Trend Analysis of area, production and productivity of Banana in Anand district of Gujarat, India

ABSTRACT

Banana (*Musa*sp.) holds the second position in terms of significance among fruit crops in India, following mango. Gujarat is ranked second and third in the production and productivity of banana respectively. This research aimed to examine the patterns in the cultivation area, production, and productivity of banana in Anand district, Gujarat. Secondary time series data spanning 16 years (from 2005-06 to 2020-21) were utilized for this analysis, sourced from the Directorate of Horticulture, Gujarat. Eight distinct linear and non-linear models were applied, and the most suitable model was chosen based on the highest adjusted R^2 and the lowest root mean square error (*RMSE*) values. The findings indicated that the cubic model demonstrated the best fit for depicting the trends in the area, production, and productivity of banana in Anand district, Gujarat. The study concluded that the cultivation area and production exhibited fluctuating trends, while productivity displayed a consistent upward trend throughout the analyzed period.

Keywords: Trend Analysis, Banana, Anand, Linear Model, Non-linear Model

INTRODUCTION:

"Banana (*Musa* sp.) is the second most important fruit crop in India next to mango. Its year round availability, affordability, varietal range, taste, nutritive and medicinal value makes it the favourite fruit among all classes of people. It has also good export potential. A ripe fruit contains as much as 22 percent of carbohydrate and is high in dietary fiber, potassium, manganese, and vitamins B6 and C" (Britannica, 2022). "Considering the nutritive value and fruit value of bananas, it could be considered as "poor man's apple" and it is the cheapest among all other fruits in the country" (Madhunaik and Yogish, 2020). "Banana ranks first in production and third in area among fruit crops in India. It accounts for about 14 per cent of the total area and 32 per cent of the total production of fruit crops. The total area under cultivation of banana in India is 8.84 million hectares, production is around 308.08 million metric tons whereas productivity is only 34.85 metric tons per hectare during 2017-18. Production is highest in Andhra Pradesh, followed by Gujarat. The other major banana producing states are Maharashtra, Tamil Nadu, Gujarat, Uttar Pradesh and Karnataka" (Anonymous, 2018; Mustaffa and Kumar, 2022; Sharma et al., 2021; Kumari et al., 2021; Rathod et al., 2021).

"In Gujarat, banana crop is cultivated in 11 districts covering an area of about 60.09 thousand hectares.Gujarat ranks second and third in production and productivity of banana. The area, production and productivity of banana in Gujarat during 2021-22 were 60.09 thousand hectare, 3971.55 thousand metric tons and 66.09 metric tons per hectare, respectively. In Gujarat, banana is majorly grown in

Anand, Bharuch, Narmada, Vadodara and Surat.Anand is the highest banana producing district in Gujarat. The total area under cultivation of banana in Anand is 127.63 thousand hectares, production is 830.23 thousand metric tons and the productivity is 65.05 metric ton per hectare" (Anonymous, 2022).In this paper, an attempt is made to assess the trend in area, production and productivity of banana crop in Anand, Gujarat. This study helps to analyze production pattern, yield variation and market dynamics over the time. It helps governments to make informed decision and policy making for optimize resource distribution and improve profitability. Moreover, it facilitates long-term planning and sustainability in banana production in the district.

METHODOLOGY:

The main objective of the present study is to estimate an appropriate regression model that can explain the trends in area, production and productivity of banana crop in selected districts of Gujarat. The districts were selected on the basis of production. The study used secondary data pertaining to area, production and productivity of banana crop for the period of 16 years from 2005-06 to 2020-21. Following growth models were employed to define the best fitted trend in area, production and productivity of fruit and vegetable crops over period studied. The estimation procedure for each model is well narrated in standard books on statistics (Draper and Smith, 1998 & Montgomery *et al.*, 2003)

Chart 1: Estimation procedure for each model

1.	**Linear Function**	$\hat{Y}_t = a + bt$
2.	**Quadratic Function**	$\hat{Y}_t = a + bt + ct^2$
3.	**Cubic Function**	$\hat{Y}_t = a + bt + ct^2 + dt^3$
4.	**Compound Function**	$\hat{Y}_t = ab^t$
5.	**Inverse Function**	$\hat{Y}_t = a + b/t$
6.	**Logarithmic Function**	$\hat{Y}_t = a + b\ln(t)$
7.	**Power Function**	$\hat{Y}_t = at^b$ **(or)** $\ln \hat{Y}_t = \ln(a) + b\ln(t)$
8.	**Exponential Function**	$\hat{Y}_t = ae^{bt}$ **(or)** $\ln \hat{Y}_t = \ln a + bt$

In all above eight growth functions variable (attributes) under study *i.e.,*

Y_t = Area, production and productivity (dependent variable)
t = Time (independent variable)
a = Intercept
b,c,d = Partial Regression coefficients

Goodness of fit of the model

The different indicators are available in literature to test the goodness of fit of the fitted models.

