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Trends of Sorghum Crop in Southern Telangan Zone, India

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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 Sorghum crop in Southern Telangana Zone. Linear and compound growth rates were calculated for this purpose. 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 AdjR^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 Southern Telangana Zone.

Introduction

Sorghum [*Sorghum bicolor* (*L.*)] is one of the main staple food for the world's poorest and most food insecure people across the semi-arid tropics. Globally, sorghum is cultivated on 41 million hectares to produce 64.20 million tonnes, with productivity hovering around 1.60 tonnes per hectare. With exceptions in some regions, it is mainly produced and consumed by poor farmers. India contributes about 16% of the world's sorghum production. On global front, sorghum was grown in 105 countries of the world in the year 2010-11 covering an area of approximately 40.5 m ha with grain production of 55.65 m tons and an average productivity of 1.374 tons per ha (FAO website: http://www.fao.org). During the last three decades period (1980-2010), cropped area and production reported an annual growth rate of -0.34% and -0.51% respectively.

Development and adoption of the improved cultivars, improved management practices have increased the productivity levels significantly despite tumbling acreage of sorghum across the globe in recent past. Sorghum primarily produced in India (7.38 m ha) constitutes about 18.21% share in global area followed by Sudan 5.61 m ha (13.85%), Nigeria 4.7 m ha (11.6%), Niger 3.3 m ha (8.14%) and USA 1.94 m ha (4.79 %) during 2010-11. But, the lion share in global sorghum production is contributed by USA

(15.7%) followed by India (12.58%), Mexico (12.47%) and Nigeria (8.59%). The productivity in developed countries is about five times higher than the productivity in developing countries. The world highest productivity levels were observed in USA (4520 kg per ha) while the productivity in India is hovering around 949 kg per ha.

Sorghum is the world's fifth most important cereal after wheat, rice, maize, and barley in both production and area planted (FAO/ICRISAT). Sorghum is one of the main staples for the world's poorest and most food-insecure people. The crop is generally suited to hot and dry areas where it is difficult to grow other food grains. These are also areas subject to frequent drought. In many of these areas, sorghum is truly a dual-purpose crop; both grain and stover are highly valued outputs. In large parts of the developing world, stover represents up to 50 percent of the total value of the crop, especially in drought years.

The present study is based on 36 years of data i.e., from 1979 to 2015 of Sorghum in Telangana State. The linear growth rate (LGR) and compound growth rate (CGR) for the crop characteristics i.e., area, production and productivity of Sorghum crop in Southern Telangana Zone are 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.

Parthasarathy and Suryanarayana (1976) analyzed regional growth rates of area, production and productivity of major food-grain crops in pre-green and green revolution periods in the selected districts of Andhra Pradesh. They computed linear growth rates and used standard deviation and coefficient of variation to study the stability or variability of area, production and productivity of certain crops. They concluded that there existed regional variations in the growth rates of area, production and productivity which could be attributed due to shifts in cropping pattern under the improved yield, increasing technology and adoption of high yielding varieties.

Singh *et al.,* (1978) had split the relative contribution of different factors of food grain production in Punjab during pre-green revolution period, Acreage contribution was 45.7 % and yield contributed 17.4 % to total production. In the post-green revolution, the trend has been reversed with yield effect contributing 50.7 % and acreage merely 12.3 %.

Ahuja (1987) in an international seminar presented the India's food demand in 2000 AD. Taking into consideration the demand for *per capita* calories and the probable increase in population and incomes in different countries, the world demand for cereals is likely to be more than double by the turn of the century as compared with level of consumption in 1970 when it was 1.2 MT. He calculated the future projections for the production of various crops. The projected production of rice, maize, jowar, gram and groundnut will be 100, 17.75, 18.72, 11.87 and 11.2 MT, respectively by the turn of the century.

Prajneshu and Das (2000) used four non-linear models for describing state wise wheat yield. Predictions were made based upon the best fitted models. Goodness of fit of a model was assessed by computing the Mean Square Error (MSE). Logistic and Gompertz curve were chosen to predict wheat yield state wise by 2020 AD. Sreekanth and Bhaskara Rao (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.

