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Growth Rates, Growth Models and Future Projections of Rice in Three Districts of Northern Telangana Zone

A. Sreenivas*, D. Srinivasa Chary and K. Supriya

Department of Statistics & Mathematics, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500030, Telangana, India

**Corresponding author*

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A B S T R A C T

Attempts have been made to examine the trends and forecasting in area, production and productivity of Rice crop in three districts of Northern Telangana Zone. Linear and compound growth rates were calculated for this purpose. Ten growth models were fitted to the area, production and productivity of Rice crop and best- fitted model for future projection was chosen based upon least Residual Mean Square (RMS) and significant Adj$^{R^2}$. Besides, the important assumption of randomness of residuals was tested using one sample run test. The reference period of study was from 1979-80 to 2012-13 and it was carried out in three districts of Northern Telangana Zone.

Introduction

Rice is the most important crop of India and it occupies 23.3 per cent of gross cropped area of the country. It contributes 43 per cent of total food grain production and 46 per cent of total cereal production and continues to play a vital role in the national food grain supply. India is at 2^{nd} position in the World Rice production. In India Rice is grown all over the country with an area of 42.95 million hectares, production of 105.24 million tonnes and with the productivity of 2450 kg/ha during 2012-13. Andhra Pradesh occupies 2nd position in production after West Bengal. In Andhra Pradesh during 2012-13, rice cropis grown in both kharif and Rabi seasons in all the Districts of the state. It accounted for 26.58 % of the total cropped area i.e., area of rice crop is 4.75 million hectares and production is 14.42 million tonnes with productivity of 3035 kg/ha. (www.indian stat.com).

Telangana was a part of Andhra Pradesh till 1 June 2014. It has become separate state on 2 June 2014. The Telangana state attained significant acceleration in agricultural growth in the first phase of green revolution (decade of 70's). The second phase of green revolution (decade of 80's) maintained the growth rate which was attained in the first phase. This achievement was due to the shifts in crops and cropping system from low valued coarse cereals and millets to high valued commercial crops such as cotton. In the 90's, the state experienced a steep decline in agricultural growth. All the major crops rice, cotton and maize registered a significant decline in the growth of output (Reddy, 2001). Areas under rice, cotton and maize crops have substantially increased. A drastic reduction in the areas of maize occurred largely due to the availability of rice and cotton at subsidized prices in the public distribution system. Even the food preferences in the rural areas shifted largely in favour of rice. The global prices are also influencing the crop scenario (Source: United Telangana: Vision 2020).

Growth models are useful in drawing inferences like the exact relationship between time and growth, the rate of growth at each point of time, the turning points in the growth, growth rates are considered as the best indices of growth. Srinivasa Rao *et al.,* (2006) made an attempt to measure the growth rates of turmeric considering the period from 1970 to 2005 and to estimate the future projections up to 2020 AD by using the regression equations like linear, quadratic, exponential, logarithmic, compound models. They concluded that the growth rate in area, production and productivity of turmeric were positive and showed increasing trend in the state of Andhra Pradesh. Hence, the future projections of area, production and productivity of turmeric in Andhra Pradesh and India were calculated based on the linear regression equation. Rao (2006) in his research on temporal variations in area, production and productivity of major horticultural crops made an attempt for the best fitted model for future projections. Sreekanth *et al.,* (2003) attempted to develop a simple forecasting model for predicting the cashew yield for area and production based on secondary data from the years 1985 to 2000. Deka *et al.,* (2002) attempted to estimate trend in area, production and productivity of nut areca in the state of Assam, India, during 1980-81 to 1999-2000. The fitted trend revealed that production of nut areca in the period under reference had been an upward trend in initial period, yet, decreased production had been prominent in the later period. On the basis of best fitted trend, future production has been predicted.