Coefficient of determination ($R^2_{Adj.}$)

The value of R^2 indicates the portion of variation observed in dependent variable due to independent variable. It may be expressed in per cent also. The remaining variation is due to external factors. The form of equation is given by

$$R^2_{Adj.} = 1 - \frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y}_i)^2}$$

Root Mean Square Error (RMSE)

The formula of RMSE is given by

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{n}}$$

Mean Absolute Error (MAE)

The mathematical expression is as following:

$$MAE = \frac{\sum_{i=1}^{n}\left|(Y_i - \hat{Y}_i)\right|}{n}$$

All above models were employed to the variable studied. But only the best fitted model (s) is presented and discussed in the present study.

RESULTS AND DISCUSSION:

The primary objective of the present investigation is to examine trends in the area, production and productivity of banana crop in Gujarat. Different growth models were fitted to the area, production and productivity data of banana crop for Anand districts of Gujarat. The characteristics of fitted models are presented and discussed as under:

Trend analysis for the area of banana for Anand district:

The Table 1 depicts the eight fitted growth model for area of banana in Anand, Gujarat. It was observed from the table that cubic model is found to be best fitted among the fitted models because of the highest value of *Adj.*R^2 (65.5%) and lowest value of RMSE (618.248) and MAE (372.061). The second best fitted model after that is quadratic model with 38.3 per cent *Adj.* R^2. The observed and predicted area of banana by best fitted model for the study period is tabulated in Table 4 and the same is plotted in Fig. 1. The similar results were found by Varalakshmi *et al.* (2022) for the area, production and productivity of banana for Karnataka. Raj *et al.* (2023) also found similar trend for the area, production and productivity of banana in Gujarat

Table 1: Parameter estimates and goodness of fit criteria by different models for area under banana for the period of 2005-06 to 2020-21.

Model	Regression constant *a*	Partial regression coefficient			Goodness of Fit		
		B	*c*	*D*	R^2 *(Adj.* R^2*)*	RMSE	MAE
Linear	12766.050	28.016	-	-	0.012	1170.163	934.634

					(-0.059)		
Logarithmic	11914.163	568.612	-	-	0.136 (0.075)	1094.163	927.570
Inverse	13599.907	-2819.368	-	-	0.312 (0.263)	976.595	796.702
Exponential	12650.179	0.003	-	-	0.021 (-0.049)	1172.480	934.318
Compound	12650.179	1.003	-	-	0.021 (-0.049)	1172.480	934.318
Power	11813.434	0.048	-	-	0.169 (0.110)	1101.935	925.508
Quadratic	10626.095	741.335	-41.960	-	0.466 (0.383)	860.660	685.128
Cubic	**8314.280****	**2162.460****	**-244.751***	**7.953****	**0.724 (0.655)**	**618.248**	**372.061**

