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Application of parametric and nonparametric models to study the trends of total foodgrains production in West Bengal

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ABSTRACT

Present investigationwas carried out to study area, production and yield trends of total foodgrains in West Bengal for the period of 1963-2012. In this study,different parametric models - linear, non-linear regression and time series models (Box Jenkins& GARCH) and nonparametric model were employed. Suitable parametric model was selected on the basis of various goodness of fit criteria and examinations of residuals. In nonparametric regression optimum bandwidth was computed by cross validation method. Epanechnikov-kernal was used as the weight function. Finally comparison was made between parametric and nonparametric models to identify the best fitted model. Non parametric function was emerged as the one of the best fitted trend function, where in parametric models ARIMA (1,1,1) was identified for yield, ARIMA(1,1,0) was appropriate for modeling of both production and area under total foodgrains. Forecasting was made up to 2020 by these selected parametric models.

***Keywords* :** Bandwidth, Cross validation, GARCH and Kernel.

1. INTRODUCTION

Major crops like Rice, Wheat, Maize and Coarse cereals are components oftotal foodgrains. India's had produced 284.83 MT of total foodgrain from area of 127.57M.ha during 2017-18. Major producing states of India for total foodgrain are Uttar Pradesh, Punjab, Madhya Pradesh, Andhra Pradesh, Rajasthan and West Bengal. The state West Bengal had produced 16.55 MT with 6.43% of total foodgrain production of India, from an area of 6.09 M.ha.in 2014-15.So, proper trend fit is very important in an economic system for such food securing crops to formulate and initiate appropriate policy measures if data with regard to the trend of production is obtained and analyzed in advance. Parametric modeling is an important statistical technique used as a basis for manual and automatic planning in many application domains (Gooijer and Hyndman, 2006).However, in parametric model, there are some important assumptions which are often violated in many situations in case of agricultural data. On the other hand, nonparametric modeling does not require many assumptions as the model is parameter-free. As an example, Rajarathinam and Vinoth (2013) reported that trend of area, production and yield of tobacco in Anand region of Gujarat were obtained only by nonparametric regression due to failure of parametric models. By considering the above facts, the present investigation is planned to study the trends of area, production and yield of total foodgrains in West Bengal by using both parametric (*i.e*., linear-nonlinear regression, ARIMAand GARCH) and nonparametric regression (Kernel) models.

2. MATERIALS AND METHODS

Data with respect to area, production and yield of total foodgrains in West Bengal for period of 1963-2012 was collected from Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India. Before analysis, as the study is dealing with time series, present data set have been verified initially for existence of outlier and randomness.

Here, Grubbs test was used for detecting outlier in time series, as the test is particularly useful in case of large sample and easy to follow. Graph pad software which is widely used, has been employed to identify the existence of outliers and if found, have been replaced by the median of respective series (Sahu, 2010). For checking randomness of the observations, Turning point test was used in the present study. Firstly, number of turning points, *i.e*. peaks and troughs, in the series is determined and this value forms the test statistic. For large sample, the dataset may be assumed to follow a normal distribution (Kanji, 2006).

Descriptive statistics are used to explain the basic features of the data in any study. The selected descriptive measures along with simple growth rates have been used to explain behavior of each series in this study. Simple growth rate (SGR) has been calculated by using the following formula :

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$$SGR(\%) = \frac{X_t - X_0}{X_0 \times n} \times 100$$

where X_t is the value of the series for the last period and X_0 is the value of the series for first period and n is the total number of periods (Sahu, 2010).

Parametric regression model

Some of parametric regression models like Linear, Quadratic, Cubic, Logarthmic, Exponential, Hyperbolic, Power, Compound and Gompertz have been applied for modeling of area, production and yield of total foodgrains in West Bengal. The models are given in the following equations.

