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Assessment of Growth Rate and Instability of Groundnut Production in Odisha, India: A Statistical Modelling Approach

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Oilseeds in Odisha has a major contribution in increasing the income of farmers which is due to their greater economic value. The important oilseed crops grown in Odisha are groundnut, mustard, sunflower, sesamum and castor. Groundnut shares 34% of total area under oilseeds in Odisha and 64% of total production of oilseeds in the state. The present makes an attempt to explore the best fit model on area, productivity and production of groundnut in Odisha and use the selected best fit model to estimate the growth rate of the variables. The instability of area, productivity and production of groundnut in Odisha is also studied with help of coefficient of variation.

Data from 1970-71 to 2019-20 have been used to estimate the growth rate and instability by dividing the whole period of study in two periods - pre-liberalisation period (1970-71 to 1995-96) which is referred as period I and post-liberalisation (1996-97 to 2019-20) which is referred as period

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II. Models considered in the analysis are linear model, logarithmic model, quadratic model, compound model and power model. Durbin-Watson test, Shapiro-wilk's test and park's test are used for testing error assumption. By testing the significance of parametric coefficient, residual diagnostics and the model fit statistics, the best fit model for the variable have been selected. Using the best fit model, the growth rate of area, productivity and production of groundnut in Odisha has been estimated. The measure of instability of area, productivity and production of groundnut is given by Coefficient of Variation.

The study reveals that different models have been found to be the best fit for different variables in different periods. The study of growth rate using the best fit model reveals that area and production of groundnut decrease in post-liberalisation period than pre-liberalisation period. The growth rate of productivity of groundnut increases in post-liberalisation period as compared to pre-liberalisation period. The situation is reverse with respect to instability. The study comes with the conclusion that as compared to pre-liberalisation period, the productivity performance of groundnut in Odisha has enhanced in post-liberalisation period. The poor performance in area under groundnut results in poor performance in production of groundnut during post-liberalisation period as compared to pre-liberalisation period. The appropriate model building technique helps in depicting a proper scenario of groundnut production in the state of Odisha.

Keywords: Error assumption; growth rate; instability; model building.

1. INTRODUCTION

Groundnut, the important oilseed crop in Odisha topped the list among the oilseed crops of Odisha with respect to production. The contribution of groundnut to the total oilseed area and production are 34% and 68% respectively. Economic liberalisation occurred in 1991 but its effect is considerably noticed from the year 1995. In the present study the effect of economic liberalisation on the agriculture aspect of Odisha with respect to production of groundnut crop has been analysed by comparing the growth rate and instability in pre and post liberalisation period. Appropriate model building technique has been followed to identify the best fit model for a particular variable (i.e. area, productivity and production of groundnut) in different periods. The measure of instability is given by Coefficient of Variation.

In view of these perspectives, the study has been made with the objectives of finding the best fit model for data on area, production and productivity of important oilseed crops in Odisha; finding the average growth rate of the area, production and productivity of important oilseed crops in Odisha in pre-liberalisation and post-liberaisation periods; studying the instability of the area, production and productivity of important oilseed crops in Odisha in pre-liberalisation and post-liberalisation periods.

2. MATERIALS AND METHODS

The present analysis is based on secondary source data relating to the area, productivity and production of groundnut in Odisha for the period from 1970-71 to 2019-20. The data are collected from Odisha Agricultural Statistics published by the Directorate Agriculture and Food production, Government of Odisha, 2020. The area, productivity and production are expressed in '000 ha, kg/ha and '000 MT and respectively. The entire study period is divided into two periods – Pre-liberalisation period (1970-71 to 1995-96) referred to as Period – I and Post-liberalisation period (1996-97 to 2019-20) referred as Period -II.

2.1 Research Hypotheses

There is no difference in growth rate of area, production and productivity of oilseed crops in Odisha between pre-liberalisation (period I) and post-liberalisation (period II).

There is no difference in C.V of area, production and productivity of oilseed crops in Odisha between pre-liberalisation (period I) and post-liberalisation (period II).

I"n the present study, time is considered as the independent variable in all the fitted models. The parametric growth models, can be taken as, linear [1] and non-linear" [2]; Draper and Smith [3]. Model selection is the task of selecting a statistical model from a set of models selected for the data. In this study the test for normality, homoscedasticity and independence of the residuals have been carried out performed for selecting the best fitted model.

