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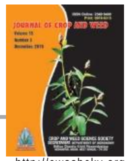

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Estimation of incidence of pest and disease and pollulation of natural enemy of rice using weather parameters

***S.T. P. KUMAR AND D. MAZUMDAR**

College of Community Science, Central Agricultural University, Tura, Meghalaya-794005

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ABSTRACT

In the present study, pest and disease incidence and population of damselfly in rice crop was estimated using conventional regression (Stepwise Regression) and Fuzzy linear regression. The weather parameters viz., Maximum Temperature, Minimum Temperature, Relative Humidity Morning, Relative Humidity Evening, Rainfall and Sunshine Hours were utilized as an explanatory variables (X's) to build a prediction model. The performance of two models was evaluated on the basis of indicators such as Root Mean Absolute Error, Root Mean Square Error and average width of the prediction interval. It was found the average width of the prediction interval obtained for fuzzy linear regression was less compared to conventional stepwise regression analysis. In case of fuzzy linear regression, the prediction interval i.e., both upper and lower interval were close to the observed incidence due to less standard error of estimate (β). Fuzzy linear regression outperformed over conventional linear regression in predicting the incidence of pest and disease, and population of damselfly.

Keywords : Fuzzy regression, interval estimation, performance indicators, stepwise regression, weather parameters.

West Bengal is a dominant agrarian state, which comprised of nearly 2.7 per cent of India's geographical area. Over 65 per cent of the population of the state resides in the villages of which 96 per cent are small and marginal farmers.West Bengal is the 3rd largest producer of rice in the country and second largest producer of potatoes in the country. Rice production for the state summed to 11.68 million tonnes in 2018-19 (Advance Estimate) and the leading producer of the fish and fish products in the country (Anon, 2019). Agriculture in the state suffered from various climatic adversities and crops were affected by various new pest, and diseases for example Brown spot of rice which was a devastating disease in the Bengal due to which entire food chain was disrupted. The importance of agriculture in the state's economy is reflected by its contribution towards State Domestic Product (SDP) which was nearly 21 per cent and which is 6th largest economy in the country (US$ 158.40 billion in 2017-18). (Adhikari *et al*. 2011; Anon 2019)

West Bengal is the richest reservoir of rice bio-diversity and the ecotypes of rice, spontaneously evolved in the state, are so diverse and different (Chatterjee *et al*., 2008). Rice was cultivated nearly 53 per cent of area of total agricultural crop area of the state during 2007- 08 and having same per cent contribution towards total production of all agricultural crops in West Bengal. (Adhikari *et al*., 2011) Paddy is mainly grown in three different seasons, *viz* Bhadui, Winter and Summer. Aman Paddy, which is grown in Winter Season, is most pre-dominant, followed by Boro in Summer Season and Aus Paddy in Bhadui Season.

The yield gaps between the potential and actual farm yields for different rice-growing environments and agro-climatic zones estimate the losses due to various biotic and abiotic stresses. According to IRRI (1979) the yield gap can be divided into two parts. Yield gap I =(Yield of experimental stations – Yield of on- farm experiments) which excludes environmental factors. The yield gap II =(maximum yield in on-farm experiments - average farm yield). The above gap in the yield is due to various biological, socio economic and soil water factors.

Insect pests and diseases, and the other stresses affect the yield significantly to rice crop. In late eighties, the number of pests and diseases had increased manifolds may be due to introduction of different high yielding varieties, and indiscriminate use of pesticides of different which created a major problem in controlling the menace of the pest complex. Due to use of high dose of pesticides than the recommended level, the pests usually gained resistance to pesticides over a period of time. Pesticides residues really pose a potentially toxic to human and can have acute and chronic health problems (WHO, 2018). Therefore, it's always advised to use recommended quantity of the pesticides and prediction of the incidence of pests and disease using weather parameters will play a major role in reducing the increasing toxicity.

In statistical inference, prediction interval is an estimate of an interval in which a future observation will fall with a certain probability. The term prediction interval is often used in regression analysis. Two cases can be discriminated in dependence on kind of output variable. The first when the output variable Y is the real

Email: pvnkmr625@gmail.com

number and the second when the output value is an interval Y <Upper, Lower>. When the predicted values are deviated from the observed values then width of the prediction interval increases.