The present study is based on 34 years of data i.e., from 1979 to 2012 of Rice in three districts of Northern Telangana Zone. The linear growth rate (LGR) and compound growth rate (CGR) for the crop characteristics i.e., area, production and productivity of rice crop in three districts of Northern Telangana Zoneare estimated by fitting the following functions, the analysis of the data has been carried out by using data on area production and productivity obtained from web site: www.indian stat.com.

Materials and Methods

Methodology for the estimation of growth rates

The study was based on 34 years of data i.e., from 1979-80 to 2012-13. Keeping the objectives in view, linear growth rate (LGR) and compound growth rate (CGR) for the crop characteristics i.e., area, production and productivity of Major crops in three districts of Northern Telangana Zone i.e., Adilabad, Karimnagar and Nizamabad were estimated by fitting the following functions.

Methodology for fitting the trend equations

The trend equations were fitted by using different growth models. Growth models are nothing but the models that describe the behaviour of a variable overtime. The growth models taken under consideration here are as follows.

Linear function

A linear model is one in which all the parameters appear linearly.

The mathematical equation is given by

$Y_t = a + bt$

Where

Y_t is the dependent variable i.e., area, production and productivity

t is the independent variable, time in years

a and b are the constants

The constants 'a' and 'b' are estimated by applying the Ordinary Leasts Square approach.

Logarithmic function

This model shows very rapid growth, followed by slower growth

The mathematical equation is given by

$Y_t = a + b \ln(t)$

Where,

Y_t is the dependent variable i.e., area, production and productivity

t is the time in years, independent variable
'a' and 'b' are constants

The constants 'a' and 'b' are estimated by applying the Ordinary Least Squares approach.

Inverse function

Inverse curve shows a decreasing growth.

Inverse fit is given by the equation

$Y_t = a + b/t$

Where,

Y_t is the dependent variable i.e., area, production and productivity

t is the independent variable, time

'a' and 'b' are parameters

The parameters can be estimated by the method of Ordinary Least Squares (OLS).

Quadratic function

This function is useful when there is a peak or a trough in the data of past periods.

Quadratic fit is given by the equation

$Y_t = a + bt + ct^2$

Where,

Y_t is the dependent variable i.e., area, production and productivity

t is the independent variable, time in years
a, b and c are constants

The constants can be calculated by applying the method of ordinary least squares approach.

Cubic function

This function is useful when there is or has been, two peaks or two troughs in the data of past periods.

Cubic fit or third degree curve is given by the equation:

$Y_t = a + bt + ct^2 + dt^3$

Where,

Y_t is the dependent variable i.e., area, production and productivity

t is the independent variable, time in years

a, b, c and d are parameters

The parameters are calculated by ordinary least squares technique.

Compound function

This function is useful when it is known that there is or has been, increasing growth or decline in past periods

Compound fit is given by

$Y_t = ab^t$

Or $\ln Y_t = \ln a + t \ln b$

Where,

Y_t is the dependent variable, area, production and productivity

t is the independent variable, time in years

a and b are parameters or constants

The constants can be obtained by using ordinary least squares technique.

S-curve

S-curve fit is given by

$Y_t = \text{Exp}(a+b/t)$

Or $\ln Y_t = a + b/t$

Where,

Y_t is the dependent variable, area, production and productivity

t is the independent variable, time in years

a and b are parameters or constants

Ordinary Least Squares (OLS) method can be applied to estimate the parameters of the model.

Growth function

The fit is given by

$Y_t = \text{Exp}(a + bt)$

or $\ln Y_t = a + bt$

Where,

Y_t is the dependent variable, area, production and productivity

t is the independent variable, time in years
a and b are parameters or constants

The constants are obtained by ordinary least squares technique.

Power function

The fit is given by the equation

$Y_t = at^b$

Or $\ln Y_t = \ln a + b \ln(t)$

Where,

Y_t is the dependent variable, area, production and productivity t is the independent variable, time in years

a and b are parameters or constants

The constants are calculated by ordinary least squares technique.

The fit is similar to exponential fit, but produces a forecast curve that increases or decreases at different rate.

