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Estimation of predictive model with their partial growth rates of area and production along with influence of area and productivity on production of rapeseed and mustard crop in Dantewada District of Bastar plateau agro-climatic zone of Chhattisgarh

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Abstract
Dantewada district comes under Bastar plateau, agro climatic zone of Chhattisgarh. In the present study, an attempt has been made to study the predictive models for area and production of rapeseed and mustard crop in Dantewada district of bastar plateau agro-climatic zone of Chhattisgarh. Time series data for the period from 2006-07 to 2009-10 on rapeseed and mustard were utilized for the study. The predictive model under study included a unique feature of structural periodic effect as a factor to capture the cyclic pattern, if any, along with trend effect in the time-series data. This periodic effect was estimated for area and production of the rapeseed and mustard. Apart from this model as a first case, wherein 4-year periodic cyclic effect is assumed along with annual effect working within it as a nested effect; another model has also been assumed with an overall periodic effect variable in combination with overall trend effect variable without any nesting, for comparison with the first case. Additionally, influences of area and productivity of the crops were also worked out to understand the impact of influencing factor (either area or productivity) on the production of rapeseed and mustard.

Keywords: Dantewada district, Rapeseed and mustard, area, production, productivity, predictive model, production function and prediction

Introduction
Chhattisgarh State comprises of three agro climatic zones, Chhattisgarh Plains, Bastar plateau and Northern Hills Region. The plateau region comprises of Bastar, Dantewada, Kanker, Narayanpur, Bijapur, Kondagaon and Sukma. The Dantewada region in 2006-07 has been divided into two districts; Dantewada and Bijapur. However, in the present study the Dantewada district has been studied for area and production of rapeseed and mustard crop in Bastar plateau region of Chhattisgarh. The time series secondary data were collected for these parameters from 2006-07 to 2009-10.

Predictive model proposed by Singh and Baghel (1991-94) [10] has been fitted separately for area and production for Dantewada region in addition to assessment of their growth rates. Apart from above a production function was also estimated to understand the influences of area and productivity on the production of the rapeseed and mustard crop in Dantewada district during this period.

Thus, the objective of present study is (i) to develop predictive models for area and production of rapeseed and mustard crop for Dantewada district, (ii) to assess growth rate of area and production of rapeseed and mustard crop for Dantewada district and (iii) to assess the influencing factor (area and productivity) on production of rapeseed and mustard crop for Dantewada district.

Material and Methods
The required time series data for the study were collected from various publications of Agricultural Statistics (2006-07 to 2009-10).

A prediction model was hypothesized as proposed by Singh and Baghel (1991-94) [10], assuming a periodic effect present in the data for a given response variable for a given region.

The predictive model included a unique feature of structural periodic effect as a factor to capture the cyclic pattern, if any, along with trend effect in the time-series data. This periodic effect was estimated for area and production of the rapeseed and mustard crop wherein, 3-year periodic cyclic effect as a factor was assumed along with annual effect within these periodic effects; another model was also assumed with an overall periodic variable, *without assuming cyclic effect*, in combination with overall trend effect, for comparison with the first case and for prediction. Thus, the following predictive model was fitted using step-wise regression technique as per Draper and Smith (1981) [6].

$$\ln Y = Int + b_P P + b_{t(p)} T + \varepsilon \quad \text{...(1a)}$$
$$\ln \hat{Y} = Int + b_P P + b_{t(p)} T \quad \text{...(1b)}$$

Where, $\ln\hat{Y}$= expected value of the natural logarithm of the response variable; Y: area or production of given region; Int = intercept; P = periodic time variable as period1 taking values from 2006-07 to 2009-10; b_P= partial linear regression coefficient corresponding to variable P; $b_{t(p)}$ = partial linear regression coefficient corresponding to variable T nested within period1; ε = error/disturbance component.

Apart from fitting above model as a first case, another model has also been fitted with a little deviation of assuming only an overall periodic variable, *without cyclic effect*, in combination with overall trend effect, for comparison with the first case, as well as for the prediction, because dummy value, otherwise in the former case, is difficult to be assigned any value with confidence for future case, *due to its being a factor (not taking any numerical value)*.

The growth rates can be estimated from the aforesaid equation (1b) only as follows. Let T be fixed at a particular position in period1, so that it may be considered constant within period1 while P varies. Then we may write (1b) in the form.