* Significant at p ≤ 0.05, ** Significant at p ≤ 0.01, NS Non-Significant

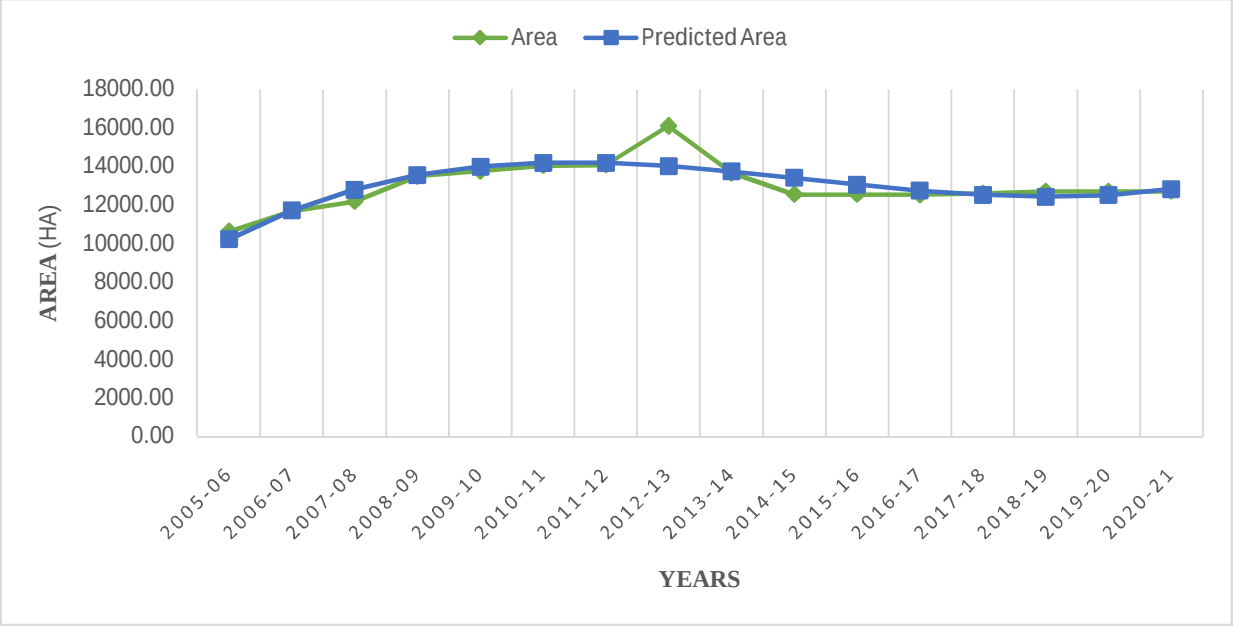

Fig 1: Observed and predicted values of area under banana by cubic model for the period of 2005-06 to 2020-21

Trend analysis for the production of banana for Anand district:

The parameter estimates of the all fitted models for banana production are presented in Table 2. The cubic model was found to be the best fit for the banana production as the parameters of this model is

found to be significant at 5 per cent level of significance with the minimum value of RMSE (46567.92). The observed and predicted production of banana by best fitted model for the study period is tabulated in Table 4 and the same is plotted in Fig. 2. The similar results were found by Varalakshmi *et al.* (2022) for the area, production and productivity of banana for Karnatakaand .

Table 2: Parameter estimates and goodness of fit criteria by different models for production of banana for the period of 2005-06 to 2020-21.

Model	Regression constant *a*	Partial regression coefficient			Goodness of Fit		
		b	*c*	*D*	R^2 ($Adj.R^2$)	RMSE	MAE
Linear	644775.89	15115.30	-	-	0.276 (0.224)	112929.48	96251.23
Logarithmic	528264.40	127800.03	-	-	0.542 (0.509)	89845.30	81436.06
Inverse	871584.62	-465360.83	-	-	0.669 (0.645)	76370.36	63813.74
Exponential	619035.99	0.02	-	-	0.318 (0.269)	117250.62	101240.87
Compound	619035.99	1.02	-	-	0.318 (0.269)	117250.62	101240.87
Power	517220.46	0.20	-	-	0.606 (0.578)	96699.50	87135.89
Quadratic	421818.88	89434.30	-4371.706	-	0.663 (0.611)	77007.46	71780.25
Cubic	**185014.20****	**235003.60***	**-25144.04***	**814.60****	**0.877 (0.846)**	**46567.92**	**35780.72**