Exponential fit

If, when the values of t are arranged in an arithmetic series, the corresponding values of y form a geometric series,

The relation is of the exponential type.

The function of this type can be given by

Y_t = a Exp (bt)

Or ln Y_t = ln a + (bt)

Where,

Y_t is dependent variable i.e., area, production and productivity

t is independent variable, time in years

a and b are constants

The constants are calculated by ordinary least squares technique

Methodology for the estimation of future projections

The future projections of area, production and productivity of major crops in three districts of Northern Telangana Zone up to 2020 AD

Were estimated upon the best fitted growth model used for fitting the trend equations.

Methodology for the best fitted model

The choice of the trend equation amongst the available alternatives is very crucial. Many researchers use coefficient of multiple determination, R^2 or adjusted R^2 ($\overline{R}^2$) as the criterion of model selection.

$$R^2 = \frac{EXPLAINED VARIATION}{TOTAL VARIATION} = \frac{\sum_{i=1}^{n}(\tilde{Y}_i - Y)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}$$

$$AdjR^2 = (\overline{R^2}) = R^2 - \left[\frac{K-1}{N-K}\right](1 - R^2)$$

Where,

K is the number of constants in the equation
N is the total number of observations

It was observed that R^2 is not enough to examine goodness of fit of a model (Reddy, 1978). So in addition to adj R^2, the residual mean square (RMS) which will also measure the accuracy in forecasting is the best criterion to choose a model from among the alternatives.

$$\text{Residual mean square} = \frac{\sum (y_i - \hat{y}_i)^2}{\text{Residual degrees of freedom}}$$

In the present study, the model with least residual mean square (RMS) and significant adj R^2 was considered to be the best fitted model.

Before choosing a model, one should be certain that the disturbance term satisfies all the conditions of randomness, non-autocorrelation, homoscedasticity and normality. In the present study, an attempt has been made to verify the most important assumption of randomness of residuals.

Test for randomness of residuals

Non-parametric one sample run test can be used to test the randomness of residuals. A *run* is defined as a succession of identical symbols in which the individual scores or observations originally were obtained. For example, suppose a series of binary events occurred in this order:

++++ - - + - - - ++ - + -

This sample of scores begins with a run of four pluses. A run of two minuses follows, then comes another run of one plus and then a run of three minuses and so on.

The total runs in the above example are 8.

If very few runs occur, a time trend or some bunching owing to lack of independence is suggested and if many runs occur, systematic short period cyclical fluctuations seem to be influencing the scores.

Let 'n_1', be the number of elements of one kind and 'n_2' be the number of elements of the other kind in a sequence of $N = n_1 + n_2$ binary events. For small samples i.e., both n_1 and n_2 are equal to or less than 20 if the number of runs r fall between the critical values, we accept the H_0 (null hypothesis) that the sequence of binary events is random otherwise, we reject the H_0.

For large samples i.e., if either n_1 or n_2 is larger than 20, a good approximation to the sampling distribution of r (runs) is the normal distribution, with

$$Mean = \mu_r = \frac{2n_1n_2}{N} + 1$$

$$\text{Standard deviation} = \sigma_r = \sqrt{\frac{2n_1n_2(2n_1n_2 - n_1 - n_2)}{(n_1+n_2)^2(n_1+n_2-1)}}$$

Then, H_0 may be tested by $Z = \frac{r - \mu_r}{\sigma_r}$

The significance of any observed value of Z computed from the above formula may be determined by reference to the Standard Normal Distribution table.