$\ln\hat{Y} = C + b_P P$, where C = Int. (since $b_{t(p)}$= 0 for constant T) …. (2a)
Or, $Y_x = a\, e^{\theta x}$, where $Y_x = Y$, $a = e^c$, $0 = b_p$, $x = P$ …….. (2b)

Again, on putting x=0 and 1 respectively we get $Y_0 = a$ and $Y_1 = a\, e^{\theta} = Y_0 (1+r_1)$, where $(1+r_1) = e^{\theta}$, say. Then we have $\%r_1 = \{(Y_p - Y_{p-1})/ Y_{p-1}\}100$ for fixed T. Also, $r_1 = e^{\theta} - 1 \approx 1 + \theta - 1 = \theta = b_p$ (higher powers of θ in e^{θ} may be ignored). Therefore, r_1 may be defined as the proportional rate of growth in response variable Y per unit change of P for fixed T, *i.e.*, a partial compound growth rate. Similarly $\%r_2 = \{(Y_{t(p)} - Y_{t(p)-1})/Y_{t(p)-1}\}100$ and $b_{t(p)}$ were interpreted with respect to variable T.

Lastly, our interest was to find the extent of influence of area and productivity on the production of rapeseed and mustard in Bastar region of Chhattisgarh. For this, an additive model with an error term $\varepsilon \sim N(0, \sigma^2)$ was hypothesized, of course, subject to the subsequent diagnostic tests. Since we have an identity, namely, "Production= Area × Productivity", in actual practice the area, production and productivity are not always reported to be accurate enough to give above identity, due to probably rounding errors and many a times due to human error in recording the data. Therefore, assuming that the error term is approximately some powers of discrepancies in the reported data compared to actual area, production and productivity; this identity could be written in the functional form. Thus, after taking natural logarithms, denoting the error component by $\varepsilon' \sim N(0, \sigma^2)$ and then by introducing the intercept term the following linear statistical model have been obtained:

$$\ln P(A,Y) = c_0 + c_1 \ln A + c_2 \ln Y + \varepsilon \quad \text{..... (3a)}$$
$$\text{Or, } \ln\hat{P}(A,Y) = c_0 + c_1 \ln A + c_2 \ln Y \quad \text{..... (3b)}$$
$$\text{Or, } \hat{P}(A,Y) = d_0 A^{c1} Y^{c2},\ d_0 = e^{c0} \quad \text{..... (3c)}$$

where A, Y and $\hat{P}(A,Y)$ denote the area, productivity and estimated production of a given region, the constant c_0 is the intercept and (c_1, c_2) are the partial regression coefficients corresponding to variables In A and In Y influencing the production, assuming that $\epsilon \sim N(0, \sigma^2)$.

Result and Discussion

Predictive models and partial growth rates

The predictive model-1 along with their estimated regression coefficients for periodic and annual effects/growth rates for area and production are shown in Table 1 to Table A 3 of Appendix-A. On perusal of Table 2, it is found that the prediction models of area and production for Dantewada district under rapeseed and mustard for years 2006-07 to 2009-10 were found to be significant for model-1 with 97.13%R^2 and 92.14%R^2 respectively and both the regression coefficients as well as the annual effect within Period1 is found to be significant at 5% level of significance (with their respective growth rates being -9.841and -19.891).

The diagnostic plots are given in Appendix-B. From the diagnostic plots of the model-1 given in Fig. 1 to Fig. 7, it is evident that the predictive models are good fit for area and production in which case a quadratic fit based on time series variable may improve the model.

On perusal of Table 2 and A-3, the expected area under rapeseed and mustard in Dantewada District would decrease from 0.293 log(000'ha) i.e. 1.340 (000'ha) approx. in 2011-12 to -0.396 log(000'ha) i.e. 0.673 (000'ha) approx. in 2018-19 after 8 years and for production, it would decrease from 0.293 log(000'tonnes) i.e. 0.313(000'tonnes) approx. in 2011-12 to -0.396 log(000'tonnes) i.e. 0.078(000'tonnes) approx. In 2018-19 after 8 years. From Fig. 5 (a) and Fig 6 (a), it is evident that the predictions are good enough from 2011-12 to 2014-15, beyond which the confidence interval widens, which is expected because the extrapolated predictions of regression models are valid within a close range only. Fig. 5 (b) and Fig 6(b) gives the same as Fig. 5 (a) and Fig 6(a) in original units without confidence limits because confidence limits are valid for log-scale only in our study.