Fuzzy regression analysis is an influential technique for the forecasting in different fields *viz* agriculture, engineering, economics, industries, *etc*. In conventional regression analysis, data should be crisp and should follow Gaussian assumption. If the data set is too small, uncertainty and, vagueness occur in this situation fuzzy regression model is appropriate and gives better results. The fuzzy linear regression is first proposed by Japanese researcher. Tanaka *et al.* (1982) to study the problems failing to satisfy validity of the linearity assumption.

Multiple linear regression models were extensively used in agricultural research. In the regression analysis, underlying relationship is assumed to be precise or crisp, due to this assumption there is possibility of losing some information (Slowinski,1998). However, in real situation underlying relationship is not precise in other words it contains some sort of vagueness. For example, Ai can be expressed as fuzzy set: $A1=<a_{1c},a_{1w}>$ where a_{1c} is centre and a_{1w} is radius or vagueness associated. The above fuzzy set describes belief of regression coefficient around a_{1c} in terms of symmetric triangular membership function. Previous function can be written as $A1= [a_{1L}, a_{1R}]$ (Kacprzyk and Fedrizzi,1992).

By considering the importance of the crop and nature of damage that pest and disease may cause in the region, the present investigation was carried out to model the pest and disease complex with the weather parameters. In the present study, the incidence of pests in rice *viz.*, brown plant hopper, gall midge and population dynamics of natural enemy damsel fly and the incidence of diseases like, blast and brown spot of rice was estimated using weather parameters (maximum temperature, minimum temperature, relative humidity morning and evening, rainfall, and sunshine hours) as an explanatory variable. To know lower and upper limit of the incidence of the pest and disease on rice crop, the techniques like conventional stepwise regression and linear programming based FLR techniques were employed. Therefore, it is useful to know the bandwidth of the pest and disease incidence instead of an estimating single value (Point Estimation).

MATERIALS AND METHODS

The present study is based on the secondary data of pest and disease incidence collected from RKVY (Rashtriya KrishiVikasYojana, Govt of India) sponsored e-Pest surveillance programme of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal. The weather parameters such as Maximum temperature, Minimum temperature, Relative Humidity morning, Relative Humidity evening, Rainfall and Sunshine Hours were collected from Directorate of Research (AICRP on Agro meteorology), Bidhan Chandra Krishi Viswavidyalaya for the Nadia district during 2013.

The data of insect pest was collected and transformed using square root transformation and disease incidence was transformed using angular transformation, and the outliers were replaced with the median value.

Stepwise regression analysis

The improvement of stepwise regression involves re-examination at every stage of the regression of the variables incorporated into the model in previous stages. The variables which may have been the best single variables to be enter in early stage, a later stage, be superfluous because of the relation between it and the other variables already there in the regression. Irrespective of the actual point of entry in to the model, any variable which may provide a non-significant contribution is removed from the model. This process is continued till no more variables will be admitted to the equation and no more variables are rejected. Steps followed in this procedure as given by the Draper and Smith (1936).

The variance inflation factor (to avoid multicollinearity) was used to include the variables in the model and VIF is given by $VIF=1/(1-R_j^2)$, Where, R_j^2-Coefficient of determination of j^{th} model. The random components were checked for its normality and randomness.

Fuzzy linear regression

In the regression analysis underlying relationship assumed to be crisp or precise but in the realistic situation, the relationship is not a crisp function instead contains vagueness or impreciseness. Due to the assumption of crisp relationship some important information may be lost therefore the technique “Fuzzy Regression” is well suited to this type of situation which can be applied to solve agriculture problems. Detailed procedure and the setup of LP problem can be seen from Tanaka (1987).

Analysis was carried out using SAS Ver 9.3.