Results and Discussion

Adilabad

The average area under Rice during the study period (1979-80 to 2012-13) was 69.85 thousand hectares. The coefficient of variation recorded for the study period was 17.89 per cent and the linear and compound growth rates recorded during the study period were 0.56 and 0.4 per cent per annum respectively. The area of Rice in Adilabad exhibited a positive trend and it was found not significant of compound growth rate and linear growth rate. The average production of Rice during the study period (1979-80 to 2012-13) was 124.9 thousand tones with a coefficient of variation of 41.21 per cent. The linear growth rate and compound growth rate recorded for the study period were 2.6 and 2.4 per cent per annum respectively. The production of Rice in Adilabad exhibited a positive trend and has been increasing significantly during the study period and the increase was significant at 1% level of significance in case of linear growth rate but it was found significant at 5%level of significance in case of compound growth rate. Regarding the productivity in Adilabad, the average yield of Rice during the study period (1979-80 to 2012-13) was 1809 kg/ha, with the coefficient of variation of 30.91 per cent. The linear and compound growth rates during the study period were 2.3 and 2.3 per cent respectively. The productivity of Rice also had exhibited a positive trend during the study period in Adilabad and was significant at 5% level of significance. As a whole, the growth rates of production were higher than growth rates of area and productivity.

The future projections of area, production and productivity of Rice in Adilabad by 2020 AD were calculated and the results were presented. Area under Rice in Adilabad was regarding the area of Rice, No model was found fitted well because all the models Adj R^2 values are non-significance. Regarding the production of Rice, Exponential function was found to be the best model for future projections by 2020 AD as it has the least residual mean square, significant Adj R^2 and also satisfied the assumption of randomness of residuals. The projected production would be increasing at 199 thousand tonnes by 2020 AD. Regarding the productivity of Rice, S-curve function was found to be the best model for future projections by 2014 AD as it has the least residual mean square, significant Adj R^2 and also satisfied the assumption of randomness of residuals. The projected production would be increasing at 1824 kg/ha by 2020 AD.

Karimnagar

The average area under Rice during the study period (1979-80 to 2012-13) was 214.2 thousand hectares. The coefficient of variation recorded for the study period was 32.31 per cent and the linear and compound growth rates recorded during the study period were 2 and1.8 per cent per annum respectively. The area of Rice in Karimnagar exhibited a positive trend and it was found significant at 5% level of significance in linear growth rate and not significant of compound growth rate. The average production of Rice during the study period (1979-80 to 2012-13) was 619.7 thousand tones with a coefficient of variation of 47.60 per cent. The linear growth rate and compound growth rate recorded for the study period were 3 and 3.2 per cent per annum respectively. The production of Rice in Karimnagar exhibited a positive trend and has been increasing significantly during the study period and the increase was significant at 1% level of significance in case of linear growth rate and compound growth rate. Regarding the productivity in Karimnagar, the average yield of Rice during the study period (1979-80 to 2012-13) was 2749.9 kg/ha, with the coefficient of variation of 19.49 per cent. The linear and compound growth rates during the study period were 1.64 and 1.7 per cent respectively. The productivity of Rice also had exhibited a positive trend during the study period in Karimnagar and was not significant. As a whole, the growth rates of production were higher than growth rates of area and productivity.

Table.1 Growth rates in area, production and productivity of rice crop in Adilabad

Adilabad (%)	Area	Production	Productivity
Linear	0.56	2.6**	2.3*
Compound	0.4	2.4*	2.3*
C.V	17.80	41.21	30.91

Table.2 Growth models of area, production and productivity of rice crop in Adilabad

AREA										
Model	Linear	Logarithm	Inverse	Quadratic	Cubic	Compound	Power	S-curve	Growth	Exponential
AdjR2	0.69	0.21	-0.011	0.097	0.068	0.024	-0.005	-0.02	0.024	0.024
RMS	143.93	151.3	156.27	139.65	144.04	142.916081	152.976	142.935	148.27607	142.865028
Runs	15	12	14	15	13	15	15	15	15	15
PRODUCTION										
AdjR2	0.367*	0.233*	0.061	0.377*	0.357*	0.278*	0.167**	0.035	0.278*	**0.278***
RMS	1676.71	2031.71	2489.48	1650.66	1703.72	1656.45927	2507.54	1643	2011.585	**1642.26715**
Runs	15	15	13	17	6	15	15	15	15	**15**
PRODUCTIVITY										
AdjR2	0.545*	0.36*	0.102**	0.558*	0.546*	0.49*	0.319*	**0.083****	0.49*	0.49*
RMS	142419	200099	281033	138343	142079	136296.196	274823	**134958**	185422.29	134999.889
Runs	13	13	9	14	14	13	11	**13**	13	13