Production function

The production function equations are given in 3(a), 3(b) and 3(c). The coefficients of determination R^2 (Adj-R^2), as shown in Table 4 of the Appendix-A, for the production function is 99.99** (1), with significant regression coefficients 1.046** ($P<$ 0.001) and 0.977** ($P<$ 0.001) respectively corresponding to area and yield components. From the diagnostic plot given in the figure Fig 7 of Appendix-B, it is moderately a good model fit (i.e. a robust fit). The influence of area and productivity on production has been determined from this production function and the estimated influence of area and productivity has been given in Table 4. It was found for Dantewada district that, the area as well as yield effects were highly significant; area effect to the extent of 93.52% ($P<$ 0.01) while the yield effect has not much influence on production (only 6.47%, $P<$ 0.01). This shows that there is lack of awareness among farmers of rapeseed and mustard with respect to use of technology in rapeseed and mustard production in Dantewada district.

Table 1: Estimated Prediction models for Area and Production of Dantewada District under Rapeseed and Mustard for Period1 (Dantewada District: 2006-07 to 2009-10) @

Dantewada		$b_p(\%r_1)$ Int/Period1	$b_t(\%r_2)$ Year1	%R^2	%Adj R^2	Remark
A	(1)$	198.287*	-0.098*	97.13*	95.7	I,Y
			(-9.841)*			
P	(1)$	399.048*	-0.198*	92.14*	88.22	I,Y
			(-19.891)*			

Note: Significance codes- 0 '***' 0.001 '**' 0.01 '*' 0.05 '#' 0.1 ' ' 1; Row(1) indicates estimates assuming non-structural periods

Table 2: Prediction of Area for Dantewada District under Rapeseed and Mustard for next 8 years from 2011-12 to 2018-19

Year	Predicted log(Area) log(000'ha)	Log(S.E.) log(000'ha)	Confidence Interval (95%) log(000'ha)		Predicted Area (000'ha)
			Lower limit	Upper limit	
2011-12	0.293	0.044	0.104	0.481	1.340
2012-13	0.194	0.055	-0.044	0.433	1.214
2013-14	0.096	0.067	-0.193	0.384	1.100
2014-15	-0.003	0.079	-0.342	0.336	0.997
2015-16	-0.101	0.091	-0.491	0.289	0.904
2016-17	-0.200	0.102	-0.640	0.241	0.819
2017-18	-0.298	0.114	-0.790	0.194	0.742
2018-19	-0.396	0.126	-0.939	0.147	0.673

Table 3: Prediction of Production for Dantewada District under Rapeseed and Mustard for next 8 years from 2011-12 to 2018-19

Year	Predicted log(Production) log(000'tonnes)	Log(S.E.) log(000'tonnes)	Confidence Interval (95%) log(000'tonnes)		Predicted Production (000'tonnes)
			Lower limit	Upper limit	
2011-12	-1.161	0.151	-1.810	-0.511	0.313
2012-13	-1.360	0.190	-2.179	-0.540	0.257
2013-14	-1.558	0.230	-2.550	-0.567	0.210
2014-15	-1.757	0.271	-2.923	-0.592	0.173
2015-16	-1.956	0.311	-3.296	-0.616	0.141
2016-17	-2.155	0.352	-3.670	-0.640	0.116
2017-18	-2.354	0.393	-4.044	-0.664	0.095
2018-19	-2.553	0.434	-4.419	-0.687	0.078

Table 4: Production Function as Influenced by the Area and Productivity of Dantewada District under Rapeseed and Mustard for Period1 (Dantewada District: 2006-07 to 2009-10)

Crop	Model: $\ln P(A,Y) = c_0 + c_1 \ln A + c_2 \ln Y$							
	Production Function				Area effect	Yield effect	Total (R^2)	%Adj R^2
Rapeseed and Mustard		Int.	Ln A	Ln Y				
	Ln P(A,Y)=	-6.805**	1.046**	0.977 **	93.52**	6.47**	99.99**	1

Note: Significance codes- 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '# ' 1