RESULTS AND DISCUSSION

Many authors viewed agriculture as a soft science, especially in regression modeling there is always contain some amount of impreciseness or vagueness or fuzziness either in the explanatory variables or response variables. In the regression models, were found more deviations between observed and predicted values and the errors were assumed to be non-random due to indefiniteness of structure of the system or imprecise observations. Therefore, uncertainty in this type of regression model

Table 1: Stepwise regression models and Fuzzy regression models for interval estimation of insect pests and natural enemy of rice for Nadia District of West Bengal

Stepwise Regression models for interval prediction				
Insect Pest/Natural enemy	**Limit**	**Equation**	**RMAE**	**RMSE**
Gall Midge	Upper	Y= (0.26+6.03) + (-0.29+0.08)X2 + (0.11+0.07) X3 + (-0.05+0.04) X5	3.99	15.91
	Lower	Y= (0.26-6.03) + (-0.29-0.08)X2 + (0.11-0.07) X3 + (-0.05-0.04) X5	3.99	15.91
Brown Plant Hopper	Upper	Y = (-2.53+4.90) + (-0.15+0.07) X2 + (0.12+0.07) X3 +(-0.04+0.033) X4	3.99	15.92
	Lower	Y = (-2.53 - 4.90) + (-0.15- 0.07) X2 + (0.12 - 0.07) X3 +(-0.04 - 0.03) X4	3.99	15.92
Damsel Fly	Upper	Y = (-71.22 + 111.54) + (-3.78 + 1.67) X2 + (2.81 + 1.59) X3 + (-1.06 + 0.75) X4	19.02	362.23
	Lower	Y = (-71.22 - 111.54) + (-3.78 - 1.67) X2 + (2.81 - 1.59) X3 + (-1.06 - 0.75) X4	19.02	362.23
Fuzzy Regression models for interval prediction				
Insect Pest/Natural enemy	**Limit**	**Equation**	**RMAE**	**RMSE**
Gall Midge	Upper	Y = (-5.53+0) + (-0.34+0.02) X2 + (0.18+0) X3 + (-0.05+0.006) X5	0.80	0.82
	Lower	Y = (-5.53 - 0) + (-0.34 - 0.02) X2 + (0.18 - 0) X3 + (-0.05 - 0.006) X5	0.84	0.85
Brown Plant Hopper	Upper	Y = (-7.07 + 0) + (-0.19 + 0) X2 + (0.18 + 0) X3 + (-0.05 + 0.006)X4	0.67	0.57
	Lower	Y = (-7.07 - 0) + (-0.19 - 0) X2 + (0.18 - 0) X3 + (-0.05 - 0.006)X4	0.69	0.59
Damsel Fly	Upper	Y = (-136.64 + 0) + (-4.96 + 0.40) X2 + (3.61 + 0) X3 + (-0.82 + 0) X4	3.17	12.88
	Lower	Y = (-136.64 - 0) + (-4.96 - 0.40) X2 + (3.61 - 0) X3 + (-0.82 - 0) X4	3.10	12.42

Table 2: Stepwise regression models and Fuzzy regression models for interval estimation of diseases of rice for Nadia District of West Bengal

Stepwise Regression models for interval prediction				
Diseases	**Limit**	**Equation**	**RMAE**	**RMSE**
Blast	Upper	Y=(-11.73+79.14)+(-4.62+1.18)X2+(2.17+1.13)X3+(-0.66+0.53)X4	16.02	257.02
	Lower	Y=(-11.73-79.14)+(-4.62-1.18)X2+(2.17-1.13)X3+(-0.66-0.53)X4	16.02	257.02
Brown Spot	Upper	Y=(478.42+62.44)+(-17.05+2.54)X2	11.16	127.40
	Lower	Y=(478.42-62.44)+(-17.05-2.54)X2	11.16	127.40
Fuzzy Regression models for Interval prediction				
Diseases	**Limit**	**Equation**	**RMAE**	**RMSE**
Blast	Upper	Y=(-61.63+0.00)+(-5.23+0.00)X2+(2.75+0.00)X3+(-0.54+0.10)X4	2.85	10.00
	Lower	Y=(-61.63-0.00)+(-5.23-0.00)X2+(2.75-0.00)X3+(-0.54-0.10)X4	2.67	9.01
Brown Spot	Upper	Y=(484.21+35.89)+(-17.00+0.00)X2	6.55	50.22
	Lower	Y=(484.21-35.89)+(-17.00-0.00)X2	5.38	38.93

Where, X_1 - Max Temperature, X_2 - Min Temperature, X_3 - Relative humidity morning, X_4 - Relative humidity evening, X_5 - Rainfall, X_6 - Sunshine hours, Y-Pest/ Disease Incidence.

