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Estimating area, production and productivity trends of cotton crop in Haryana state

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Abstract: Different models *viz.,* Linear, Logarithmic, Inverse, Quadratic, Cubic, Compound, Growth models like Logistic Model, Goempertz model, Monomolecular were employed to study the trends in area, production and productivity of cotton. The results revealed that future projections of trends in areas and productivity should be calculated based on the cubic model and, in production, on the basis of compound model. The study further revealed that the production and productivity of cotton crop grown in Haryana show increasing trend whereas the area shows decreasing trend over the reported periods. One most important point that the area under the cotton crop is declining day by day and this is due to the replacement of area by paddy crop, unfavorable weather condition and low price.

Key words: Adjusted (R^2), mean square error, root mean square error, Shaprio Wilks test

Cotton is a commercial crop that plays an important role in strengthening economy of about 82 countries across the world. In India, apart from providing 60 per cent of the fiber used in textile industries, the crop is also a source for 11.5 lakh tones of oil, 90 lakh tones of animal feed and about 200 lakh tones of cotton stalk that is used for fuel. India accounts for about 32 percent of the global cotton area and contributes to 21 per cent of the global cotton produce, currently ranking second after China. In India area under cotton as well as the production during 2013-2014 as per second advance estimate season was117.53 lakh ha and 365.00 lakh bales, respectively.

Cotton contributes about 65 per cent of the total raw material needs of textile industry in India. India has achieved significant breakthrough in cotton yarn exports besides increasing its global market share in cotton textiles and apparels. Cotton provides employment and sustenance to a population of nearly 42 million people, who are involved directly or indirectly in cotton production, processing, textiles and related activities. It is estimated that more than 6.0 million farmers cultivate cotton in India and about 36 million persons are employed directly by the textile industry. Therefore, cotton production in India is considered to have a wide reaching impact not only on the livelihood of farmers and economy of the country, but also on international trade. In Haryana the area of cotton is 0.625 million ha with production 2.39 million bale and average yield is 650 kg/ha. Verma *et al.,* (2014) studied the zonal yield models incorporating a linear time trend and agro meteorological (agromet) variables each spanning successive fortnights within the growth period of the cotton crop are developed within the framework of multiple linear regression analysis. These models have been used to predict the cotton yields in 5 cotton growing districts namely; Hisar, Sirsa, Bhiwani, Rohtak and Jind covering more than 90 per cent of cotton production of the Haryana State. Debnath *et al.,* (2013) studied about the forecasting the cultivated area and production of cotton in India using Autoregressive Integrated Moving Average (ARIMA) model. He studied the time series data covering the period of 1950 to 2010.Kalubarme *et al.,* (2016) studied the district level agrometerological cotton yield model in Punjab by using the variable like mean maximum temperature, mean minimum temperature (MNT) and total rainfall (TRF) from first fortnight of June to First fortnight of November of every year for 24 years (1980-2003). The crop condition (CC) term was also incorporated into the yield model to account for yield losses due to pest/disease or drought conditions. Josily *et al.*, (2013) studied the scenario of area, production and productivity of cotton in major growing states like Maharashtra and Gujarat. Samuel *et al.*, (2015) studied the economic analysis of production, growth and export competitiveness of raw cotton in India. Haryana is also a cotton crop growing state therefore in this study an attempt has been made to assess the trend of area, production and productivity of cotton crop in Haryana by using 47 years data from 1966 to 2012. Besides, the growth rates, the projection was also estimated upto 2016.

MATERIALS AND METHODS

The time series data on area, production and productivity for the period of 1966-1967 to 2011-2012 were collected through the Haryana Statistical Abstract. The data were analyzed by fitting the different models and the conclusion is given based on the best fitted models to study the trends and growth rate of cotton production in Haryana.

Model	Equation
Linear	$Y_t = a + b_1*t$
Logarithmic	$Y_t = a + (b_1* \ln(t))$
Inverse	$Y_t = a + b_1 / t$
Quadratic	$Y_t = a + b_1*t + b_2*t^2$
Cubic	$Y_t = a + b_1*t + b_2*t^2 + b_3*t^3$
Compound	$\ln(Y_t) = \ln(a) + (\ln(b_1) * t)$.
Logistic Model	$Y_t = b_3 / [1 + b_2*\exp(-b_1*t)]$
Goempertz model	$Y_t = b_3*\exp(-b_2*\exp(-b_1*t))$
Monomolecular	$Y_t = b_3-(b_3- b_2)*\exp(-b_1*t)$

To analyze trend of area, production and productivity following models were selected

In case of Logistic, Goempertz and Monomolecular model Y_t denotes the variable under study at time t, 'b_1' denote the intrinsic growth rate, 'b_3' the carrying capacity of the environment, $b_2 = [b_2-Y(0)]/Y(0)$ and Y(0) is the value of Y(t) at t = 0 and **e(t)** is the error term. In general the parameter 'b_1' is the coefficient of external influence emanating from the outside system.