Pandey (2004) calculated the area, production, productivity and exports of vegetables in India in the 1990s and also the demand projections for vegetables upto the year, 2021. He identified constraints in vegetable production and marketing and also the thrust areas for research and policy reforms. He also discussed the research, policy and government interventions in support of the Indian vegetable sector.

Materials and Methods

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 Southern 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 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

$$Yt = a + bt$$

Where

Yt 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

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

Where,

Yt 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

$$Yt = a + b/t$$

Where,

Yt 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

Yt = a + bt + ct2

Where,

Yt 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: Yt = a + bt + ct2 + dt3

Where,

Yt 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 Yt = abt

Or ln Yt = ln a + t ln b

Where,

Yt 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

Yt = Exp (a+b/t)

Or ln Yt = a + b/t

Where,

Yt 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

Yt = Exp (a + bt) or ln Yt = a + bt

Where,

Yt 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 Yt = atb

Or ln Yt = ln a + b ln(t)

Where,

Yt 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

Yt = a Exp (bt)

Or ln Yt = ln a + (bt)

Where,

Yt 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 Southern 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, R2 or adjusted R2 ($\overline{R}^2$) as the criterion of model selection.

$$R^2 = \frac{EXPLAINEDVARIATION}{TOTALVARIATION} \quad = —$$

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

Where,

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

It was observed that R2 is not enough to examine goodness of fit of a model (Reddy, 1978). So in addition to adj R2, 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.

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 R2 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 ‘n1’, be the number of elements of one kind and ‘n2’ be the number of elements of the other kind in a sequence of N = n1 + n2 binary events.

For small samples i.e., both n1 and n2 are equal to or less than 20 if the number of runs r fall between the critical values, we accept the H0 (null hypothesis) that the sequence of binary events is random otherwise, we reject the H0.

For large samples i.e., if either n1 or n2 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, H0 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

In Southern Telangana Zone the area under Sorghum during 1979-80 was 584 thousand hectares and in 2015-16 was 35.91 thousand hectares and average area under Sorghum during the study period (1979-80 to 2015-16) was 305.75 thousand hectares. The coefficient of variation recorded during study period was 61.98 per cent and the linear and compound growth rates recorded during the study period were -5.65 and -7.3 per cent per annum respectively.

The area of Sorghum in Southern Telangana Zone exhibited a negative trend and it was found significant at 1% level of significance in both of compound growth rate and linear growth rate.

The production of Sorghum in 1979-80 was 319 thousand tonnes and in 2015-16 was 36.71 thousand tonnes and the average production during the study period (1979-80 to 2015-16) was 188.10 thousand tonnes with a coefficient of variation of 49.15 per cent. The linear growth rate and compound growth rates of production recorded were -4.26 and -5.3 per cent per annum respectively.

The production of Sorghum in Southern Telangana Zone exhibited a negative trend and had been decreasing significantly during the study period at 1% level of significance.

Regarding the productivity in Southern Telangana Zone, the average yield of Sorghum during the study period ((1979-80 to 2015-16) was 715.05 kg/ha, with the coefficient of variation of 27.61 per cent. The linear and compound growth rates during the study period were 2.16 and 2.2 per cent respectively.

The productivity of Sorghum had not followed a particular trend during the study period in Southern Telangana Zone and the positive growth rates were 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 Southern Telangana Zone were shown in the table 4.2. 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 Southern 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 4.11.

The Adj R2 values for all the models were ranging between 0.189 in case of S-curve function and 0.978 in case of cubic function, respectively. Except S-curve function remaining all functions 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 significant Adj R2 and also satisfied the assumption of randomness of residuals.

The Production of Sorghum in Southern Telangana Zone showed a decreasing growth pattern during the study period. The results obtained by fitting all the ten growth models were presented in Table 4.12. The Adj R2 values for all the models were ranging from 0.163 in case of S-curve and 0.889 in case of quadratic function respectively. For almost all the models, Adj R2 values were significant at 1% level of significance. Only linear, logarithmic, quadric and cubic functions satisfied the assumption of randomness of residuals. Quadratic function was found to be the best trend equation for the purpose future projection of production it has exhibited the least RMS and significant Adj R2 and also satisfied the assumption of randomness of residuals.

