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Assessing trends in sorghum crop for central Telangana zone

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Abstract
Attempts have been made to examine the trends and forecasting in area, production and productivity of Sorghum crop in Central Telangana Zone. For this purpose linear and compound growth rates were calculated. Ten growth models were fitted to the area, production and productivity of Sorghum 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 2015-16 and it was carried out in Central Telangana Zone.

Keywords: Forecasting, growth models, sorghum, linear trend

Introduction
All India total sorghum production has registered a constant growth rate of 0.10% per annum during the period 1967-68 to 2010-2011 which can be mainly attributed to negative production of *kharif* sorghum rather than positive growth in *rabi* sorghum production. Though, *kharif* sorghum yield growth rates were relatively higher, it could not offset the declining growth rates in production, as the growth rates in *kharif* sorghum area were negative and high. Just opposite is true in case of *rabi* sorghum where the area decline was not sufficient to undermine the yield growth, thus resulting in positive production growth rates.

Telangana is the twelfth largest state in India in terms of area. Sorghum is an important staple cereal crop grown mostly under rainfed conditions in Telangana. The crop is grown in *kharif* season in about 1.09 Lakh ha in Telangana with a production of about 1.11 Lakh mt at an average productivity of about 1015 kg/ha. (www.icrisat.in retrieved on 2014-03-29). The present study has been undertaken to evaluate the growth in area, production and productivity of Sorghum crop in central Telangana zone of Telangana State by using different growth models and also to project the same. This study has been undertaken to throw light on the policy decision to invest accordingly for the short and long-term plans and also to provide a direction of research which would bring sustainable development in agriculture.

Singh *et al*. (1997) [5] studied the trend in area, production and yield of major food grains, coarse cereals, pulses, oilseeds, sugarcane and cotton at the state level in India and the factors responsible for determining yield and acreage of important food grain crops. Compound growth rates of area, production and yield were estimated by fitting log-linear functions using data for 1960/61 to 1992/93. The determinants of yield levels of important food grain crops were examined by fitting multiple regression equations using data for the period 1972/73 to 1992/93. The study reveals that for total food grains, as well as for all the individual food grain crops, yield witnessed a higher growth rate as compared to acreage during 1972/73 to 1992/93.

Trends and growth performance in area, production and yield of chickpea in the four zones of India. The study utilized the secondary time series data of area, production and productivity of chickpea in different zones for the period of 30 years from 1975-76 to 2004-05. They observed that the maximum area and production of chickpea was in the Central Zone followed by the North West Plain Zone and North East Plain Zone while the lowest area and production was in the South Zone. The highest compound growth rate of area and production was observed in the South Zone followed by the Central Zone, while the lowest growth was registered in the North West Plain Zone followed by the North East Plain Zone (Devraj *et al*. 2007) [2]. Sharma Amod Kalita (2008) [4] showed trends in area, production and productivity of major fruit crops in Jammu and Kashmir based on the secondary data for the period of 1974-75 to 1999-2000. This study revealed that area, production and productivity of major fruit crops had a positive and statistically significant growth during the study period.

The coefficient of variation of area, production and productivity for almost all crops were less than 50%, indicating that less risk of cultivation in the state.

Aparna *et al*. (2008) [1] noted that the trend in growth rates of major vegetables in Visakhapatnam district with the help of compound growth rates. Compound growth rates are calculated by using exponential growth function. They concluded that the compound growth rates of area registered negative significant growth rate as where production and productivity showed positive but non-significant growth rates.

Rao and Rao (1984) [3] fitted linear regression, considering time as independent variable and area, production and productivity as dependent variable for sugarcane crop in India to calculate the trend coefficients. They also used indices and percentage change over previous year's area or production or productivity as a measure of assessing annual fluctuations. All India total sorghum production has registered a constant growth rate of 0.10% per annum during the period 1967-68 to 2010-2011 which can be mainly attributed to negative production of *kharif* sorghum rather than positive growth in *rabi* sorghum production. Though, *kharif* sorghum yield growth rates were relatively higher, it could not offset the declining growth rates in production, as the growth rates in *kharif* sorghum area were negative and high. Just opposite is true in case of *rabi* sorghum where the area decline was not sufficient to undermine the yield growth, thus resulting in positive production growth rates.