The following models are used for the study:

i. First order polynomial model - $Y_t = \beta_0 + \beta_1 t + \varepsilon_t$
ii. Second order polynomial model $Y_t = \beta_0 + \beta_1 .t + \beta_2 . t^2 + \varepsilon_t$
iii. Semi-log model - $Y_t = \beta_0 .t^{\beta 1}. \exp(\varepsilon_t)$
iv. Compound model - $Y_t = \beta_0 . \beta_1^t . \exp(\varepsilon_t)$
v. Logarithmic model - $Y_t = \beta_0 + \beta_1 .\ln(t) + \varepsilon_t$

Where, β_0, β_1 and β_2 are the parameters of the model and ε_t is the error.

The error assumptions are independency, homoscedasticity and normality of residuals.

In all the cases the parameters of the model are estimated optimally using the data.

The models are fitted separately for the two periods i.e. pre-liberalisation period (1970-71 to 1995-96) and post-liberalisation period (1996-97 to 2019-20) to make a comparative study of the two periods. The respective best fit models for the data in the two periods are fitted to find the growth rate. CV is used as a measure of instability.

Using ordinary least square technique, the estimated values of the coefficients β_0, $\beta_1$and β_2 are found out. The estimated values of β_0, β_1,β_2 are written as b_0, b_1, b_2 respectively.

The significance of the estimated coefficient is tested by applying *t* test statistic.

Null hypothesis, H_0: $\beta_j = 0$

Alternate hypothesis, H_1: $\beta_j \neq 0$

$t = \frac{\beta_j}{S.E(\beta_j)}$, which follow '*t*' distribution with n-p degrees of freedom,

n is the number of observations. And p is the no. of coefficients I volved in the model.

The overall significance of the model is tested by applying *F* statistic.

Null hypothesis, H_0: $\beta_1=\beta_2=\ldots\ldots=\beta_j$ is tested against the

Alternate hypothesis H_1: $\beta_1\neq \beta_2\neq\ldots\ldots\neq\beta_j$ for at least one j (j= 0,1,2 for quadratic and j= 0,1 for other models).

$F = \frac{MSM}{MSE}$, $F \sim F_{p-1,n-p}$

MSM is the mean square of the model, MSE is the error mean square;

$MSM = \frac{\sum_{i=1}^{n}(\hat{y}_i-\bar{y})^2}{p-1}$, $\mathbf{MSE} = \frac{\sum_{i=1}^{n}(y_i-\hat{y}_i)^2}{n-p}$, n is the number of observations and p is the number of parameters involved in the model.

"Assumptions in the model are: Errors should be (i) independent, (ii) have constant variance i.e. errors should be homoscedastic and (iii) must follow normal distribution" [4]

The assumptions regarding the errors are tested by using

(a) Durbin Watson test: It is used for testing independence of residuals. The test uses the first order autocorrelation among the residuals [1].

(b) Park's test: It is used for testing homoscedasticity of residuals. In this test, natural logarithm of the residual (ε_t) is regressed with natural logarithm of the independent variable (which is time *t*) by fitting linear regression, i.e, $\ln(\varepsilon_t)$ = a+ b ln(t). "If the slope '*b*'of the regression coefficient is found to be insignificant, then it is concluded that residuals are homoscedastic (i.e. constant error variance) otherwise, residuals are heteroschedastic (error variance not remaining constant)" [5].
(C) Shapiro-Wilk's test: It is used for testing normality of residuals. Shapiro-Wilk's test statistic i.e., S-W test statistic, $w = s^2/b$

Where, $s^2 = \Sigma\ a(k)\ \{\ x_{(n+1-k)} - x_{(k)}\ \}$; $b= \sum_{t=1}^{n}(y_t - \bar{y})^2$ [6]. The parameter *k* takes the values 1, 2,…, n/2, when *n* is even and 1,2,…,(n-1)/2, when *n* is odd.
n is the number of observations. X_k is the k^{th} order statistic of the set of residuals.

The values of coefficients a(k) for different values of *n* and *k* are obtained from the table of Shapiro-Wilk. If *w* is non-significant, then the residuals are normally distributed.

The model fit statistics, viz. R^2, adjusted R^2 and RMSE (Root mean Square Error) are also computed. Among the models fitted for the dependent variable, which satisfy the error assumptions and show overall significance and significant parameter estimates, the one having highest adjusted R^2 and lowest RMSE is considered to be the best fit model for that variable.