Table.3 Future projections of area, production and productivity of rice crop in Adilabad

Year	Area ('000'ha)	Production ('000'tonn)	Productivity(kg/ha)
2013-14		175.5	1819.4
2014-15		179.7	1820.3
2015-16		184.1	1821.1
2016-17		188.6	1821.8
2017-18		193.1	1822.6
2018-19		197.8	1823.2
2019-20		199.0	1824.0

Table.4 Growth rates in area, production and productivity of rice crop in Karimnagar

Karimnagar (%)	Area	Production	Productivity
Linear	2*	3**	1.64
Compound	1.8	3.2**	1.7
C.V	32.31	47.60	19.49

Table.5 Growth models of area, production and productivity of rice crop in Karimnagar

AREA										
Model	Linear	Logarithmi	Inverse	Quadratic	Cubic	Compound	Power	S-curve	Growth	Exponential
AdjR2	0.352*	0.255*	0.1**	0.363*	**0.375***	0.26*	0.207*	0.092*	0.26*	0.26*
RMS	3106.06	3507.89	4314.27	3054.81	**2997.28**	3012.0529	4235.1683	3099.6302	3485.9603	3098.7973
Runs	13	11	11	13	**14**	12	13	12	11	12
PRODUCTION										
AdjR2	0.522*	0.379*	0.144**	0.538*	0.538*	0.46*	0.382*	**0.18***	0.46*	0.46*
RMS	41550	54066	74441	40162	40199	40621.224	73276.186	**39786.395**	51333.154	39813.691
Runs	11	11	11	13	12	12	11	**12**	11	12
PRODUCTIVITY										
AdjR2	**0.693***	0.551*	0.223*	0.683*	0.678*	0.633*	0.516*	0.214*	0.633*	0.633*
RMS	**88265**	128896	223258	91110.63	92483	87406.093	210821.84	87304.55	113594.76	87291.628
Runs	**19**	18	13	18	18	18	17	13	17	17

Table.6 Future projections of area, production and productivity of rice crop in Karimnagar

Year	Area ('000'ha)	Production ('000'tonn)	Productivity(kg/ha)
2013-14	351.5	620.0	3539.1
2014-15	373.2	620.6	3584.2
2015-16	397.0	621.1	3629.3
2016-17	422.9	621.6	3674.4
2017-18	451.0	622.1	3719.5
2018-19	481.5	622.6	3764.6
2019-20	490.0	626.0	3773.0

Table.7 Growth rates in area, production and productivity of rice crop in Nizamabad

Nizamabad (%)	Area	Production	Productivity
Linear	0.49	2.8**	1.98*
Compound	0.3	2.1*	1.8
C.V	23.98	50.84	26.09

Table.8 Growth models of area, production and productivity of rice crop in Nizamabad

AREA										
Model	**Linear**	**Logarithmi**	**Inverse**	**Quadratic**	**Cubic**	**Compound**	**Power**	**S-curve**	**Growth**	**Exponential**
AdjR2	0.1	-0.025	-0.029	**0.121****	0.159	-0.018	-0.03	-0.031	-0.018	0.018
RMS	1167.44	1203.82	1213.4	**900**	991.263	1147.99	1194.5538	1148.1748	1187.8163	1147.8783
Runs	13	13	14	**14**	14	13	14	13	14	13
PRODUCTION										
AdjR2	0.286*	0.13**	0.13	0.491*	**0.573***	0.192*	0.079**	0.005	0.192*	0.192*
RMS	25698	31326	35342	18340	**15388.39**	25887.522	35722.342	25700.132	31835.19	25703.205
Runs	11	11	11	14	**15**	13	11	13	11	13
PRODUCTIVITY										
AdjR2	0.537*	0.309*	0.087**	0.684*	0.698*	0.493*	0.293*	0.089*	**0.493***	0.493*
RMS	197783.7	295144	389929	134863	128862	179292.37	379781.61	177914.28	**132506**	177930.28
Runs	11	9	7	15	15	11	7	11	**9**	11