By considering the data of 47 years, different models *viz.,* Linear, Logarithmic, Inverse, Quadratic, Cubic, Compound, Growth models like Logistic Model, Goempertz model, Monomolecular were employed to observe the trends of area, production and productivity of cotton crop in Haryana state. Among the models, the models having the highest adjusted R^2 with significant F value was selected, so that it satisfied test for goodness of fit.Normality of residuals was examined by using Shaprio-Wilks test. Randomness assumption of the residuals required to be tested before taking any final decision about the accuracy of the model developed. To carry out the above analysis "Run test" procedure developed in the literature was used. In case of more than one model being the good fit for the data, the best model was selected based on lower values of Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) values.

RESULTS AND DISCUSSION

Different models were employed to study the area, production and productivity data of the cotton crop. The analyzed data for the area under the cotton crop revealed that among the fitted models to the area under the cotton crop, the maximum adjusted R^2 of 90 per cent was observed in case of cubic model with comparative lower value of RMSE(1998.03) and MAE(31.860) (Table 1). The Shapiro Wilks test, a test for

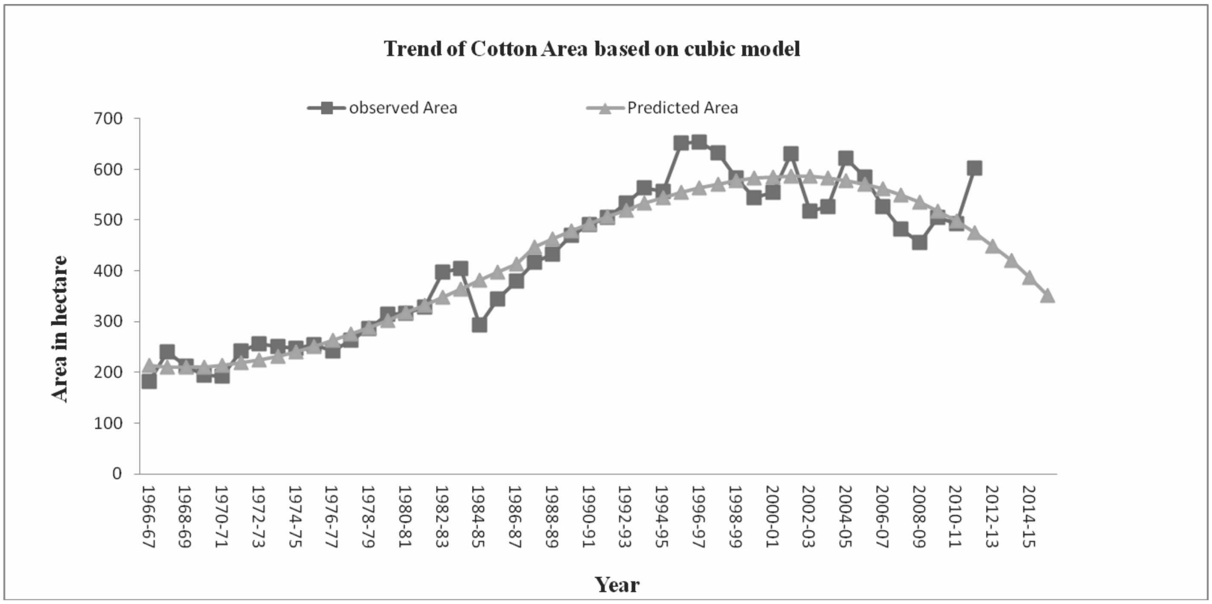

Fig. 1. Graph showing the fitted trend for the area of cotton crop using the cubic model.