* Significant at p ≤ 0.05, ** Significant at p ≤ 0.01, NS Non Significant

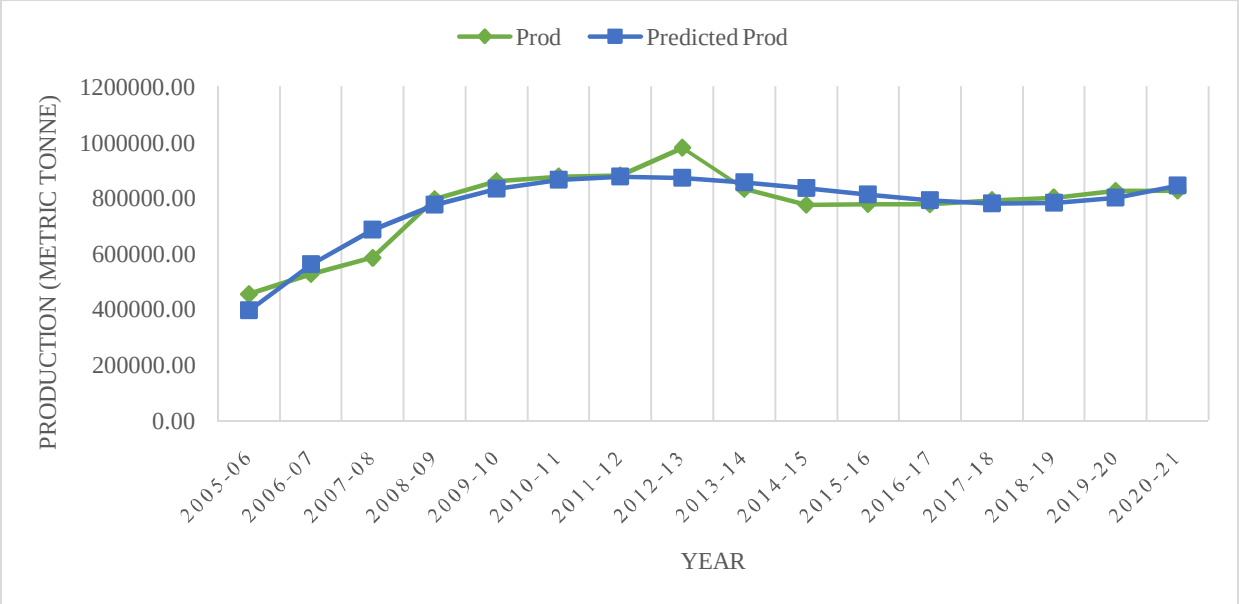

Fig 2: Observed and predicted values of banana production by cubic model for the period of 2005-06 to 2020-21

Trend analysis for the productivity of banana for Anand district:

The eight different models were fitted to study the trends present in the productivity of banana for the Anand district. The results are resented in the Table 3 reveals that, among the different fitted models, Cubic model was found to be the best fit with the highest adj. R^2 value of 90.2 per cent and minimum RMSE value of 1.919. All the parameters of the cubic model are also significant at 5 per cent level of significance. The observed and predicted productivity of banana by best fitted model for the study period is tabulated in Table 3 and the same is plotted in Fig. 3.Similar results were found by Okeke and Akarue (2019)for area, production and yield of cashew in Nigeria.Raj *et al.* (2023) also found similar trend for the area, production and productivity of banana in Gujarat

Table 3: Parameter estimates and goodness of fit criteria by different models for banana productivity for the period of 2005-06 to 2020-21.

Model	**Regression constant *a***	**Partial regression coefficient**			**Goodness of Fit**		
		b	***c***	***d***	***R^2 (Adj.R^2)***	**RMSE**	**MAE**
Linear	49.290	1.156	-	-	0.603 (0.575)	4.318	3.551
Logarithmic	43.480	8.155	-	-	0.826 (0.813)	2.864	2.267
Inverse	64.663	-26.270	-	-	0.798 (0.784)	3.082	2.105
Exponential	48.935	0.021	-	-	0.584 (0.554)	4.527	3.842
Compound	48.935	1.022	-	-	0.584 (0.554)	4.527	3.842
Power	43.782	0.153	-	-	0.822 (0.809)	3.088	2.522
Quadratic	40.850	3.969	-0.165	-	0.811 (0.782)	2.979	2.687
Cubic	**32.053****	**9.377***	**-0.937****	**0.030****	**0.922 (0.902)**	**1.919**	**1.510**