$R^2 = \frac{SSM}{SSE}$, where, SSM is the sum of square due to model; SSE is the sum of square due to error.

SSM = $\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2$;

SSE = $\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$

Adjusted R^2 = $1 - (1 - R^2) \times \frac{n-1}{n-p}$; [7]

RMSE (Root Mean Square Error) = $\left\{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)}{n-p}\right\}^{1/2}$

Where *'n'* is the number of observations; *p* is the no. of parameters involved in the model.

Using this best fit model, the estimated/predicted values ($\hat{Y}_t$ of the dependent variable (Area/Production/Productivity) in time period 't' are found for the period I and period II. By using the predicted values, the annual growth rates are found.

Annual Growth Rate for the year *t*, (AGR_t) = $\frac{\hat{Y}_t - \hat{Y}_{t-1}}{\hat{Y}_{t-1}}$ X 100 [8]

Average Growth rate for the period I (1970-71 to 1995-96) and period II (1996-97 to 2019-20) is obtained by taking arithmetic mean of the annual growth rates of the respective periods [9]. Also the difference in average growth rates of period I and period II is obtained as, $\Delta GR = GR_2 - GR_1$.

To test the significance growth rate of each period, t-test has been used.

The null hypothesis H_0: GR = 0
Alternate hypothesis H_1: GR ≠ 0

Test statistics (t) = $\frac{GR}{SE(GR)}$

If the calculated value of t is greater than or equal to tabulated value of at α level of significance and n-2 degree of freedom then t is considered to be significant otherwise insignificant.

To test the significance of difference of growth rate in two periods we used *t- test.*

The null hypothesis H_0: ΔGR = 0 is tested against the

Alternate hypothesis H_1: ΔGR ≠ 0

Test statistics (t) = $\frac{\Delta GR}{SE(\Delta GR)}$ [10]

If the calculated value of t is greater than or equal to tabulated value of at α level of significance and $n_1 + n_2$ -2 degree of freedom then t is consider to be significant otherwise non-significant.

Coefficient of Variation (CV) = $\frac{\text{Standard deviation } (\sigma)}{\text{Mean } (\mu)}$ X100

t- test is used to test the CV of each period.

The null hypothesis H_0: CV = 0 is tested against the

Alternate hypothesis H_1: CV ≠ 0

Test statistics (t) = $\frac{CV}{SE(CV)}$ [11]

If the calculated value of t is greater than or equal to tabulated value of at α level of significance and n-2 degree of freedom then t is consider to be significant otherwise insignificant.

To test the significance difference of CV in two periods we used *t- test.*

The null hypothesis H_0: ΔCV = 0 is tested against the

Alternate hypothesis H_1: ΔCV ≠ 0

t = $\frac{\Delta CV}{SE(\Delta CV)}$

If the calculated value of t is greater than or equal to tabulated value of at α level of significance and $n_1 + n_2$ -2 degree of freedom then t is considered to be significant otherwise insignificant.

3. RESULTS AND DISCUSSION

The study of the scatter plot of area under groundnut depicted in Fig. 1 shows that the area under groundnut increases rapidly in period I but it declines slowly in the initial part of period II which becomes stable afterwards. The study of scatter plot of productivity of groundnut shown in Fig. 2 reveals that the productivity of groundnut increases at lesser rate in period I which then increases at ac comparatively higher rate in period II. The study of scatter plot of production of groundnut available in Fig. 3 shows that the production of groundnut is increasing rapidly in period I which then shows a sudden fall in initial year of period II and then increases slowly.

The study of the Table 1 shows that except quadratic model all the models have significant estimated parametric coefficients. So the quadratic model is rejected. The F-value of all the models are highly significant. All models satisfy the normality and homoscedasticity assumption of errors but only power model satisfies the assumption of independency of errors as it has insignificant D-W statistic.Thus the only model found fit to the data on area under groundnut for period I is power model. The adjusted R^2 of power model is high and RMSE is low. Thus, power model the best fit model for area under groundnut for period I.