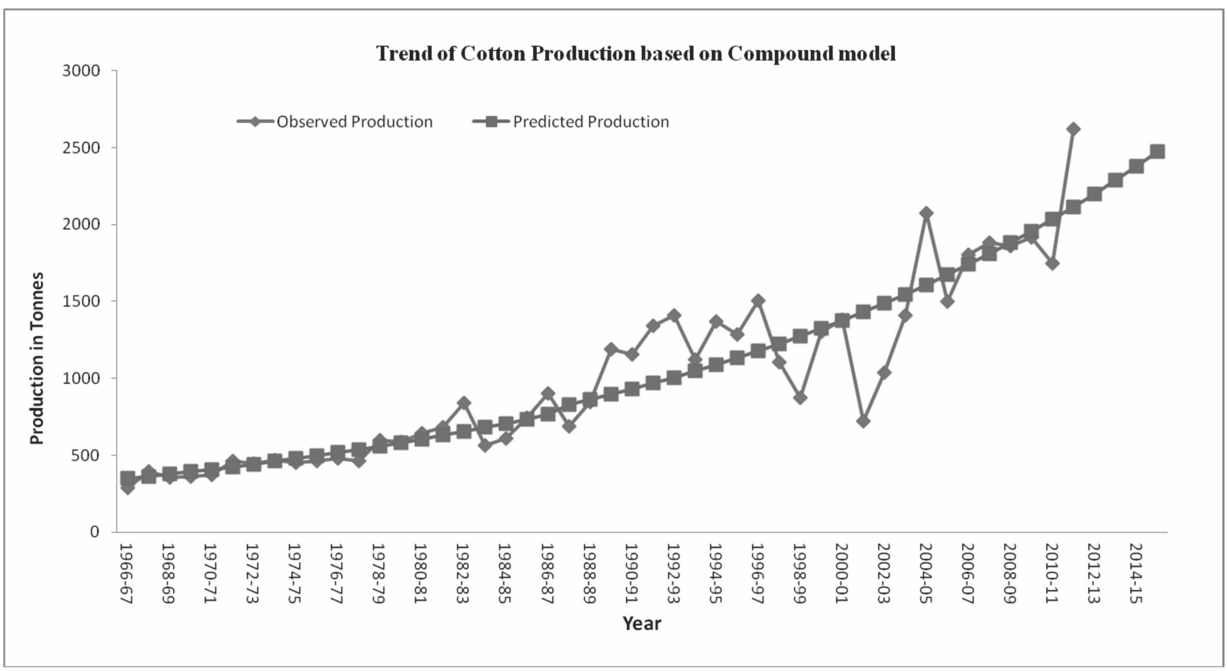

Fig. 2. Graph showing the fitted trend for the production of cotton crop using the growth model

normality, was found to be non significant indicating that the residuals were found to be normally distributed due to this model. However the run test (test for randomness) value was significant indicating that the residuals were correlated. The best fitted model for trend in area of cotton is found to be:

$Y = 218.493-6.117*t + 1.130*t^2-.019*t^3$ (R^2 = .904).

In case of production data of cotton crop, the growth model had maximum adjusted R^2

Table 1. Characteristics of the fitted different model for area under the cotton crop in Haryana

	Constant	Parameter			R^2(%)/Adj.R^2(%)	Shapiro-Wilks- test	Run test	MAE	RMSE
		b_1	b_2	b_3					
Linear	194.78**(20.760)	9.420**(.750)			0.78[.77]	0.976(.458)	.000	51.832	4651.96
Logarithmic	13.243^{ns}(39.804)	140.368**(13.101)			0.72[.71]	0.956(.077)	.000	62.790	5908.46
Inverse	468.914**(21.31)	-499.036**(113.498)			0.30[0.28]	0.932(.010)	.000	104.836	14815.31
Quadratic	107.639**(27.152)	20.217**(2.634)	-.225**(.053)		0.84[0.83]	0.982(.681)	.101	45.530	3360.69
Cubic	218.493**(29.86)	-6.117^{ns}(5.201)	1.130**(0.250)	—.019**(.003)	**0.91(.90)**	0.972(.324)	.000	**31.860**	**1998.03**
Compound	214.661**(10.93)	1.026**(.002)			.81[.80]	0.969(.258)	.000	61.537	6944.66
Logistic Model		.101(.016)	3.302(.540)	595.342(27.890)	[0.859]	.985(.817)	.002	61.537	6796.90
Goempertz model		.067(.014)	1.572(.159)	626.541(444.448)	[0.844]	.984(.762)	.000	42.366	3153.29
Monomolecular		.034(.012)	120.226(34.825)	714.407(105.170)	[0.827]	.983(.713)	.000	44.895	3473.36