(i) Linear : $Z_t = a + bt + e_t$ (ii) Quadratic : $Z_t = a + bt + ct^2 + e_t$

(iii) Cubic : $Z_t = a + bt + ct^2 + dt^3 + e_t$ (iv) Logarthmic : $Z_t = a + b \ln(t) + e_t$

(v) Exponential : $Z_t = a [\mathrm{Exp}(bt)] + e_t$ (vi) Hyperbolic : $Z_t = a + (b/t) + e_t$

(vii) Power : $Z_t = a\, t^b + e_t$ (viii) Compound : $Z_t = a\, b^t + e_t$

(ix) Gompertz : $Z_t = a [\exp(-\exp(b-ct))] + e_t$

where a is constant; b, c, d represents regression coefficient; t and e_t are time, error term respectively in the models.

ARIMA model

According to Box and Jenkins (1976), a non-seasonal ARIMA model is denoted by ARIMA (p,d,q) which is a combination of Auto Regressive (AR) and Moving Average (MA) with an order of integration or differencing (d), where p and q are the order of autocorrelation and moving average respectively (Gujarati *et al.* 2012).

ARIMA in general form is as follows : $Z_t = a + (\varnothing_1 Z_{t-1} + \ldots + \varnothing_p Z_{t-p}) - (\theta_1 e_{t-1} + \ldots + \theta_q e_{t-q}) + e_t$

ARIMA methodology consists of four steps viz. model identification, model estimation, diagnostic checking and forecasting (Sankar, 2011).

Model identification by ARIMA (p, d, q) is based on the concept of time-domain analysis *i.e.* autocorrelation function (ACF) and partial autocorrelation function (PACF).In this present study, Augmented Dickey Fuller (ADF) test has been used to find unit root in the time series data under consideration (Dickey and Fuller, 1979) for identification of data stationarity. After identification of the appropriate p and q values for the model, the parameters of the autoregressive and moving average terms have been estimated. Standard statistical package SAS was used to estimate relevant parameters using iterative procedure. After identification and estimation, the estimated model was checked to verify if it adequately represents the series or not further by selective diagnostic checks. For evaluating the adequacy of selective process, various reliability statistics along with residual plots for ACF and PACF have been used. In the present study, normality and randomness of residuals were tested by Shapiro-Wilk and Run tests respectively. The model with minimum values of Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE), Akaike Information Criterion (AIC), Schwarz Bayesian Information Criterion (SBC) and with high value of coefficient of determination (R^2) are considered as appropriate to select model of the particular data series (Shafaqat, 2012).

GARCH

GARCH stands for Generalized Autoregressive Conditional Heteroskedasticity. GARCH is a mechanism that includes past variances in the explanation of future variances. More specifically, GARCH is a time series technique that allows users to model and forecast the conditional variance of the errors. If an ARMA model is assumed for the error variance, the model is called GARCH (Bollerslev, 1986).If the sum of ARCH and GARCH coefficients areclose to 1, it indicates that volatility is quite persistent in the selected series.

To measure the extent of series volatility, GARCH (1, 1) model is specified as :

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1}$$

α_0 - Constant term

ε_{t-1}^2 - ARCH term this is the news about volatility from the previous period, measured as the lag of the squared residual from the mean equation model

h_{t-1} - GARCH term, it is the last periods forecast variance

In this present study, initially residuals of mean equation model is tested for ARCH-LM (ARCH-Lagrange Multiplier) test, if found significance then only GARCH to be applied and the same test again applied at end, as to check weather fitted GARCH model has still any ARCH effect. If not, then that selective model has to be further verified for normality and randomness of residuals.

Among the competitive models, best models are selected based on minimum value of Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE), maximum value of Coefficient of Determination (R^2) and of course the significance of the coefficients of the models. Best fitted models are also verified through ACF and PACF plots of the residuals

Nonparametric regression

In general, nonparametric regression model is of the form $Z_t = m(x_i) + \varepsilon_t$ where Z is the response variable. The mean response E(Z | X=x) or regression function m(X) is assumed to be smooth and is the independently and identically distributed random error with mean zero. In this nonparametric regression, the optimum bandwidth estimation was done by cross validation method and Epanechnikov-kernel was used as the weight function (Hardle 1990). Here, Matlab software was used to estimate optimum band width and trend. After fitting the model, residual analysis was carried out to test the randomness.