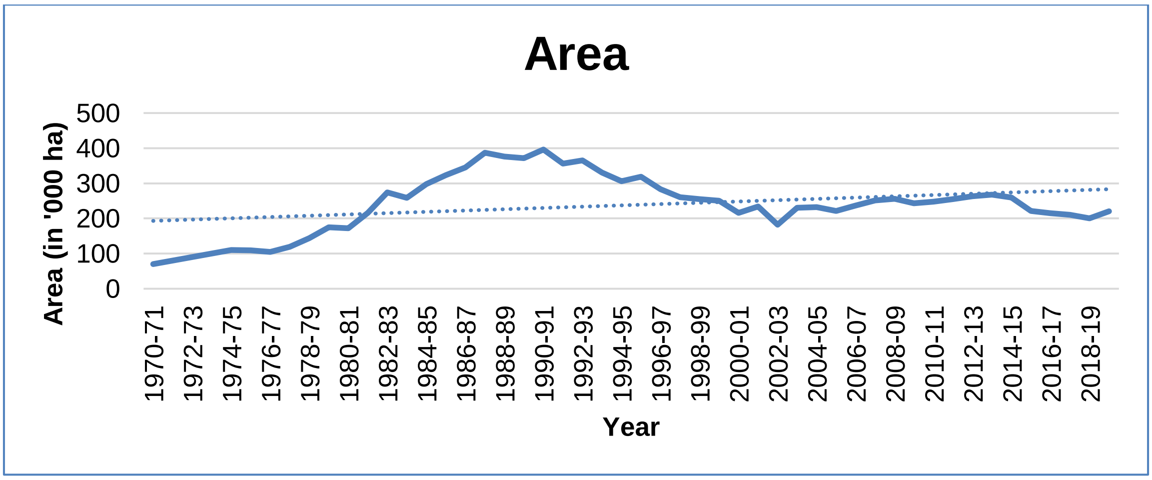

Fig. 1. Scatter diagram of area under groundnut

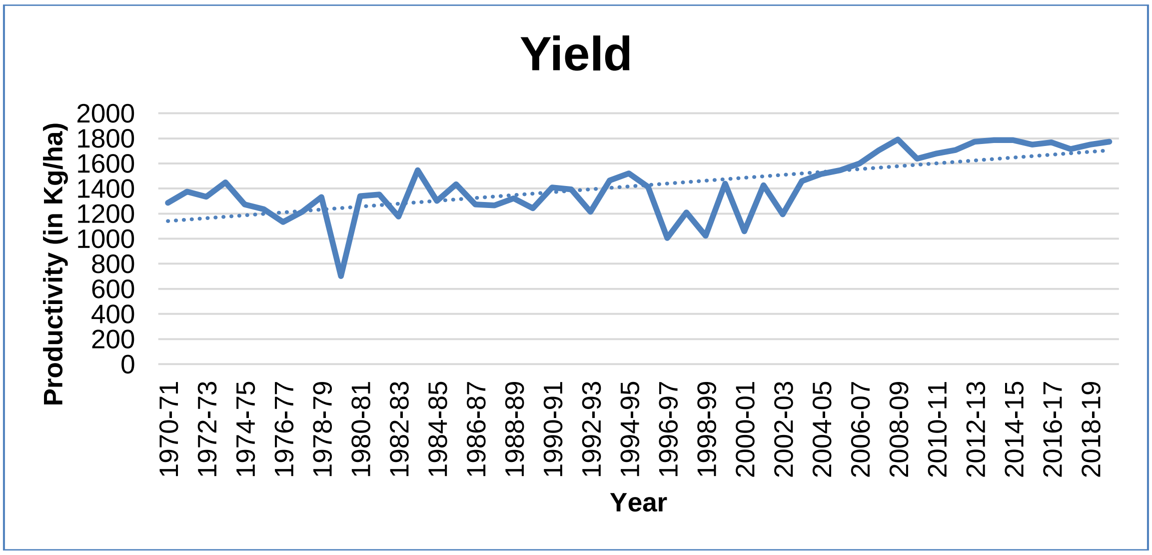

Fig. 2. Scatter diagram of productivity of groundnut

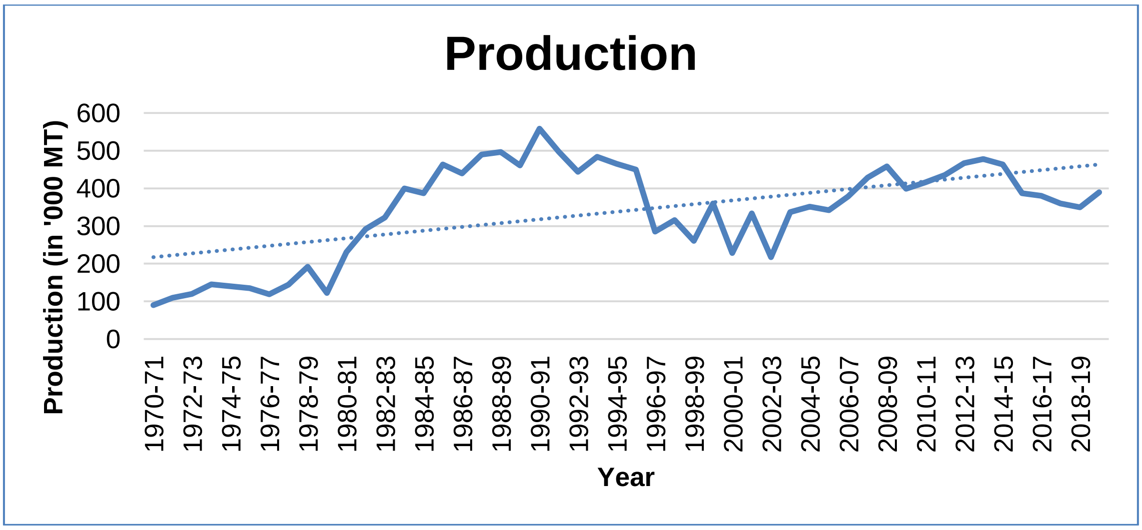

Fig. 3. Scatter diagram of production of groundnut

The study of the Table 2 reveals that except compound model all the models have in significant estimated parametric coefficients. So we reject all the models except compound model. The compound model also satisfies all assumptions of errors and have high values of adjusted R^2 and low value of RMSE. Thus, the best fit model for area under groundnut in period II is compound model.

The study of the Table 3 reveals that except quadratic model all the models fitted to the data on productivity of groundnut have significant estimated parametric coefficients. So we reject quadratic model. The F-value of all the models except quadratic and power model are significant. Out of all the fitted models, only compound model satisfies all assumptions of errors and have high values of adjusted R^2 and low value of RMSE. So the best fit model for productivity of groundnut for period I is compound model.

The study of the Table 4 shows that the estimated coefficients of all the fitted models are significant. The F-value of all the models are highly significant. But the only model found to be best fit to the data on productivity of groundnut for period II is compound model as only this model satisfies the error assumptions have high adjusted R^2 and low RMSE.