RMSE- Root Mean Square Error, RMAE- Root Mean Absolute Error

Table 3: Comparative study between stepwise regression and fuzzy regression models for interval prediction gall midge incidence in rice for Nadia district of West Bengal

Fuzzy regression			Stepwise regression		
Upper limit	**Lower limit**	**Width**	**Upper limit**	**Lower limit**	**Width**
3.5388	2.0800	1.4588	19.0776	-13.4059	32.4836
3.7585	2.3666	1.3919	19.0788	-12.9150	31.9938
3.7207	2.3052	1.4155	19.1258	-13.0857	32.2115
3.3601	1.8659	1.4943	19.0293	-13.6852	32.7145
3.2312	1.6912	1.5400	19.0522	-14.0181	33.0704
3.5880	2.1190	1.4690	19.1869	-13.4812	32.6681
3.5009	2.0650	1.4359	18.9744	-13.2633	32.2377
3.4787	2.0688	1.4099	18.8606	-13.0880	31.9486
3.3600	1.9723	1.3876	18.6575	-12.9522	31.6097
3.5600	2.1329	1.4271	19.0201	-13.2018	32.2219
4.1652	2.8179	1.3473	19.3980	-12.5744	31.9723
3.9800	2.6045	1.3754	19.3108	-12.8008	32.1116
4.4107	3.0719	1.3388	19.6684	-12.5032	32.1716
5.2195	4.0486	1.1709	20.0476	-11.2928	31.3404
5.3162	4.3300	0.9862	19.6212	-10.0741	29.6952
4.7100	3.8503	0.8597	18.7049	-9.3858	28.0907
	Average Width	**1.3443**		**Average Width**	**31.7838**

Table 4: Comparative study between stepwise regression and fuzzy regression models for interval prediction brown plant hopper incidence in rice for Nadia district of West Bengal

Fuzzy regression			Stepwise regression		
Upper limit	**Lower limit**	**Width**	**Upper limit**	**Lower limit**	**Width**
2.0115	0.9981	1.0134	17.9142	-14.8281	32.7423
1.9279	0.9013	1.0266	17.8500	-14.9024	32.7524
2.0331	1.0178	1.0153	17.9148	-14.7941	32.7089
2.1668	1.1997	0.9672	17.9130	-14.4907	32.4036
2.1782	1.2015	0.9767	17.9560	-14.5445	32.5005
2.2619	1.2815	0.9804	18.0190	-14.4926	32.5116
2.1317	1.1786	0.9531	17.8356	-14.4234	32.2590
2.1216	1.1996	0.9220	17.7446	-14.2694	32.0140
2.0650	1.1854	0.8796	17.5842	-14.0831	31.6672
2.2906	1.3667	0.9239	17.8777	-14.1646	32.0423
2.3801	1.3893	0.9908	18.0718	-14.3760	32.4479
2.4249	1.4642	0.9607	18.0218	-14.1853	32.2070
2.6510	1.6564	0.9946	18.2382	-14.1435	32.3816
3.4098	2.5274	0.8824	18.3863	-12.8729	31.2592
3.5384	2.8181	0.7203	17.8110	-11.6143	29.4253
2.8184	2.1528	0.6656	16.6047	-11.1011	27.7058
	Average Width	**0.9295**		**Average Width**	**31.8143**

Table 5: Comparative study between stepwise regression and fuzzy regression models for interval prediction damsel fly population in rice for Nadia district of West Bengal