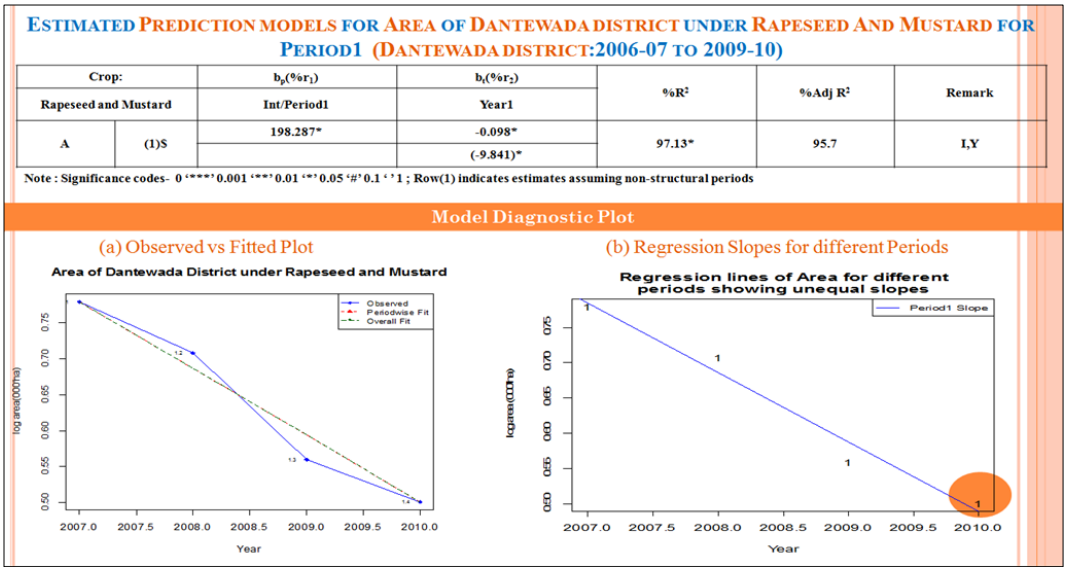

Fig 1: Prediction models for Area of Dantewada District under Rapeseed and mustard from 2006-07 to 2009-10 (a) Observed vs. Fitted Plot (b) Regression slopes for different periods.

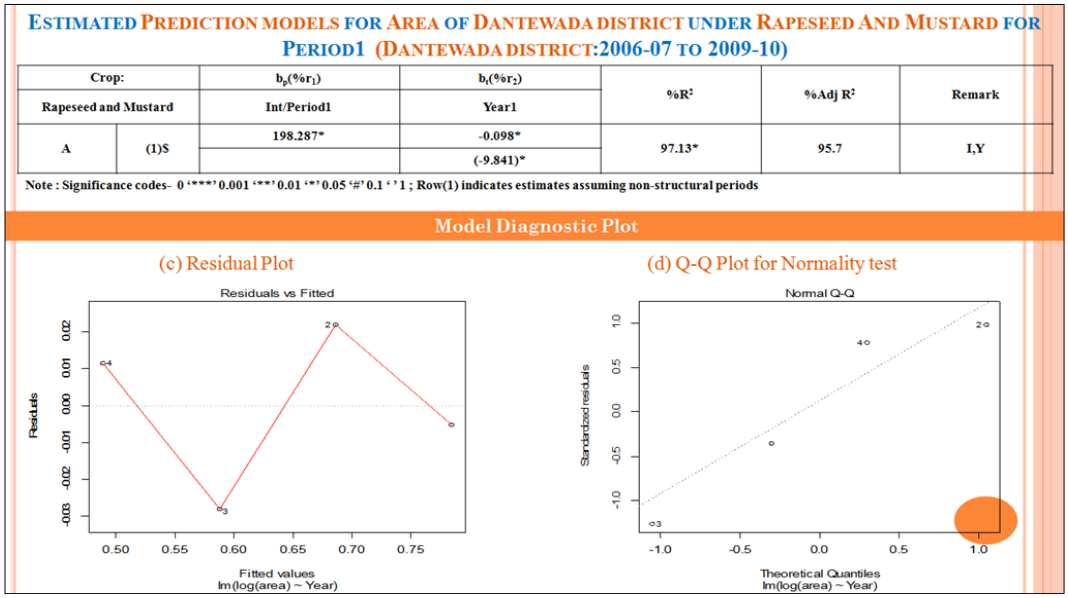

Fig 2: Prediction models for Area of Dantewada District under Rapeseed and mustard from 2006-07 to 2009-10 (c) Residual Plot (d) Q-Q Plot for Normality test.