The study of the Table 5 shows that except compound, power and linear model all the models have insignificant estimated parametric coefficients. So quadratic and logarithmic models are rejected. The F-value of all the models are highly significant. Only compound model satisfies all error assumptions. Thus on the basis of significance of parametric coefficient and residual diagnostics, the only model fit to the data on production of groundnut for period I is compound model. The adjusted R^2 of compound model is highand RMSE is low. So, the best fit model for production of groundnut in period I is compound model.

The study of the Table 6 reveals that except quadratic model all other models fitted to the data on production of groundnut in period II have significant estimated parametric coefficients. So quadratic model is rejected. The F-value of all the models are highly significant. All the error assumptions are satisfied by only the linear model. The adjusted R^2 of linear model is highest and RMSE is lowest than the other models. So the best fit model for production of groundnut for period II is linear model.

Table 7 shows that the growth rate of area is found positive and significant only in period-I, whereas, in period-II it is found to be insignificant. Productivity of groundnut shows positive and significant growth rate only in period – II. But production of groundnut has positive and significant growth rate in both the periods. The growth rate of area and production is quite high in period I i.e. the pre-liberalisation period which decreases in the period -II i.e. post-liberalisation period, whereas, that of productivity is low in period I and increases slightly in period-II. The Coefficient of Variation for all the variables are also significant in both the periods. The CV has increased in post-liberalisation period for area and production but deceased in case of productivity of groundnut.