3. RESULTS AND DISCUSSION

Univariate data of area, production and yield of total foodgrains in West Bengal from 1963-2012 were investigated for randomness and outliers by Turning point test and Grubbs method respectively. It was clear from table 1 that the series under consideration having random pattern for area only and no outliers were detected in all the three cases.

Table 1 : Test for randomness and outliers for area, production and yield of foodgrains in West Bengal

Total foodgrains	No. of Observations	No. of Turnings (p)	Mean E(p)	Variance V(p)	Test statistic (τ_{cal})	Inference	Outlier
Area	50	30	32	8.567	0.683	Random	No
Production	50	24	32	8.567	2.733	Trend	No
Yield	50	24	32	8.567	2.733	Trend	No

From descriptive statistics (Table 2) for area, production and yield of total foodgrains, it was observed that area under foodgrains had varied from 5469 to 7166 ('000 ha) with an average of 6262('000 ha), registering a simple growth rate of almost 0.227% per annum. Similarly, the average values of production and yield were 11059('000 tonne), 1755 (kg ha^{-1}) with simple growth rate of 3.678%, 3.098% per annum respectively.

Before analyzing by time series models, selected linear-nonlinear regression models were applied to all the datasets under consideration. Estimated parameters and goodness of fit for the models were depicted in Table 3 for area under foodgrains cultivation. It was revealed from the results that among the fitted models, the maximum R^2value of 79% was observed in case of Cubic model with minimum values of RMSE (307.44) and MAPE (3.68) in comparison to those of the other models. However, the residual analysis confirmed that the assumptions of independence (by Run test) of error terms were failed by all the models employed. Hence it was concluded that none of the selected nonlinear regression models was found suitable to fit the cultivable area under foodgrains in West Bengal. Similar kind of findings was reported by Rajarathinam and Parmer (2011) who studied the linear and nonlinear models to fit the area of castor in Anand district of Gujarat. In case of production and yield of foodgrains also again cubic model was appeared to be most plausible due to same criterion as tabulated in table 4 and 5.

For employing the ARIMA technique, stationarity of data series was tested first. For this, Augmented Dickey Fuller (ADF) test was applied. From table 6, it was concluded that all the three data series were non stationary and became stationary at first difference.

As per autocorrelation and partial autocorrelation considerations, possible ARIMA (p,d,q) models were selected and compared to each other as depicted in table 7. In all of these models, ARIMA(1,1,0) was appropriate in case of area as due to highest value of R^2 and lowest values of other criterion. Normality and randomness properties of residuals were also satisfied as these were non significant. From the residual ACF and PACF plots of ARIMA(1,1,0), it was clear that all autocorrelations and partial autocorrelations lie between 95% confidence limits as shown in Figure1. This also confirmed the 'good fit' of the selected model. Equation of the ARIMA model was formulated as : Total foodgrainsArea$_t$ (Z_t)=11.71– 0.42Z_{t-1} + e_t

Table 2: Descriptive statistics for area, production and yield of total foodgrains in West Bengal

	Area ('000 ha)	Production ('000 tonne)	Yield (kg ha^{-1})
Mean	6262.058	11059.210	1755.794
Standard Deviation	397.753	3748.256	551.705
Skewness	-0.048	0.117	0.204
Kurtosis	2.763	1.521	1.584
Maximum	7166.645	16546.5	2717.441
Minimum	5469	5377	958
CV (%)	6.352	33.893	31.422
SGAR (%)	0.227	3.678	3.098

Table 3:Fitting of nonlinear models for area undertotal foodgrains in West Bengal