* Significant at 5% level ** Significant at 1% levelRMSE : Root Mean Square Error MAE : Mean Absolute Error
Values in brackets ( ) indicate standard errors

Table 2. Characteristics of the different fitted models for production under the cotton crop in Haryana

	Constant	Parameter			R^2(%)/Adj	Shapiro-Wilks- test	Run test	MAE	RMSE
		b_1	b_2	b_3					
Linear	129.162**(72.879)	36.543^{ns}(2.633)			.81[.81]	.925(.006)	.011	163.25	57329.77
Logarithmic	-404.77*(181.976)	485.954**(59.89)			.59[.59]	.943(.026)	.000	267.48	123492.68
Inverse	1159.424**(86.193)	-1588.048**(459.039)			0.21[19]	.897(.001)	.101	403.44	242345.45
Quadratic	333.251*(105.725)	11.256^{ns}(10.258)	0.527^{ns}(.208)		.83[.83]	.923(.005)	.101	144.10	50954.35
Cubic	205.981^{ns}(145.730)	41.490^{ns}(26.076)	-1.028^{ns}(1.252)	.022^{ns}(.017)	.84[.83]	.945(.029)	.064	148.42	50215.59
Compound	**336.722**(19.689)**	**1.040**(.002)**			**.88[.88]**	**.928(.007)**	**.139**	**145.86**	**49409.74**
Logistic Model		.043(.014)	29.858(73.779)	10445.942 (26454.172)	.841	.929(.008)	.297	145.86	48359.53
Goempertz model				No Goemertz Model					
Monomolecular				No Monomolecular model					

* Significant at 5% level ** Significant at 1% levelRMSE : Root Mean Square Error MAE : Mean Absolute Error
Values in brackets ( ) indicate standard errors

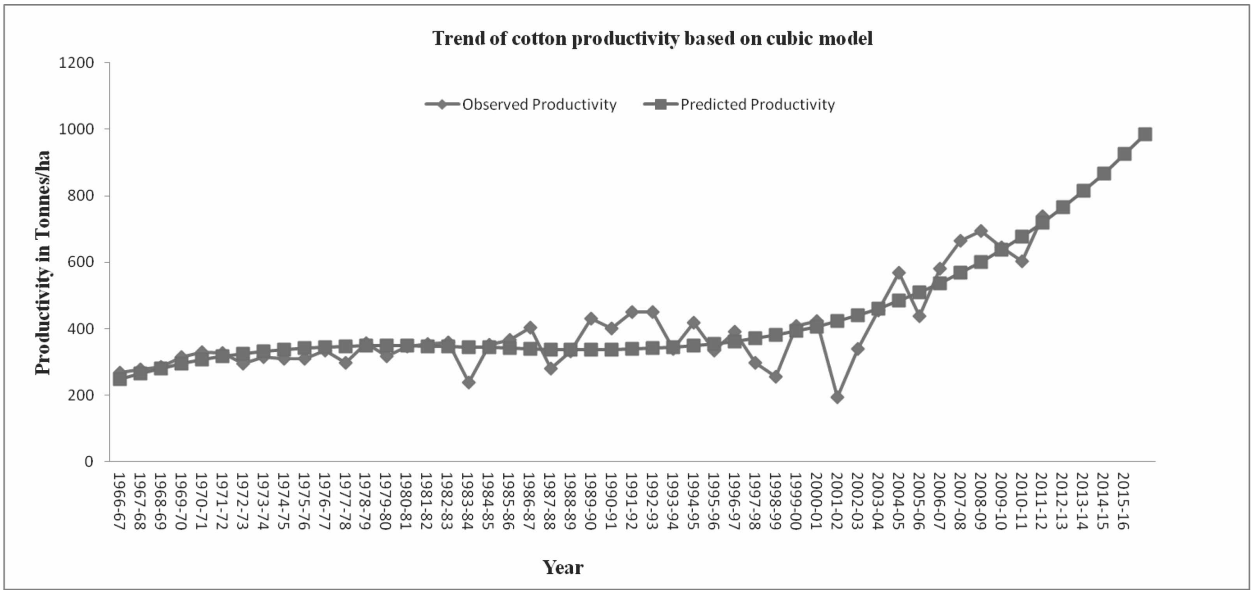

Fig. 3. Graph showing the fitted trend for the productivity of cotton crop using the cubic model