Table 1. Estimated coefficients, model fit statistics and residual diagnostics of the models fitted to data on area under groundnut of Odisha in period I (1970-71 to 1995-96)

Models	b_0	b_1	b_2	R^2	Adjusted R^2	RMSE	F	S-W statistic	D-W statistic	Coefficient of ln(t)
Linear	141.85** (24.73)	13.33** (2.06)		0.69	0.68	53.24	41.68**	.95	0.26**	-0.19 (0.66)
Logarithmic	58.24* (25.69)	105.63** (11.37)		0.82	0.81	40.27	83.30**	.95	0.52**	0.01 (0.44)
Quadratic	23.28 (17.50)	45.66** (3.83)	1.54** (0.17)	0.94	0.93	22.86	114.35**	.96	4.00**	-0.28 (0.56)
Compound	142.42** (15.38)	1.06** (0.01)		0.69	0.68	68.65	41.87**	.93	0.20**	0.66 (0.50)
Power	**95.21** (8.45)**	**0.48** (0.03)**		**0.89**	**0.88**	**43.82**	**148.85****	**.95**	**1.87**	**0.92 (0.83)**

*(Figures in the parentheses represent the standard error) * Significance at 1% level; ** Significance at 5% level Model highlighted as bold is the best fit model*

Table 2. Estimated coefficients, model fit statistics and residual diagnostics of the models fitted to data on area under groundnut of Odisha in period II (1996-97 to 2019-20)

Models	b_0	b_1	b_2	R^2	Adjusted R^2	RMSE	F	S-W statistic	D-W statistic	Coefficient of ln(t)
Linear	240.67** (10.73)	.256 (.896)		0.005	-0.05	23.10	1.08	0.94	0.99**	-0.75 (0.49)
Logarithmic	253.40** (14.55)	-4.74 (6.44)		0.62	-0.02	22.81	0.54	0.92	0.99**	-0.04 (0.45)
Quadratic	266.32** (15.79)	-6.73 (3.4)	0.33 (0.16)	0.20	-0.04	23.13	2.20	0.83	2.4	-0.19 (0.66)
Compound	**238.87** (11.08)**	**1.001* (0.004)**		**0.007**	**0.11**	**20.63**	**2.12****	**0.94**	**1.99**	**-0.96 (0.92)**
Power	251.36** (15.90)	-0.01 (0.02)		0.02	-0.03	22.83	0.38	0.93	0.99**	-0.12 (0.98)

*(Figures in the parentheses represent the standard error) * Significance at 1% level; ** Significance at 5% level*
Model highlighted as bold is the best fit model

Table 3. Estimated coefficients, model fit statistics and residual diagnostics of the models fitted to data on productivity of groundnut of Odisha in period I (1970-71 to 1995-96)

Models	b_0	b_1	b_2	R^2	Adjusted R^2	RMSE	F	S-W Statistic	D-W Statistic	Coefficient of ln(t)
Linear	1150.19** (75.26)	14.50* (6.28)		0.229	0.186	162.02	5.33*	.871*	2.615*	-0.354 (0.554)
Logarithmic	1081.69** (103.74)	104.32* (45.9)		0.223	0.180	162.60	5.16*	.846**	2.596*	-0.432 (0.516)
Quadratic	1115.82** (123.57)	23.88 (27.10)	-0.446 (1.25)	0.234	0.144	161.42	2.60	.877*	3.73**	-0.251 (0.818)
Compound	1128.55** (79.37)	1.01** (.006)		0.203	0.159	163.09	4.58*	.886	2.182	-0.136 (0.630)
Power	1066.29** (103.66)	0.089 (0.043)		0.193	0.148	162.71	4.29	.859**	2.593*	-0.634 (0.609)

*(Figures in the parentheses represent the standard error) * Significance at 1% level; ** Significance at 5% level*
(Model highlighted as bold is the best fit model)

Table 4. Estimated coefficients, model fit statistics and residual diagnostics of the models fitted to data on productivity of groundnut of Odisha in period II (1996-97 to 2019-20)

Models	b_0	b_1	b_2	R^2	Adjusted R^2	RMSE	F	S-W statistic	D-W statistic	Coefficient of ln(t)
Linear	1073.88* (56.98)	41.04** (4.75)		0.805	0 .794	122.67	74.43*	.967	2.514*	-1.266 (0.631)
Logarithmic	876.29** (80.22)	296.93* (35.49)		0.795	0.784	133.90	69.97*	.866**	2.377	-1.913 (0.783)
Quadratic	932.85** (83.08)	79.50** (18.22)	-1.83* (.843)	0.848	0.830	108.52	47.27*	.938	3.669*	-0.655 (0.780)
Compound	1090.50* (49.32)	1.02** (.004)		0.767	0.754	125.74	59.12*	.954	2.114	-1.039 (1.238)
Power	939.37** (55.39)	0.214** (.026)		0.790	0.778	117.57	67.57**	.882*	2.693*	-1.699 (1.117)