Model	Parameter Estimates				Goodness of Fit					
	a	b1	b2	b3	RMSE	MAPE	MAE	R^2	SW test	Run test
Linear	5923*	13.29*			342.87	4.17	259.53	0.64	0.61	0.01
Quadratic	5571	53.97*	-0.80*		310.18	3.72	233.31	0.78	0.08	0.01
Cubic	**5693**	**26.48***	**0.54***	**-0.02***	**307.44**	**3.68**	**230.28**	**0.79**	**0.06**	**0.01**
Logarthmic	5471*	266.38*			316.33	3.68	230.94	0.72	0.22	0.01
Exponential	5916*	0.01*			345.06	4.19	260.75	0.69	0.35	0.01
Hyperbolic	6382*	-1330*			334.51	4.18	260.63	0.48	0.89	0.02
Power	5490*	0.04*			317.11	3.71	232.08	0.63	0.21	0.02
Compound	5916*	1.02			345.18	4.21	262.21	0.56	0.60	0.01
Gompertz	6409.57	-1.64*	0.15*		312.82	3.65	229.84	0.78	0.19	0.01

** Significant at 5% level: SW test= Shapiro-wilk test*

Table 4:Fitting of nonlinear models for production of foodgrains in West Bengal

Model	Parameter Estimates				Goodness of Fit					
	a	b1	b2	b3	RMSE	MAPE	MAE	R^2	SW test	Run test
Linear	4706*	249.15*			916.85	7.63	764.08	0.93	0.36	0.01
Quadratic	4992*	216.14*	0.65*		908.90	7.42	752.13	0.94	0.39	0.01
Cubic	**6615***	**-147.92***	**18.32***	**-0.23***	**758.02**	**6.89**	**654.96**	**0.95**	**0.72**	**0.02**
Logarthmic	381.19	3596*			1936.6	16.79	1595.9	0.73	0.28	0.01
Exponential	5691*	0.03*			1047.8	7.51	821.54	0.92	0.15	0.01
Hyperbolic	12148*	-12095*			3193.4	30.25	2923.3	0.30	0.01	0.01
Power	3585*	0.359*			1530.3	12.84	1298.9	0.83	0.18	0.01
Compound	5691	1.03			1045.54	7.46	819.69	0.92	0.19	0.01
Gompertz	33613*	0.65*	0.02*		884.41	7.32	732.41	0.94	0.29	0.01

* Significant at 5% level:SW test= Shapiro-wilk test

Table 5: Fitting of nonlinear models for yield of total foodgrains in West Bengal

Model	Parameter estimates				Goodness of Fit					
	a	b1	b2	b3	RMSE	MAPE	MAE	R^2	SW test	Run test
Linear	808.79*	36.68*			107.68	6.07	90.36	0.96	0.75	0.01
Quadratic	943.73*	21.56*	0.31*		93.64	5.08	79.57	0.96	0.11	0.01
Cubic	**1106**	**-14.77***	**2.07***	**-0.02***	**82.18**	**4.72**	**69.13**	**0.97**	**0.83**	**0.09**
Logarthmic	217.82	516.21*			292.29	15.79	244.07	0.71	0.06	0.01
Exponential	959.56*	0.02*			99.82	5.14	83.44	0.96	0.62	0.01
Hyperbolic	1901*	-1666*			473.45	27.29	430.04	0.23	0.01	0.01
Power	650.31*	0.32*			236.69	12.81	207.24	0.81	0.04	0.01
Compound	959.56	1.02			94.78	4.94	79.36	0.96	0.33	0.01
Gompertz	21693	1.15*	0.01		89.16	4.98	76.05	0.96	0.19	0.01
** Significant at 5% level:SW test= Shapiro-wilk test*										

Table 6:Result of ADF test for area, production and yield of total foodgrains in West Bengal

Total Foodgrains	Data type	ADF statistic	Critical values at			Decision
			1%	5%	10%	
Area	ADF at level	-2.589	-3.5713	-2.9228	-2.5990	Data Non-Stationary
	ADF at 1st difference	-6.455	-3.5745	-2.9241	-2.5997	Data became stationary
Production	ADF at level	-0.417	-3.5713	-2.9228	-2.5990	Data Non-Stationary
	ADF at 1st difference	-6.694	-3.5745	-2.9241	-2.5997	Data became stationary
Yield	ADF at level	0.525	-3.5713	-2.9228	-2.5990	Data Non-Stationary
	ADF at 1st difference	-6.863	-3.5745	-2.9241	-2.5997	Data became stationary