The Productivity of Sorghum in Southern Telangana Zone showed a increasing trend during the study period. The results obtained by fitting all the ten growth models were presented in Table 4.13. The Adj R2 values for all the models were ranging between 0.161 in case of S-curve and 0.730 in case of quadratic function respectively. For almost all the models Adj R2 values were significant at 1% level of significance. Only linear, quadratic, cubic, and compound models satisfied the test of randomness of residuals.

Cubic 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 R2 and also satisfied the assumption of randomness of residuals.

Table.1 Growth rates of area, production, productivity of Sorghum in Southern Telangana Zone

	Area	**Production**	**Productivity**
Linear	-5.65**	-4.26**	2.16**
Compound	-7.3**	-5.3**	2.2**
C.V (%)	61.98	49.15	27.61

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

Table.2 Average Area, Production and Productivity of Sorghum in Southern Telangana Zone

Items	**Southern Telangana Zone**
Area('000ha)	305.74
Production('000 tonnes)	188.10
Productivity(kg/ha)	715.9

Table.3 Linear and compound Growth rates of Area, Production and Productivity of Sorghum in STZ

STZ	**Area**	**Production**	**Productivity**
Linear growth rate	-5.65**	-4.26**	2.16**
Compound growth rate	-7.3**	-5.3**	2.2**

** Significant at 1% level STZ-Southern Telangana Zone

Table.4 Growth Models for the Area, Production and Productivity of Sorghum in Southern Telangana Zone

Area										
Model	**Linear**	**Logarithmic**	**Inverse**	**Quadratic**	**Cubic**	**Compound**	**Power**	**S-Curve**	**Growth**	**Exponential**
Adj R2	0.974**	0.805**	0.324**	0.975**	**0.978****	0.904**	0.602**	0.189*	0.904**	0.904**
RMS	925.74	7018.12	24274.7	886.3	**748.4**	9056.67	61244	99036.9	66399	9071.27
Runs	14	3	5	10	**14**	5	3	2	3	5
Production										
Adj R2	0.878**	0.662**	0.254**	**0.889****	0.886**	0.82**	0.526**	0.163**	0.82**	0.82**
RMS	1039	2891.55	6381.54	**922.64**	925.71	2661.18	10026	2656.62	8771	2698.82
Runs	17	11	5	**17**	13	7	3	7	7	7
Productivity										
Adj R2	0.71**	0.491**	0.146**	0.73**	**0.723****	0.721**	0.522**	0.161**	0.721**	0.721**
RMS	11295	19857.1	33296.9	10225.83	**10205**	10476.05	32796	10745.2	17838	10754.15
Runs	13	12	7	16	**16**	14	11	13	11	13

Table.5 Projections of Area, Production and Productivity Sorghum in Southern Telangana Zone of Telangana State

Year	Area (' 000 ha)	Production (' 000 tonnes)	Productivity (kg/ha)
2016-2017	26	35.68	1000.05
2017-2018	19	26.39	1019.77
2018-2019	13	17.07	1039.42
2019-2020	9	7.75	1058.99
2020-2021	3	Meager	1078.47