*(Figures in the parentheses represent the standard error) * Significance at 1% level; ** Significance at 5% level*
(Model highlighted as bold is the best fit model)

Table 5. Estimated coefficients, model fit statistics and residual diagnostics of the models fitted to data on production of groundnut of Odisha in period I (1970-71 to 1995-96)

Models	b_0	b_1	b_2	R^2	Adjusted R^2	RMSE	F	S-W statistic	D-W statistic	Coefficient of ln(t)
Linear	156.89** (33.17)	20.57** (2.76)		0.75	0.74	71.41	55.21**	.946	0.57**	0.15 (0.427)
Logarithmic	37.35 (36.20)	158.54* (16.01)		0.84	0.83	57.74	97.97**	.975	1.005*	0.10 (0.68)
Quadratic	7.59 (28.98)	61.29** (6.35)	-1.93** (0.29)	0.93	0.92	37.85	114.53*	.960	1.85	-1.12 (0.54)
Compound	160.73** (20.63)	1.07** (0.012)		0.70	0.69	100.6	43.75**	.940	1.84	0.88 (0.71)
Power	101.52** (12.39)	0.569* (0.054)		0.86	0.85	60.57	110.91*	.946	0.78**	1.30 (0.70)

*(Figures in the parentheses represent the standard error) * Significance at 1% level; ** Significance at 5% level*
(Model highlighted as bold is the best fit model

Table 6. Estimated coefficients, model fit statistics and residual diagnostics of the models fitted to data on production of groundnut of Odisha in period II (1996-97 to 2019-20)

Models	b_0	b_1	b_2	R^2	Adjusted R^2	RMSE	F	S-W Statistic	D-W Statistic	Coefficient of ln(t)
Linear	254.47** (22.21)	10.73** (1.85)		0.65	0.63	47.82	33.51**	.905	2.09	-0.84 (0.94)
Logarithmic	219.58** (35.83)	69.73** (15.85)		0.58	0.49	56.16	19.34**	.906	1.54	-0.62 (0.48)
Quadratic	250.09** (36.58)	11.93 (8.02)	-0.057 (.371)	0.65	0.61	47.79	15.86**	.909	3.92**	-0.95 (0.83)
Compound	260.49** (18.35)	1.03** (.006)		0.59	0.57	48.59	26.69**	.859*	2.04	-0.95 (0.86)
Power	236.12** (26.10)	0.19** (0.04)		0.47	0.44	53.99	16.24**	.899*	1.65	-0.61 (0.98)

*(Figures in the parentheses represent the standard error) *Significance at 1% level; ** Significance at 5% level*
Model highlighted as bold is the best fit model

Table 7. Growth rate and coefficient of variation of area, productivity and production of groundnut in Odisha

Crop	Growth Rate			Coefficient of Variation		
	PI	**PII**	**∆P**	**PI**	**PII**	**∆P**
Area	8.17**(0.47)	0.13(7.99)	-8.03**(2.06)	298.63**(47.21)	1079.6**(170.69)	780.96**(123.48)
Productivity	1.26(1.78)	2.94**(1.46)	1.68**(7.95)	725.44**(114.70)	556.13**(87.93)	-169.30**(-26.76)
Production	7.34**(8.27)	3.04**(0.02)	-4.29**(0.12)	266.04**(42.06)	466.31**(73.73)	200.26**(31.66)

*(Figures in the parentheses represent the standard error)   * Significance at 1% level; ** Significance at 5% level*

4. SUMMARY AND CONCLUSION

Different models are found to be appropriate for different variables under study (i.e., area, productivity and production of groundnut) in different periods (i.e., pre and post liberalization period). The change in growth rate of both area and production of groundnut from pre-liberalisation to post-liberalisation period is negative, whereas, change in coefficient of variation is positive. This shows that the decrease in growth rate of area and production of groundnut in Odisha is accompanied with increase in instability. This is considered to be poor performance of the state with respect to area and production of groundnut in post liberalization period. The change in growth rate of productivity under groundnut is positive and coefficient of variation is negative. This shows that the increase in growth rate of productivity under groundnut is accompanied with decrease in instability. This is very good performance of the state with respect to productivity of groundnut in post liberalization period. Thus it is found that though the state performs well w.r.t. productivity of groundnut but the poor performance in area results in poor performance in production of groundnut. Thus, it is found that fitting appropriate model to the variable under study could depict the true picture of the performance of the crop with respect to the variable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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