Table 7: ARIMA model fit statistics for area under foodgrain production in West Bengal

Model	Parameter estimates				Goodness of Fit							Arch LM test
	a	Autoregressive Coefficient		Moving Average Coefficient	RMSE	MAPE	R^2	AIC	SBC	SW test	Run test	
		AR1	AR2	MA1								
(1,1,1)	10.79	-0.17		0.31	290.97	3.48	0.82	561.97	567.65	0.60	0.11	0.58
(1,1,0)	11.71	-0.42*			290.29	3.42	0.84	559.09	563.87	0.62	0.34	0.52
(0,1,1)	10.81			0.44*	291.93	3.45	0.81	560.30	564.08	0.48	0.61	0.49
(2,1,0)	10.54	-0.48*	-0.16		290.53	3.47	0.82	561.83	567.50	0.58	0.27	0.53
(2,1,1)	10.60	-0.67	-0.23	-0.19	290.46	3.47	0.81	563.81	571.37	0.56	0.12	0.53
* Significant at 5% level; SW test= Shapiro-wilk test												

ARCH-LM test was found nonsignificantin all the three cases of foodgrains. So GARCH model was not developed. Hence, among selected parametric models - ARIMA(1,1,0) was considered as appropriate for modeling of Total foodgrains area in West Bengal.

In addition to these parametric models, nonparametric regression model (Kernel) was also applied to data on area of total foodgrains in West Bengal, as discussed about importance of nonparametric models in theintroduction. In this, optimum bandwidth was computed as 0.08 by cross validation method. Using Kernel smoothing, the diagnostic criteria i.e., RMSE (245.87) and MAPE (2.53) were slight lower than those of the earlier parametric models. On the other hand, a high R^2 (0.88) value was also obtained using this method as depicted in Table 8. Residuals were distributed independently as probability value of run test was found to be 0.659 *i.e.* nonsignificant. Hence nonparametric model was considered as one of the best fit for modeling to area under total foodgrains of West Bengal.

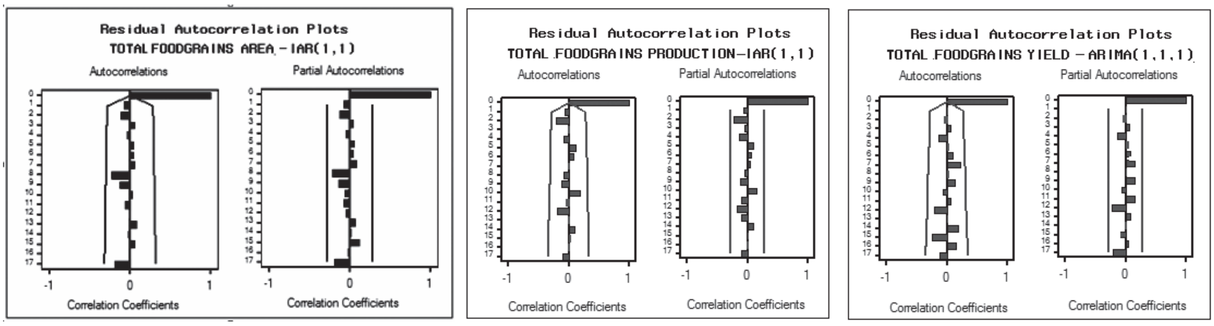

Fig. 1: Residual ACF and PACF of ARIMA(1,1,0), ARIMA(1,1,0) and ARIMA(0,1,1) models for area, production and yield respectively

Table 8: Model fit statistics for area, production and yield of total foodgrains in West Bengal by nonparametric regression