Methodology for the estimation of growth rates

The study was based on 36 years of data i.e., from 1979-80 to 2015-16. 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 Sorghum crop in Central Telangana Zone is 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 behavior 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

$$Y_t = ab^t$$

$$\text{or } \ln Y_t = \ln a + t \ln b$$

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 = 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 = 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 Sorghum in Central 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.

$$R^2 = \frac{\text{Explainedvariation}}{\text{Totalvariation}} = \sum_{i=1}^{n}\left(\tilde{Y}_i - Y\right)^2 \sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2$$

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

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

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

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

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

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

In Central Telangana Zone the area (Table 1) under sorghum in 1979-80 was 545 thousand hectares and in 2015-16 was 16.30 thousand hectares and the average area during the study period (1979-80 to 2015-16) was 189.41 thousand hectares. The coefficient of variation recorded in study period was 83.0 per cent and the linear and compound growth rates recorded were -7.17 and -8.6 per cent per annum respectively (Table 2). The area of Sorghum in Central Telangana Zone exhibited a negative trend and it has been decreasing significantly during the study period and this decrease was significant at 1% level of significance.

The production of sorghum in 1979-80 was 454 thousand hectares and 2015-16 was 15.58 and the average production during the study period (1979-80 to 2015-16) was 125.61 thousand tonnes with a coefficient of variation of 79.83 per cent. The linear and compound growth rates were recorded for the study period were -6.34 and -6.8 per cent per annum respectively. The production of Sorghum exhibited a negative trend in Central Telangana Zone and it was found to be significant at 1% level of significance in both of compound growth rate and linear growth rate.

Regarding the productivity of Sorghum in Central Telangana Zone is 1979-80 was 833.03 and in 2015-16 was 955.78 and the average yield of Sorghum during the study period (1979-80 to 2015-16) was 769.51 kg/ha, with the coefficient of variation of 27.79 per cent. The linear and compound growth rates during the study period were 1.98 and 2 per cent respectively.

The productivity of Sorghum had not followed a particular trend during the study period in Central Telangana Zone and was significant at 1% level of significance.

Growth rates of area, production and productivity of the Sorghum crop for the study period (1979-80 to 2015-16) in Central Telangana Zone were shown in the Figure 1.

As a whole, the growth rates of productivity were higher than growth rates of area and production.

Fitting of Different Growth Models

Area of Sorghum in Central Telangana Zone showed a decreasing growth pattern during the study period from 1979-80 to 2015-16. The results obtained by fitting all the ten growth models were presented in Table 3 and Figure 2. The Adj R^2 values for all the models were ranging from 0.292 in case of S-curve function and 0.965 in case of cubic function. For almost all the models Adj R^2 values were significant at 1% level of significance. Only logarithmic and cubic models were satisfied the assumption of randomness of residuals.

Cubic function was found to be the best trend equation for the purpose of future projection of area as it has exhibited the least RMS and significant Adj R^2 and also satisfied the assumption of randomness of residuals.

The Production of Sorghum in Central Telangana Zone showed decreasing decreasing growth pattern. The results obtained by fitting all the ten growth models were presented in Table 3 and Figure 3. The Adj R^2 values for all the models were ranging between 0.376 in case of s-curve and 0.901 in case of logarthmic function respectively. For almost all the models Adj R^2 values were significant at 1% level of significance. Only logarithmic, cubic and s-curve models satisfied the test of randomness of residuals.

Logarithmic function was found to be the best trend equation for the purpose of future projection of production it has exhibited the least RMS and significant Adj R^2 and also satisfied the assumption of randomness of residuals.

The Productivity of Sorghum in Central Telangana Zone showed increasing trend during the study period. The results obtained by fitting all the ten growth models were presented in Table 3 and Figure 4. The Adj R^2 values for all the models were ranging from 0.004 in case of s-curve and 0.745 in case of cubic functions respectively. Except inverse and s-curve. For almost all the models, Adj R^2 values were significant at 1% level of significance. Only linear, cubic, compound, s-curve and exponential models satisfied the test of randomness of residuals.