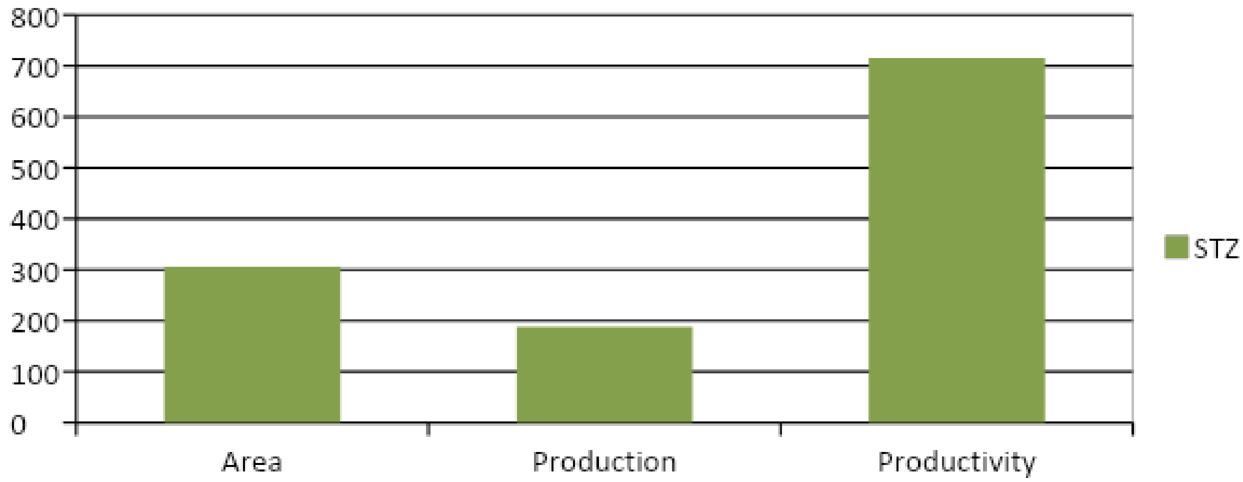

Fig.1 Average Area, Production and Productivity of Sorghum in Southern Telangana Zone