Area		Production		Yield	
MSE	60452	**MSE**	46943	**MSE**	4239.4
RMSE	245.87	**RMSE**	675.97	**RMSE**	65.11
MAPE	2.53	**MAPE**	4.82	**MAPE**	3.68
MAE	170.81	**MAE**	547.66	**MAE**	53.04
R-square	0.88	**R-square**	0.98	**R-square**	0.98

From table 6, it was observed that both production and yield data of total foodgrains became stationary at first difference. So by fixing d=1, different ARIMA models were tried and tabulated in table 9. From this, ARIMA(1,1,0) was selected for Total foodgrains production as due to high R^2 (0.96) and low values of MAPE (5.71), AIC (649.65)and SBC (653.43). Similarly, in case of yield - ARIMA(1,1,1) was selected. Residuals of these models were satisfied both the normality and randomness assumptions as shown in table 10. All the estimated parameters, in both the

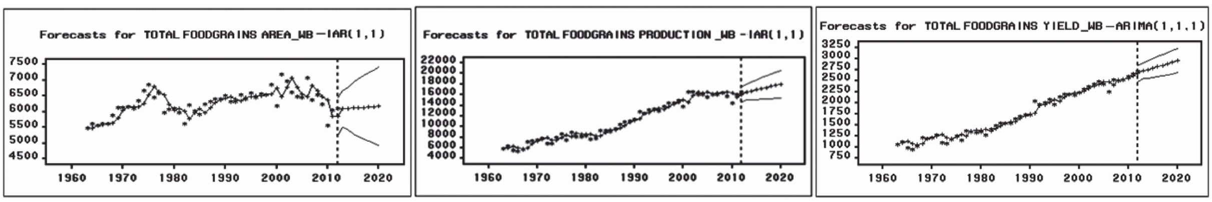

Fig. 2:Trends for area, production and yield of total foodgrains in West Bengal by ARIMA model

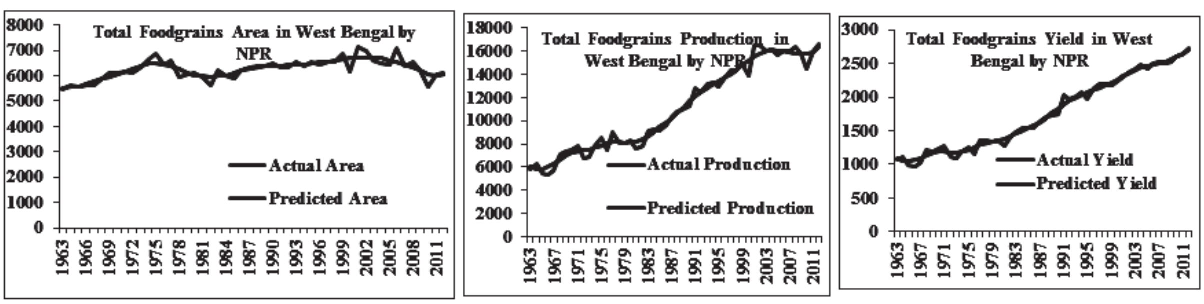

Fig. 3:Trends for area, production and yield of total foodgrains in West Bengal by nonparametric model

Table 9:ARIMA model fit statistics for production and yield of total foodgrains in West Bengal

Model	Parameter estimates					Goodness of Fit							Arch LM
	a	Autoregressive coefficient		Moving average coefficient		RMSE	MAPE	R^2	AIC	SBC test	SW test	Run test	
		AR1	AR2	MA1	MA2								
(1,1,0)	216.1*	-0.29*				721.52	5.71	0.96	649.65	653.43	0.68	0.57	0.71
(0,1,1)	215.84*			0.45*		723.09	5.75	0.94	651.25	657.04	0.72	0.19	0.83
(0,1,2)	217.72*			0.39*	0.11	722.95	5.73	0.96	651.57	656.84	0.53	0.47	0.83
Yield of total foodgrains													
(1,1,1)	34.15*	0.23*		0.68*		77.18	4.02	0.98	441.89	446.08	0.32	0.65	0.79
(1,1,0)	33.44*	-0.29*				81.17	4.19	0.97	446.25	453.03	0.11	0.75	0.67
(0,1,1)	33.91*			0.52*		79.04	4.16	0.97	442.82	446.61	0.06	0.44	0.85
(2,1,0)	33.78*	-0.38*	-0.26*			80.32	4.11	0.97	445.14	452.82	0.24	0.61	0.64
(2,1,1)	34.17*	0.18	-0.09	0.61*		82.04	4.21	0.97	446.71	454.27	0.12	0.76	0.69