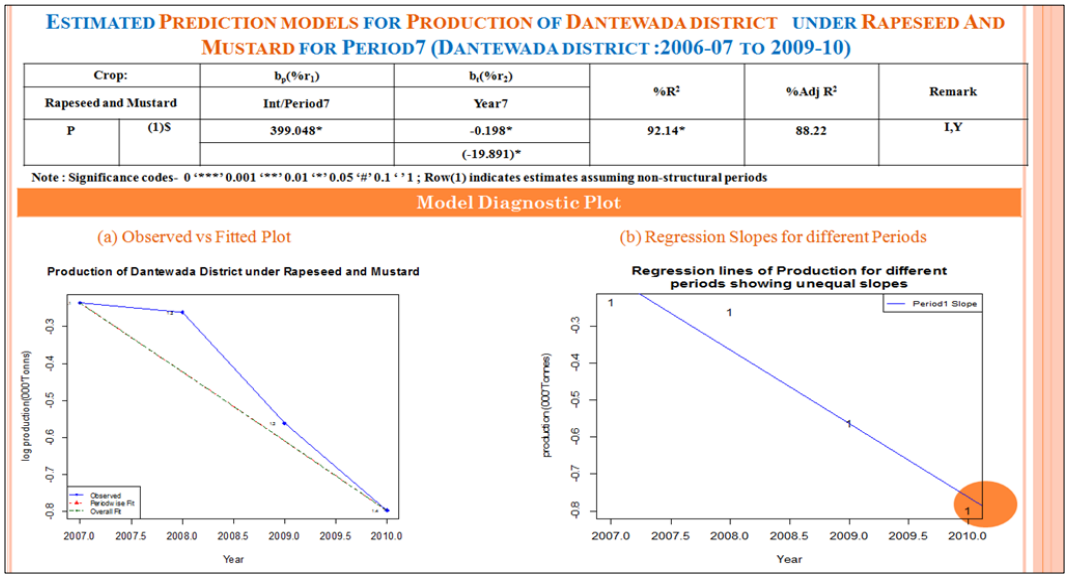

Fig 3: Prediction models for Production of Dantewada District under Rapeseed and mustard from 2006-07 to 2009-10 (a) Observed vs. Fitted Plot (b) Regression slopes for different periods.

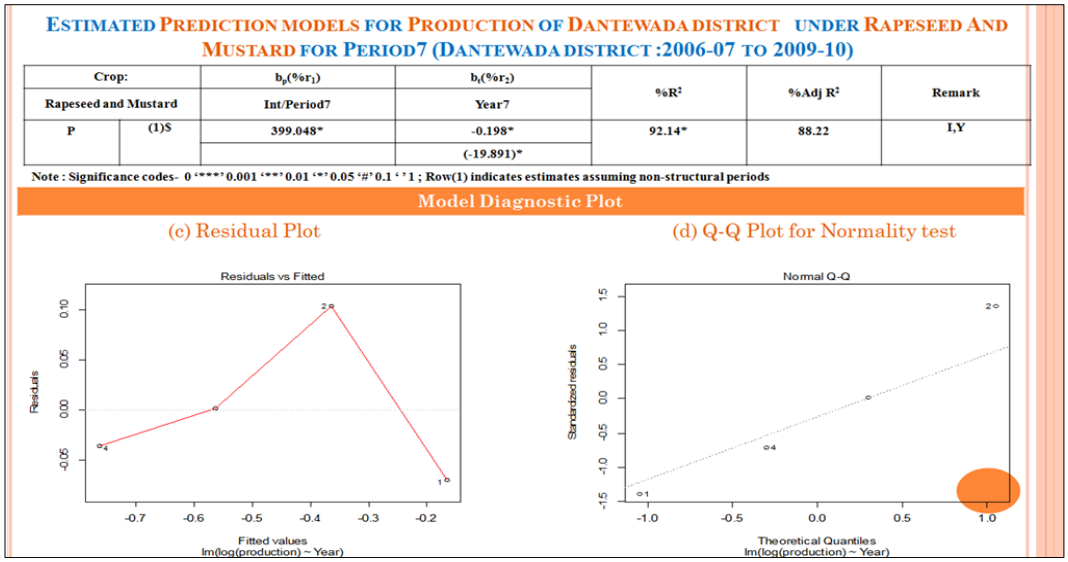

Fig 4: Prediction models for Production of Dantewada District under Rapeseed and mustard from 2006-07 to 2009-10 (c) Residual Plot (d) Q-Q Plot for Normality test.