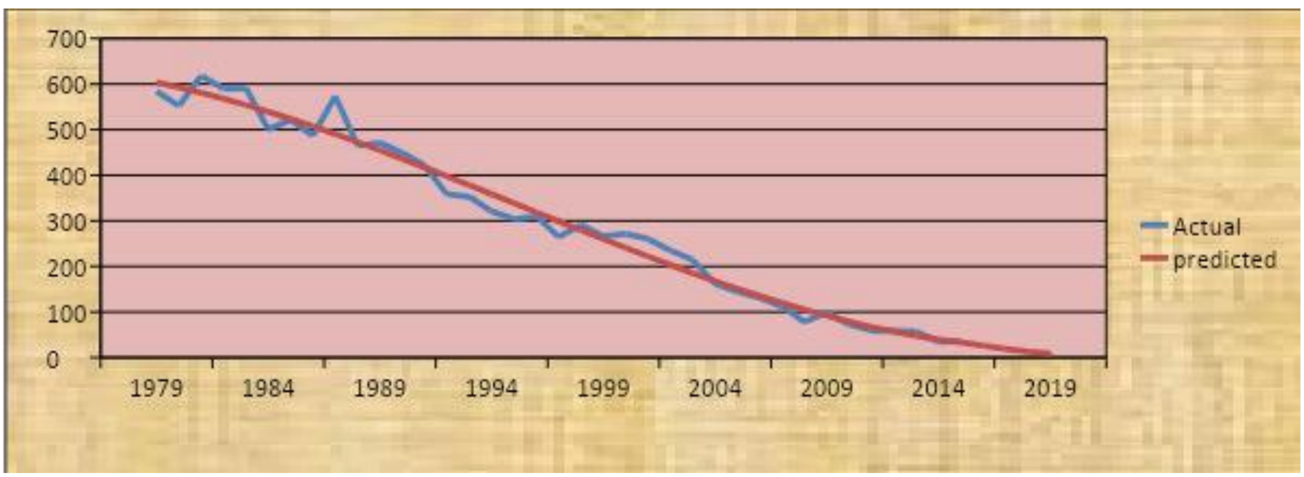

Fig.2 Trend of Sorghum Area in Southern Telangana Zone of Telangana State

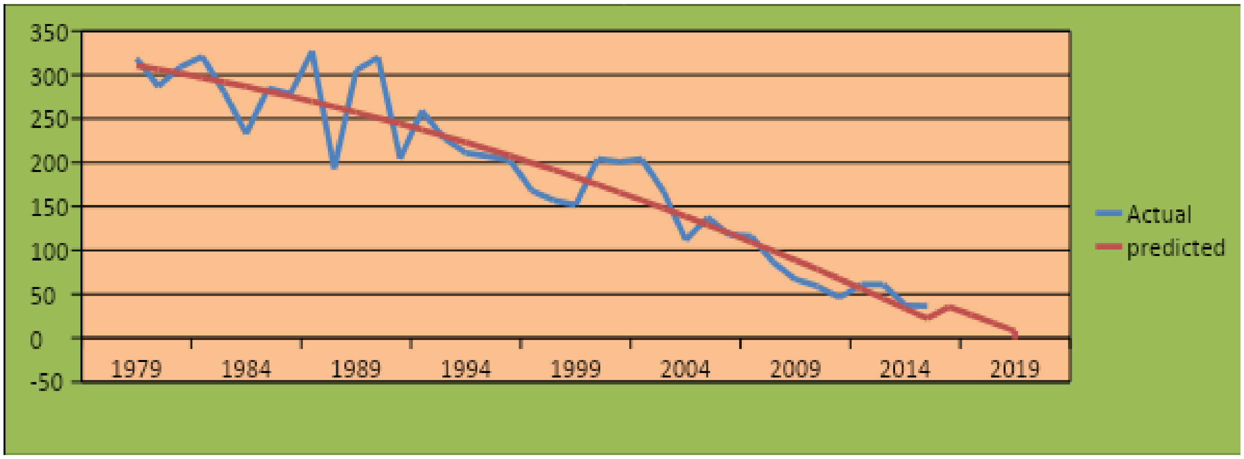

Fig.3 Trend of Sorghum Production in Southern Telangana Zone of Telangana State

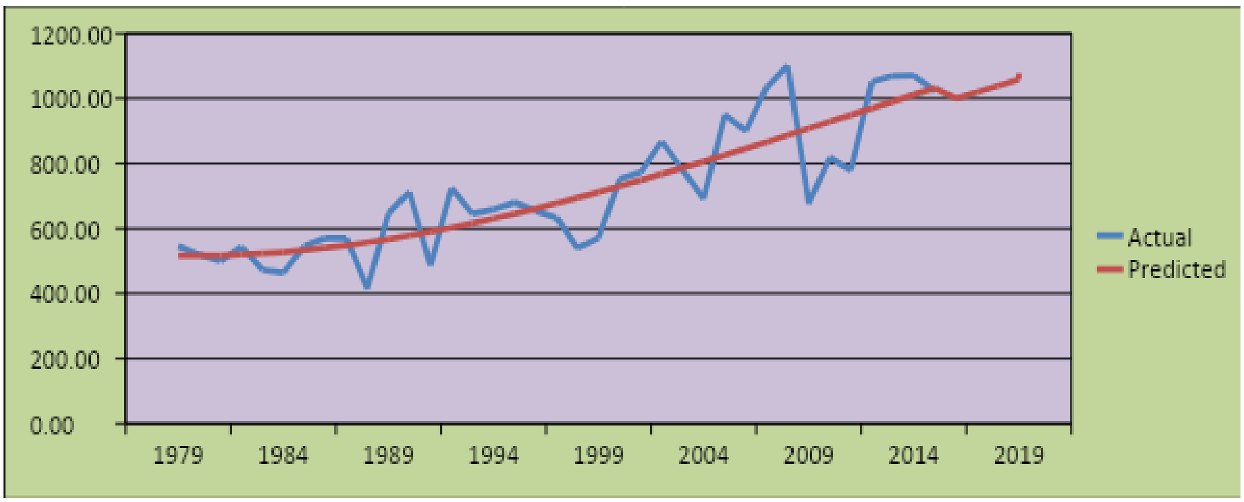

Fig.4 Trend of Sorghum Productivity in Southern Telangana Zone of Telangana State

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

The future projections of area, production and productivity of Sorghum in Southern Telangana Zone by 2020 AD were calculated and the results were presented in the Table 4.21.

Area under Sorghum in Southern Telangana Zone was projected by using cubic function which was found to be best for this purpose as it had significant Adj R2 and also fulfilled the assumption of randomness of residuals.

The area under Sorghum projected by cubic function by 2020 AD would be 3.00 thousand hectares which as in decreasing trend. Regarding the production of Sorghum, quadratic function was found to be the best model for future projections by 2020 AD as it has the significant Adj R2 and also satisfied the assumption of randomness of residuals.

The projected production would be decreasing at which is not possible in real. It is indicates that the future production would be meagre by 2020 AD. Productivity of Sorghum was projected by using cubic function which has lest RMS, significant Adj R2 and also has showed significant runs. The future projection for productivity of Sorghum is in increasing trend and it would be 1078.47 kg/ha by 2020 AD.

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