* Significant at 5% level:SW test= Shapiro-wilk test

Table 10:Model validation as well as forecasts of total Foodgrains in West Bengal by selected model

	Area under total foodgrains by ARIMA (1,1,0)			Production of total foodgrains by ARIMA (1,1,0)			Yield of total foodgrains by ARIMA (1,1,1)		
Year	Actual area ('000 ha)	Predicted area ('000 ha)	Absolute forecast error	Actual production ('000 tonne)	Predicted production ('000 tonne)	Absolute forecast error	Actual yield (kg ha^{-1})	Predicted yield (kg ha^{-1})	Absolute forecast error
2012	6089	5861	0.039	16547	15987	0.035	2717	2664	0.020
2013	6240	6087	0.025	17051	16514	0.033	2732	2724	0.003
2014	6104			16730			2752		
2015	6114			16946			2785		
2016	6126			17161			2819		
2017	6138			17377			2853		
2018	6150			17593			2887		
2019	6161			17809			2921		
2020	6193			18025			2955		

Absolute Forecast Error =Absolute (Actual-Predicted)/ Predicted

cases, were significant at 5% significant level. Residual ACF, PACF also confirmed the 'good fit' of these selected models as shown in figure 1. Equations of the ARIMA model for production and yield of total foodgrains in West Bengal were formulated as:

$\text{Production}_t\ (Z_t) = 216.1 - 0.29\ Z_{t-1} + e_t$

$\text{Yield}_t\ (Z_t) = 34.15 + 0.23\ Z_{t-1} - 0.68e_{t-1} + e_t$

Residuals of all selective ARIMA models were applied for ARCH-LM test at various lags, but it was found that none of model was significant as shown in table 9. So it was concluded that there was no ARCH effect, hence GARCH models were not tried for both production and yield of total foodgrains in West Bengal. Similar result was obtained by Sundaramoorthy*et al,* (2014) for volatility of oilseeds and edible oil prices.

Nonparametric regression model (Kernel) was applied to data of both production and yield of foodgrains in West Bengal. In this, optimum bandwidth was computed as 0.08 by cross validation method for both production and yield also. Diagnostic criteria were slight lower than those of the earlier parametric models in both the cases as represented in table-8. Residuals of models were distributed independently as probability value of run test was found to be 0.248 and 0.673 *i.e*. not significant, for production, yield respectively. Hence nonparametric model was considered as one of the best fit for modeling to the production and yield of total foodgrains in West Bengal.

Finally, ARIMA (1,1,0) was selected as good fit for modeling of both area and production,where ARIMA(1,1,1) selected for yield of total foodgrains in West Bengal. Similarly, nonparametric models also having good criterion, so the trend graphs of area, production and yield were fitted by both ARIMA and Kernel regression as depicted in figure.2, 3 respectively. Further predicted values by selected parametric models were depicted in table 10.

4. CONCLUSION

From the above discussion on the analysis of area, production and yield of total foodgrains data based on different parametric models namely linear & non-linear regression, ARIMA, GARCH as well as nonparametric (kenel) regression models, it can be concluded that, the among parametric models, based on many assumptions and diagnostic criterion - ARIMA (1,1,0) was selected as good fit for forecasting of area and production, where ARIMA(1,1,1) was appropriate for yield of total foodgrains in West Bengal. Similarly, nonparametric models also suitable for to study the trend in addition to these selected parametric models. It was observed that there would be an increasing trend in futurefor all the three cases.

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