Fuzzy regression			Stepwise regression		
Upper limit	**Lower limit**	**Width**	**Upper limit**	**Lower limit**	**Width**
24.8402	3.7433	21.0970	385.7339	-359.0517	744.7857
23.4069	2.4089	20.9980	384.3092	-360.7075	745.0167
25.4534	4.5359	20.9175	385.8194	-358.2064	744.0258
27.7491	6.8517	20.8974	385.7974	-351.2854	737.0828
28.0054	7.0817	20.9237	386.7640	-352.5227	739.2867
29.8841	9.1893	20.6947	388.2893	-351.2482	739.5375
26.9805	6.0878	20.8928	384.0392	-349.7530	733.7921
26.5249	5.5765	20.9485	381.9527	-346.2676	728.2203
25.0168	3.9384	21.0784	378.2563	-342.0761	720.3324
30.1319	9.4991	20.6328	385.1093	-343.7533	728.8626
32.9077	12.8690	20.0387	389.7549	-348.3332	738.0881
33.6461	13.6754	19.9707	388.6485	-343.9613	732.6098
39.0218	19.8124	19.2095	393.8749	-342.7060	736.5808
55.1224	38.0170	17.1053	398.1210	-312.9281	711.0491
58.1853	42.6952	15.4901	385.7043	-283.6304	669.3347
45.8816	32.3780	13.5036	359.0411	-271.1799	630.2210
	Average Width	**19.6499**		**Average Width**	**723.6766**

Table 6: Comparative study between stepwise regression and Fuzzy regression models for interval prediction of blast incidence in rice for Nadia district of West Bengal

Stepwise regression			Fuzzy regression		
Upper	**Lower**	**Width**	**Upper**	**Lower**	**Width**
285.809	-242.658	528.466	31.016	14.375	16.641
285.074	-243.557	528.630	30.336	13.479	16.858
286.301	-241.627	527.927	31.903	15.231	16.672
285.947	-237.054	523.001	32.973	17.092	15.881
286.687	-237.878	524.565	33.255	17.218	16.037
288.387	-236.355	524.743	35.244	19.145	16.099
284.528	-236.138	520.666	32.184	16.534	15.650
282.588	-234.124	516.712	31.246	16.107	15.139
279.181	-231.935	511.115	29.172	14.729	14.443
285.696	-231.472	517.168	34.715	19.545	15.170
291.078	-232.636	523.714	39.137	22.868	16.269
290.165	-229.662	519.827	39.394	23.620	15.774
296.105	-226.540	522.645	45.667	29.335	16.331
303.238	-201.291	504.528	60.846	46.356	14.489
296.358	-178.571	474.930	64.254	52.427	11.827
280.512	-166.665	447.176	58.361	47.432	10.929
	Average Width	**513.488**		**Average Width**	**15.263**

Table 7: Comparative study between stepwise regression and fuzzy regression models for interval prediction brown spot incidence in rice for Nadia district of West Bengal

Stepwise regression			Fuzzy regression		
Upper	**Lower**	**Width**	**Upper**	**Lower**	**Width**
160.189	-97.969	258.158	74.110	2.316	71.794
161.976	-95.556	257.532	76.203	4.409	71.794
163.427	-93.597	257.024	77.904	6.110	71.794
163.790	-93.107	256.897	78.329	6.535	71.794
163.316	-93.747	257.063	77.773	5.979	71.794
167.448	-88.169	255.617	82.614	10.820	71.794
163.874	-92.994	256.868	78.427	6.633	71.794
162.869	-94.350	257.219	77.250	5.456	71.794
160.524	-97.516	258.040	74.502	2.708	71.794
168.564	-86.662	255.226	83.922	12.128	71.794
179.285	-72.188	251.473	96.482	24.688	71.794
180.513	-70.530	251.043	97.921	26.127	71.794
194.249	-51.986	246.235	114.013	42.219	71.794
232.217	-0.727	232.944	158.496	86.702	71.794
261.364	38.622	222.742	192.643	120.849	71.794
297.211	87.017	210.194	234.639	162.845	71.794
	Average Width	**249.017**		**Average Width**	**71.794**

becomes fuzziness and not randomness and applicable when explanatory and response variables all are crisp but underlying phenomenon assumed to be fuzzy in nature. This is an LP problem solved by using simplex method.