Table 4. Projection of Area, Production and Productivity of Haryana

Year	Area (000,ha)	Production (000, t/ha)	Productivity (t/ha)
2012-2013	449.34	2199.13	765.26
2013-2014	420.19	2286.81	814.73
2014-2015	387.77	2377.99	867.78
2015-2016	351.98	2472.79	924.54

(88%) with the comparatively lower value of RMSE (49409.74) and MAE(145.86) among the fitted models was found to be for the compound models (Table 2). Moreover Shapiro Wilks test values were found to be significant indicating that the residuals due to this model were not normally distributed whereas the run test (test for randomness) value was non significant indicating that residual were not correlated. The best fitted model is given below to find out for trend of cotton

$Y = e^{336.722 + 1.040*t}$ (R^2 = .884)

The data presented in Table 3 for the productivity of cotton crop revealed that among the various fitted model, the maximum adjusted R^2 (70%) was found to be for the cubic models with the lower MAE (3.140) and RMSE (4386.93) The Shapiro-Wilks test (test for normality) was found to be significant indicates that residual were not normally distributed whereas the run test was found to be non significant shows that residuals full fill the model selection criteria. The best fitted model for trend in area of cotton is found to be:

Y = 227.172"21.249*t "1.179*t^2+.020 *t^3 (R^2 = .704)

Among various fitted models, the cubic model was found suitable to fit the trends in productivity of cotton crop. The analysis shows that if the present growth rates continue then the cotton area, production and yield in the year 2020 will be 10.92 million hectares, 39.19 million bales of 170 kg of each and 527 kg/ha respectively. Whereas Kalubarme *et al.,* (2016) observed that most significant variable in the regression equations of five district of Punjab were crop condition, total rainfall, minimum temperature and maximum temperature and concluded that relative deviations were in the range of 0.5 to 10 per cent in all the district form 1980 to 2003 period. In the present studies we have used the concept of simple modeling and it was observed that cubic model was found to be the best fit for the projection of area and productivity of cotton whereas the compound growth model was found to be the best fit for the

Table 3. Characteristics of the fitted non-linear model for Productivity under the cotton crop in Haryana

	Constant	Parameter			Adjusted R^2	Shapiro-Wilks- test	Run test	MAE	RMSE
		b_1	b_2	b_3					
Linear	238.876**(26.990)	6.252**(.975)			.48[47]	.952(.054)	.180	62.404	7863.13
Logarithmic	165.057**(53.204)	77.109**(17.511)			.30[.29]	.949(.041)	.053	72.128	10555.91
Inverse	413.029ns(20.403)	-249.596**(108.62)			.10[.08]	.883(.000)	.011	84.465	13579.68
Quadratic	346.36**(36.02)	-7.066**(3.495)	.278**(.071)		.61[.60]	.932(.010)	.297	55.963	5916.10
Cubic	**227.172**(43.07)**	**21.249*(7.707)**	**-1.179*(.370)**	**.020**(.005)**	**.72[.70]**	**.938(.017)**	**.456**	**3.140**	**4386.93**
Compound	266.609**(17.50)	1.014**(1.002)			.43[.42]	.945(.031)	..297	58.861	7620.82
Logistic Model		.018(.016)	5882344.867 (1.196E+13)	1438144530 (2.923E+15)	.536	.920(.004)	.297	58.861	7458.67
Goempertz model		.002(.024)	8.548(86.499)	1255803.030 (108765003.1)	.529	.925(.006)	.297	61.184	7382.49
Monomolecular		3.015E-.005(.028)	238.869(41.690)	207582.849 (172433918.8)	.483	.952(.054)	.180	61.406	7489.72

* Significant at 5% level ** Significant at 1% levelRMSE : Root Mean Square Error MAE : Mean Absolute Error
Values in brackets ( ) indicate standard errors

production of cotton. Fig. 1 and Fig. 3 shows the trend of area and productivity of cotton on the basis of cubic model whereas Fig. 2 shows the trend of production of cotton on the basis of compound model.

Projections: It is found that the cubic model is the best fit of its highest coefficient of determination with respect to cotton area and productivity whereas the compound model is the best fit model for the production. Hence the future projections of areas and productivity of cotton crop in Haryana states were calculated based on the cubic model and, production was calculated on the basis of compound model and the results are presented in the Table 4. The results revealed that the cotton production in Haryana may reaches to 2472.79 thousands tones in 2016 and the productivity is also increases to 924.54 t/ha in 2016 whereas the area decreases upto 352 thousand ha.

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