**Significant at 1% level
*Significant at 5% level

Table.9 Future projections of area, production and productivity of rice crop in Nizamabad

Year	Area ('000'ha)	Production ('000'tonn)	Productivity(kg/ha)
2013-14	185.40	949.1	3337.6
2014-15	191.2	1056.8	3398.2
2015-16	197.40	1174.9	3459.9
2016-17	199.5	1303.9	3522.8
2017-18	201.5	1444.3	3586.7
2018-19	206.1	1596.5	3651.9
2019-20	210.5	1626.0	3680.0

The future projections of area, production and productivity of Rice in Karimnagar by 2020 AD were calculated and the results were presented in the Table. Area under Rice in Karimnagar was regarding the area of Rice, cubic function was found to be the best model for future projections by 2020 AD as it has the least residual mean square, significant Adj R^2 and also satisfied the assumption of randomness of residuals. The projected Area would be increasing at 490 thousand tonnes by 2020 AD. Regarding the production of Rice, S-curve function was found to be the best model for future projections by 2020 AD as it has the least residual mean square, significant Adj R^2 and also satisfied the assumption of randomness of residuals. The projected production would be increasing at 626 thousand tonnes by 2020 AD. Regarding the productivity of Rice, Linear function was found to be the best model for future projections by 2014 AD as it has the least residual mean square, significant Adj R^2 and also satisfied the assumption of randomness of residuals. The projected production would be increasing at 3773 kg/ha by 2020 AD.

Nizamabad

The average area under Rice during the study period (1979-80 to 2012-13) was 143 thousand hectares. The coefficient of variation recorded for the study period was 23.98 per cent and the linear and compound growth rates recorded during the study period were 0.49 and 0.3 per cent per annum respectively. The area of Rice in Nizamabad exhibited a positive trend and it was found not significant of linear growth rate and compound growth rate. The average production of Rice during the study period (1979-80 to 2012-13) was 373.3 thousand tones with a coefficient of variation of 50.84 per cent. The linear growth rate and compound growth rate recorded for the study period were 2.8 and 2.1 per cent per annum respectively. The production of Rice in Nizamabad exhibited a positive trend and has been increasing significantly during the study period and the increase was significant at 1% level of significance in case of linear growth rate and 5% level of significance in the case of compound growth rate. Regarding the productivity in Nizamabad, the average yield of Rice during the study period (1979-80 to 2012-13) was 2504.9 kg/ha, with the coefficient of variation of 26.09 per cent. The linear and compound growth rates during the study period were 1.98 and 1.8 per cent respectively. The productivity of Rice also had exhibited a positive trend during the study period in Nizamabad the linear growth rate was significant at 5% level of significance and compound growth rate there is no significant. As a whole, the growth rates of production were higher than growth rates of area and productivity.

The future projections of area, production and productivity of Rice in Nizamabad by 2020 AD were calculated and the results were presented in the Table 4.6.7. Area under Rice in Nizamabad was regarding the area of Rice, Quadratic function was found fitted well least residual mean square, significant Adj R^2 values. Regarding the production of Rice, Cubic function was found to be the best model for future projections by 2020 AD as it has the least residual mean square, significant Adj R^2 and also satisfied the assumption of randomness of residuals.

The projected production would be increasing trend at 1626 thousand tonnes by 2020 AD. Regarding the productivity of Rice, Growth function was found to be the best model for future projections by 2014 AD as it has the least residual mean square, significant Adj R^2 and also satisfied the assumption of randomness of residuals. The projected production would be increasing trendat3680 kg/ha by 2020 AD.

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