The Coefficients are estimated by minimizing 'Total vagueness' of model subject to constraints (Weather parameters) that each data point must lie within estimated value of response variable (Incidence of pest / Mean population of natural enemy). In case of linear regression models amount of impreciseness (Error) in the estimated coefficients will be more due to this predicted value will have more deviation from the observed incidence but in fuzzy regression, the amount impreciseness in the coefficients estimated with high precision (Less standard error) and therefore predicted value (Upper and Lower bounds) will almost lie very close to the observed value of the response. Therefore, an attempt was made to compare fuzzy regression and stepwise regression in predicting the pest and disease incidence interval based on the performance indicators.

The explanatory variables (X's) were exposed to multicollinearity test (VIF) and those variables were included in the model whose VIF value was less than 8 (Robert M.O'brien 2007). Results from Table 1 revealed that, interval prediction for gall midge, brown plant hopper and damsel fly, the fuzzy regression models exhibited less root mean square error (Gall Midge- <0.85, 0.82>,BPH- <0.59,0.57>, Damsel Fly- <12.42,12.88>) and root mean absolute error(Gall Midge- <0.84, 0.80>,BPH- <0.69,0.67>, Damsel Fly- <3.10,3.17>) as compared to conventional regression models (RMSE- Gall Midge- <15.91, 15.91>,BPH- <15.92, 15.92>, Damsel Fly- <362.23,362.23>, RMAE- Gall Midge- <3.99, 3.99>,BPH- <3.99, 3.99>, Damsel Fly- <19.02, 19.02>). The standard error of an estimate was less for the fuzzy regression estimates but in case of linear regression, estimates were associated with large standard error values (crispiness or impreciseness). Due to larger standard error values for the regression estimates (â), both upper and lower limits of the prediction intervals were more deviated from the observed incidence but in case of fuzzy regression models predicted intervals were close to observed incidence. Therefore, the estimates obtained from fuzzy linear regression were more precise as compared to that of linear regression.

It was confirmed from the Tables 3, 4, and 5 that, average width of the predicted interval was less for fuzzy regression models (Gal Midge- 1.344, BPH-0.929, and Damsel fly- 19.649) as compared to regression model (Gal Midge- 31.783, BPH-31.814, and Damsel fly- 723.676). In both the cases fuzzy regression models were performed better as compared to linear regression model (Kwangjaekim *et al.*, 1996).

The fuzzy regression model for upper and lower limit were associated with less root mean square error and root mean absolute error. In case of blast disease of rice, fuzzy regression estimates were associated with less standard error *i.e.*,0 to 0.10 but in case of linear regression model, the standard error was ranging from 0.53 to 79.14. Due to larger value of the standard error of the estimates for regression model, prediction interval (Upper and Lower) was deviated more from the observed incidence (Table 2). The performance indicators *viz*., RMSE (257.02) and RMAE (16.02) obtained from regression models were high as compared to Fuzzy regression model (RMSE- <9.01, 10.00>& RMAE- <2.67, 2.85>). From the Table 6, it was confirmed that, the average width of the prediction interval obtained from fuzzy regression model (AW-15.263) was less compared to linear regression model (AW-513.488).

From the results it is to be concluded that effect of mean incidence of gall midge and brown plant hopper was significantly low but these pests would cause considerable loss to the crop yield in the near future. To avoid the loss due to insect pests the models proposed could be used as a forewarning tool and the weather parameters which were extracted may be used to forecast the future incidence. Another important aspect of this research was the estimation of damselflies population (Satpathi and Mondal, 2016) and these group of insects may play a crucial role in biological control.

The fuzzy regression model was outperformed linear regression in predicting the upper and lower interval of brown spot disease of rice (Boreux *et al*.,1998). (Table 2, 7). The fuzzy linear regression by using linear programming was performed well as compared to least square techniques (Chiang Kao *et al*., 2002; Kyung Kim *et al*., 2005) and it was evident from the above results.

From the above results it's evident that, LP based fuzzy linear technique outperformed conventional linear regression in predicting the intervals of the incidence of pest and disease, and population of damsel flies. The impreciseness in the explanatory variables and response variables could be overcome from the fuzzy regression technique because obtained estimates were associated with less error. When the estimates associated with the less standard error then the gap between observed and predicted incidence diminishes. Therefore, fuzzy regression was found to be a better technique compared to linear regression when the underlying relationships are not crisp.

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