Exponential function was found to be the best trend equation for the purpose future projection of productivity it has exhibited the least RMS and significant Adj R^2 and also satisfied the assumption of randomness of residuals.

Future Projections of Area, Production and Productivity up to 2020 AD

The future projections of area, production and productivity of Sorghum in Central Telangana Zone by 2020 AD were calculated and the results were presented in the Table 4

Area under Sorghum in Central Telangana Zone was projected by using cubic function which was found to be best for this purpose as it had significant Adj R^2 and also fulfilled the assumption of randomness of residuals. The area under Sorghum projected by cubic function by 2020 AD would be 2 thousand hectares which is in decreasing trend.

Production under Sorghum in Central Telangana Zone was projected by using logarithmic function which was found to be best for this purpose as it had significant Adj R^2 and also fulfilled the assumption of randomness of residuals. The area under Sorghum projected by cubic function by 2020 AD would be which is not possible, it indicates that the future production. Productivity of Sorghum was projected by using exponential function which has less RMS, significant Adj R^2 and also has showed significant runs. The future projection for productivity of Sorghum also is in increasing trend and it would be 1117.005 kg/ha by 2020.AD.

Table 1: Average Area, Production and Productivity of Sorghum in Central Telangana Zone

Items	CTZ
Area(‘000ha)	189.41
Production(‘000 tonnes)	125.61
Productivity(kg/ha)	769.51

Table 2: Growth rates of area, production, productivity of Sorghum in Central Telangana Zone

Particulars	Area	Production	Productivity
Linear	-7.17**	-6.34**	1.98**
Compound	-8.6**	-6.8**	2.0**
C.V (%)	83.0	79.83	27.79

** Significance at 1% level
* Significance at 5% level

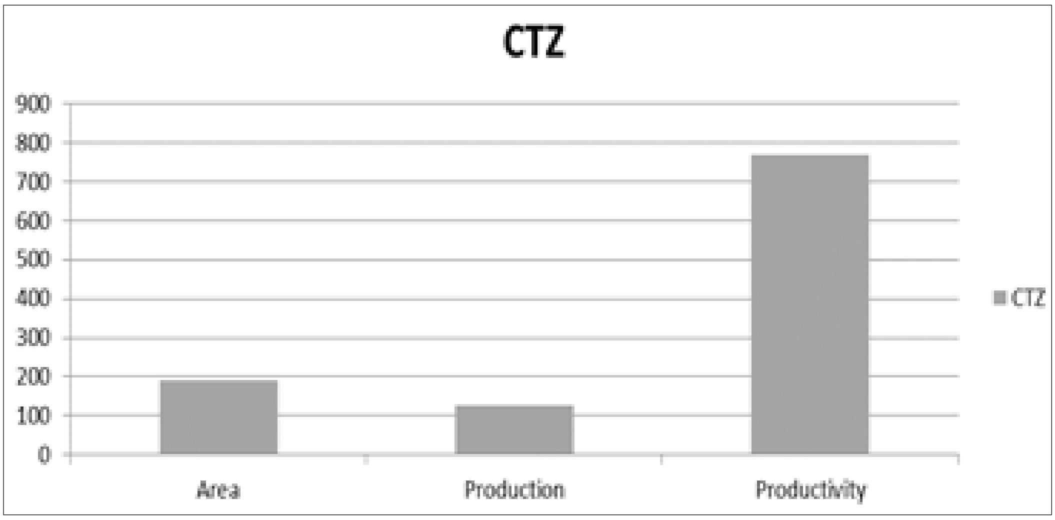

Fig 1: Average Area, Production and Productivity of Sorghum in Central Telangana Zone

Table 3: Growth Models for the Area, Production and Productivity of Sorghum in Central Telangana Zone