PREDICTION OF AREA FOR DANTEWADA DISTRICT UNDER RAPESEED AND MUSTARD FOR NEXT 8 YEARS FROM 2011-12 TO 2018-19

Year	Predicted log(Area) log(000'ha)	Log(S.E.) log(000'ha)	Confidence Interval (95%) log(000'ha)		Predicted Area (000'ha)
			Lower limit	Upper limit	
2011-12	0.293	0.044	0.104	0.481	1.340
2012-13	0.194	0.055	-0.044	0.433	1.214
2013-14	0.096	0.067	-0.193	0.384	1.100
2014-15	-0.003	0.079	-0.342	0.336	0.997
2015-16	-0.101	0.091	-0.491	0.289	0.904
2016-17	-0.200	0.102	-0.640	0.241	0.819
2017-18	-0.298	0.114	-0.790	0.194	0.742
2018-19	-0.396	0.126	-0.939	0.147	0.673

PREDICTION PLOT OF AREA FOR DANTEWADA DISTRICT UNDER RAPESEED AND MUSTARD FOR 8 YEARS

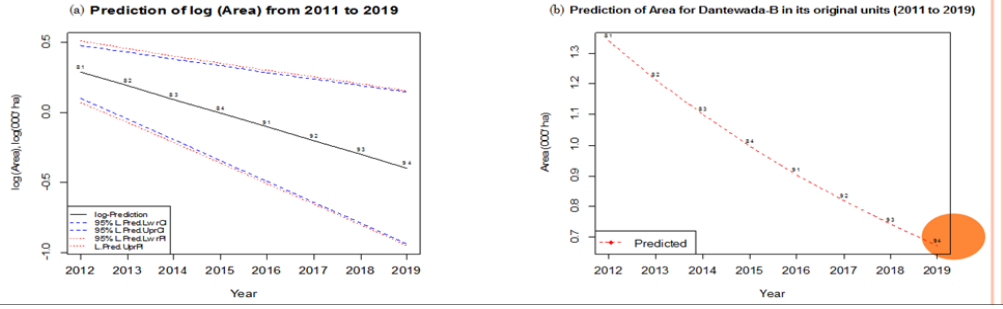

Fig 5: Prediction of Area for Dantewada District under Rapeseed and Mustard for next 8 years from 2011-12 to 2018-19 (a) Predicted area (b) prediction compared with observed area.

PREDICTION OF PRODUCTION FOR DANTEWADA DISTRICT UNDER RAPESEED AND MUSTARD FOR NEXT 8 YEARS FROM 2011-12 TO 2018-19

Year	Predicted log(Production) log(000'tonnes)	Log(S.E.) log(000'tonnes)	Confidence Interval (95%) log(000'tonnes)		Predicted Production (000'tonnes)
			Lower limit	Upper limit	
2011-12	-1.161	0.151	-1.810	-0.511	0.313
2012-13	-1.360	0.190	-2.179	-0.540	0.257
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PREDICTION PLOT OF PRODUCTION FOR DAANTEWADA DISTRICT UNDER RAPESEED AND MUSTARD FOR 8 YEARS