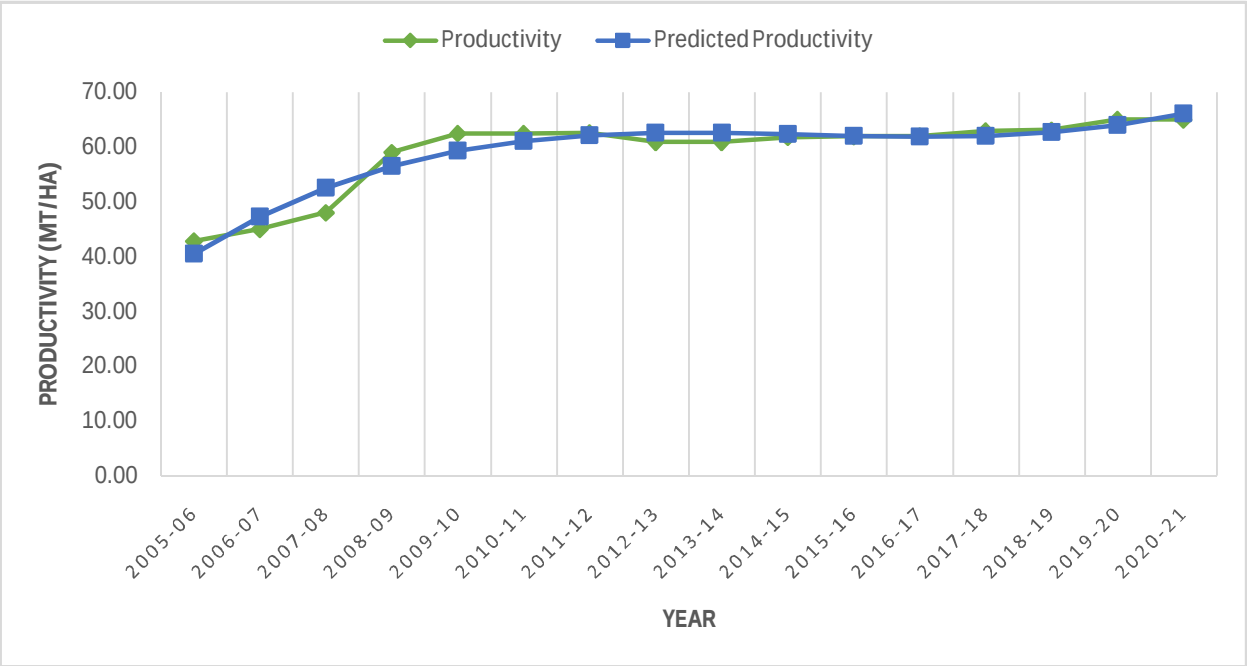

Fig 3: Observed and Predicted values of banana productivity by cubic model for the period of 2005-06 to 2020-21

Table 4: The observed and predicted values of area, production and productivity of banana by best fitted models

Years	By Cubic model		By Cubic model		By Cubic model	
	Observed Area	Predicted Area	Observed Production	Predicted Production	Observed Productivity	Predicted Productivity
2005-06	10625.00	10239.94	454750.00	395688.37	42.80	40.52
2006-07	11693.00	11723.82	526185.00	560962.05	45.00	47.30
2007-08	12195.00	12813.62	585360.00	685722.85	48.00	52.57
2008-09	13500.00	13557.08	796500.00	774858.39	59.00	56.50
2009-10	13770.00	14001.89	860220.00	833256.28	62.47	59.29
2010-11	14045.00	14195.78	877391.00	865804.12	62.47	61.11
2011-12	14085.00	14186.45	881021.00	877389.52	62.55	62.15
2012-13	16100.00	14021.64	980634.00	872900.10	60.91	62.58
2013-14	13666.00	13749.05	832396.00	857223.46	60.91	62.59
2014-15	12558.00	13416.40	775457.00	835247.21	61.75	62.36
2015-16	12560.00	13071.40	778092.00	811858.97	61.95	62.08
2016-17	12540.00	12761.77	777229.20	791946.33	61.98	61.91
2017-18	12600.00	12535.22	792540.00	780396.92	62.90	62.05
2018-19	12700.00	12439.47	801370.00	782098.34	63.10	62.68

2019-20	12710.00	12522.24	826150.00	801938.20	65.00	63.97
2020-21	12720.00	12831.24	826800.00	844804.11	65.00	66.12

CONCLUSION

The present study concluded that cubic model was the best fit for area, production and productivity of banana crop based on higher R^2 and lower *RMSE* value. Furthermore, it can be said that throughout the study period, there have been both increasing and decreasing trends in the area and production of bananas. Whereas the productivity of banana shows increasing trend during the study period.

COMPETING INTERESTS

The authors declare that they have no competing interests.

Disclaimer (Artificial intelligence)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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