Model	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S-Curve	Growth	Exponential
Area										
Adj R2	0.872**	0.928**	0.531**	0.959**	0.965**	0.958**	0.737**	0.292**	0.958**	0.958**
RMS	3168.3	1779.47	11603	978.16	817.3	1478.3	77568	1443.74	55573	1477.73
Runs	5	11	8	8	12	9	3	7	3	9
Production										
Adj R2	0.734**	0.901**	0.692**	0.841**	0.89**	0.89**	0.76**	0.376**	0.89**	0.89**
RMS	2673.4	996.75	3101.98	166510.3	1042.9	1359.01	18857	1358.67	6518.6	1359.28
Runs	11	16	9	4	17	12	5	14	9	12
Productivity										
Adj R2	0.588**	0.291**	0.011	0.67**	0.745**	0.561**	0.275**	0.004	0.561**	0.561**
RMS	18842	32433.47	45228.8	837675.8	11018	17344.22	45774	17296.7	30576	17237.96
Runs	19	9	5	6	16	18	7	14	7	18

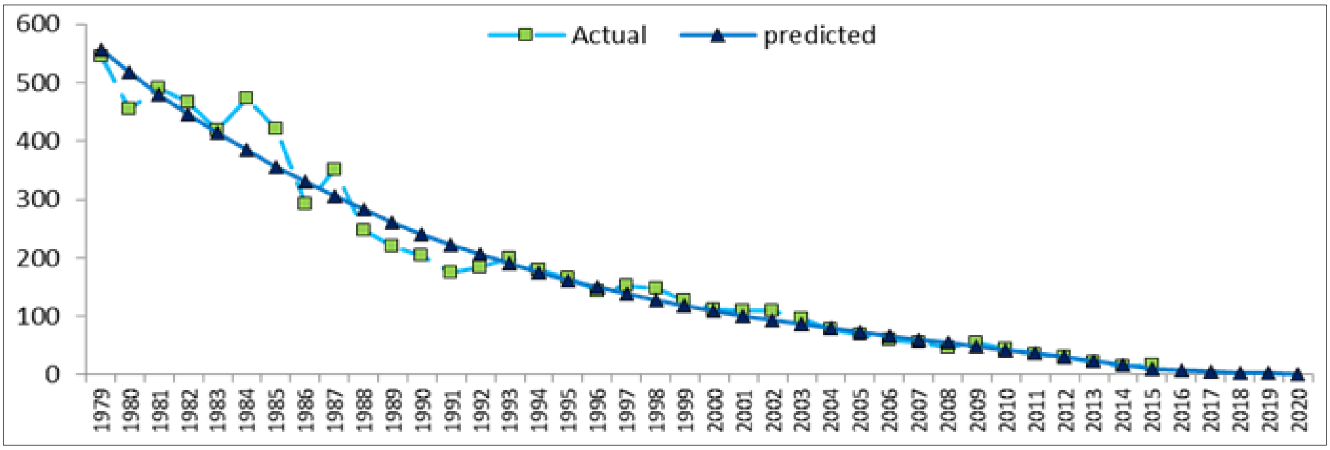

Fig 2: Trend of Sorghum Area in Central Telangana Zone of Telangana State

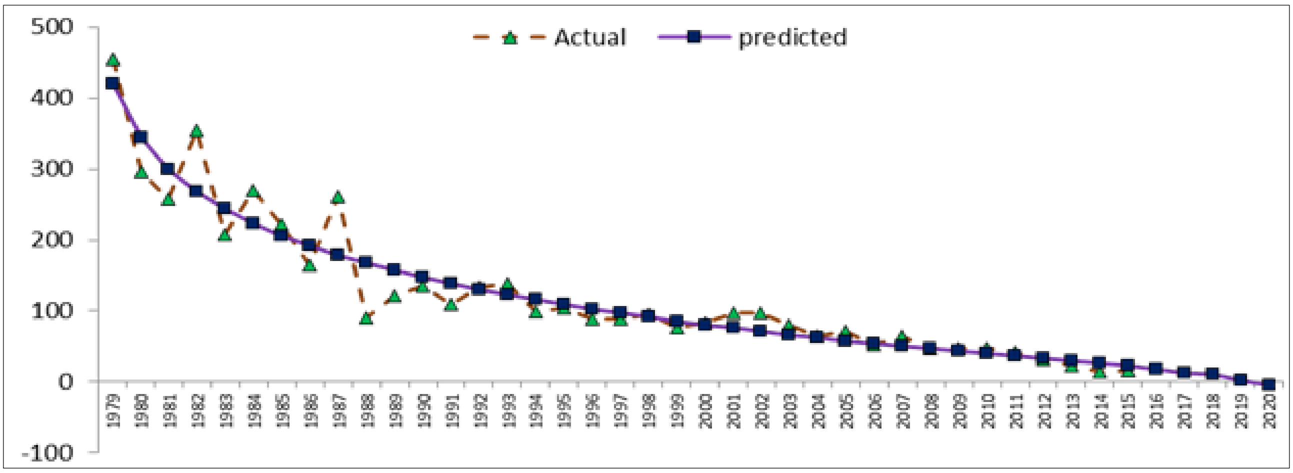

Fig 3: Trend of Sorghum Production in Central Telangana Zone of Telangana State

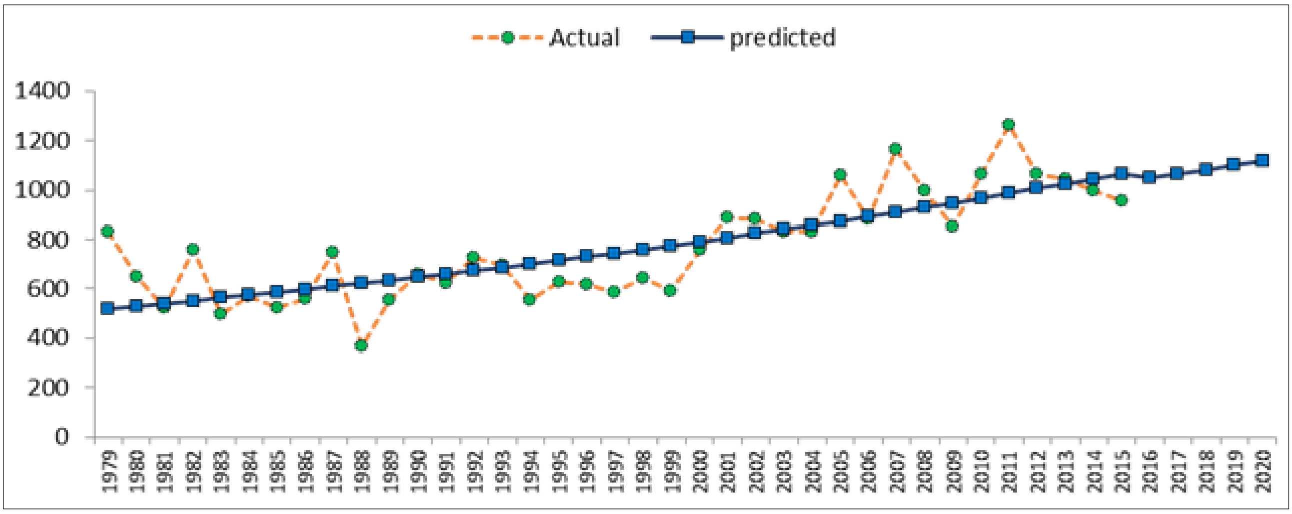

Fig 4: Trend of Sorghum productivity in Central Telangana Zone of Telangana State

Table 4: Projections of Area, Production and Productivity Sorghum in Central Telangana Zone of Telangana State

Year	Area (' 000 ha)	Production (' 000 tonnes)	Productivity (kg/ha)
2016-2017	7	18	1049.385
2017-2018	5	13	1066.225
2018-2019	4	11	1083.115
2019-2020	4	3	1100.046
2020-2021	2	Meager	1117.005

Conclusions

From the above study of trends and forecasting in area, production and productivity of sorghum crop in Central Telangana zone during 1979-80 to 2015-16, ten growth models were fitted to the area, production and productivity of sorghum crop and best- fitted model for future projection was chosen based upon least residual mean square (RMS) and significant adj r2. The best fitted model was cubic function for predicting area and Productivity of sorghum whereas, quadratic function was resulted as best model for predicting quadratic function.

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