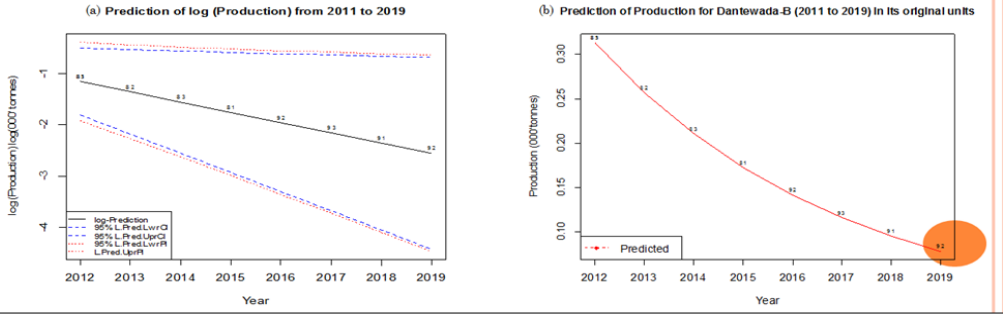

Fig 6: Prediction of Production for Dantewada District under Rapeseed and Mustard for next 8 years from 2011-12 to 2018-19 (a) Predicted area (b) prediction compared with observed area.

PRODUCTION FUNCTION AS INFLUENCED BY THE AREA AND PRODUCTIVITY OF DANTEWADA DISTRICT UNDER RAPESEED AND MUSTARD FOR PERIOD1 (DANTEWADA DISTRICT :2006-07 TO 2009-10)

Crop	Model: $\ln P(A,Y) = c_0 + c_1 \ln A + c_2 \ln Y$						
	Production Function				Area effect	Yield effect	Total (R^2)	%Adj R^2
Rapeseed and Mustard		Int	lnA	lnY				
	lnP(A,Y)=	-6.805**	1.046**	0.977 **	93.52**	6.47**	99.99**	1

Note:Significance codes- 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '#' 1

Model Diagnostic Plot

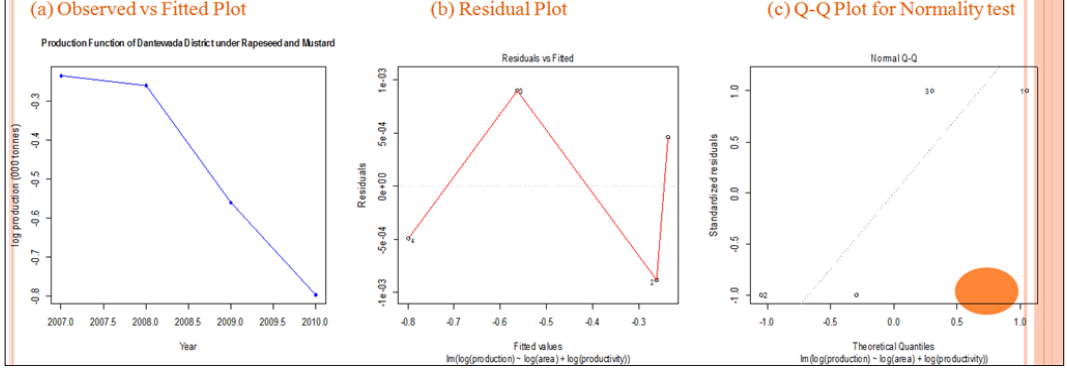

Fig 7: Production function as influenced by Area and Productivity under Rapeseed and mustard in Dantewada District from 2006-07 to 2009-10 (a) Observed vs. Fitted Plot (b) Residual Plot (c) Q-Q Plot for normality test.

Conclusion

From the present study, it can be concluded that the estimated predictive models for area and production under rapeseed and mustard crop in Dantewada district were highly significant. For area under rapeseed and mustard, model-1, predictive model was mainly dependent on the changes occurring in period-1 and on annual growth rates for Year1. For production under rapeseed and mustard, model-1, the predictive model mainly depended on changes due to periodic effects period-1 and annual effects/growth rates under Year-1.The predictions for area and production of Dantewada district are good enough from 2011-12 to 2014-15, beyond which the confidence interval widens. The influence of area and productivity on production gives a moderately good model fit (i.e. a robust fit), wherein it is concluded that the area alone has significantly contributed towards production of rapeseed and mustard in Dantewada district to the extent of 93.52% in contrast to the influence of (6.47%), which shows that there is lack of awareness among farmers of rapeseed and mustard with respect to use of technology in rapeseed and mustard production in Dantewada district.

Acknowledgement

The authors acknowledge the staff of Land Records of Chhattisgarh and publications of erstwhile Land Record of Madhya Pradesh, who have provided the secondary data for rapeseed and mustard crop used in the study. Further, this research work has been successfully completed with facilities extended by the Department of Agricultural Statistics and Social Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur.

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