to estimate heavy metal concentrations in rice by integrating spectral indices and environmental parameters was also proposed by Liu et al. (2011). The research verified that the GDFNN model could provide an effective and accurate estimate of Cu and Cd concentrations in rice. It can also provides a technical approach for getting the best suitable genotype of rice in a particular time/ conditions. By using this method the burden for selecting the crop could be reduced for the farmers.

REFERENCES

Confalonieri R and Bocchi S (2005). Evaluation of crop syst for simulating the yield of flooded rice in northern Italy. European. Journal. Agron. 23: 315-326

Confalonieri R, GusbertiD S, Bocchi and AcutisM (2006a). The crop syst model to simulate the N balance of rice for alternative management. Agronomy for Sustainabble Develop. 26: 241-249

Day W (2001). Modelling crop physiology for integrated decision making. Annals of Applied Biology 138: 215-219

Gowing J, Tarimo A and El-Awad O (1996). A rational method for assessing irrigation performance at farm level with the aid of fuzzy set theory. Irrigation and Drainage Systems 10: 319-330

Konstantinov K and Yoshida T (1992). Knowledge based control of fermentation processes. Biotechnology and Bioengineering 39: 479-486

Kumar S and Kumar N (2012). A novel method for rice production forecasting using fuzzy time series. International Journal of Computer Science Issues. 9: 455-459

Liu M, Liu X, Wub M, Li L and Xiu L (2011). Integrating spectral indices with environmental parameters for estimating heavy metal concentrations in rice using a dynamic fuzzy neural-network model. Computers & Geosciences 37: 1642-1652

Qaddoum K, Hines E and Iliescu DD (2013). Yield prediction for tomato greenhouse using EFuNN. ISRN Artificial Intelligence 13:1-9

Petermeier H, Benning R, Delgado A, Kulozik U, Hinrichs J and Becker T (2002). Hybrid model of the fouling process in tubular heat exchangers for the dairy industry. Journal of Food Engg. 55: 9-17

Sharma DK and Jana RK (2009). Fuzzy goal programming based genetic algorithm approach to nutrient management for rice crop planning. Int. J. Prod. Econ. 121: 224-232

Stathakis D, Savin I and Nègre T (2006). Neuro- fuzzy modeling for crop yield prediction. ISPRS Commission VII Mid-term Symposium "Remote Sensing: From Pixels to Processes", Enschede, the Netherlands, May 8th to11th 2006 pp. 358-361

Verma B (1995). Application of fuzzy logic in post-harvest quality decisions. Proceedings of the national seminar on post-harvest technology of fruits. University of Agricultural Sciences. Bangalore, India pp. 18-20

ZadehL A (1965). Fuzzy Sets. Information Control. 8(3): 338-353

Zareiforoush H, Mahdavian A and Hosseinzadeh B (2012). An approach to estimate the shear strength of rice stem using a fuzzy logic model. Computer Science. and Applications 1(2): 4-7