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Statistical analysis of production trends of marigold in Tumkur district of Karnataka

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Abstract
Marigold, a vibrant and economically significant flower crop, plays a vital role in Karnataka's floriculture sector, particularly in the Tumkur district. Widely cultivated for its use in garlands, religious ceremonies, decorative purposes, and the extraction of natural pigments, Marigold cultivation provides substantial income opportunities for small and marginal farmers. In this study, secondary data on Marigold production in Tumkur district from 1981 to 2023 were obtained. A comprehensive trend analysis was performed using various statistical models, including Linear, Quadratic, Cubic, Exponential, and Sinusoidal models, to examine long-term changes in production. The models were evaluated based on R-squared (R^2) values, which indicate the proportion of variance explained, and Root Mean Square Error (RMSE), which reflects prediction accuracy. Among the models assessed, the cubic model provided the best fit for Marigold production, exhibiting the highest R^2 and the lowest RMSE values, signifying its superior ability to capture the underlying pattern in the data. These results suggest that Marigold production in Tumkur has undergone non-linear changes over the years, possibly influenced by varying agro-climatic conditions, market demand, and farmer adoption of improved varieties.

Keywords: Linear, quadratic, cubic, exponential, sinusoidal, root mean sum of squared r squared

Introduction
Statistical analysis is a powerful tool for examining, interpreting, and drawing conclusions from data. In agriculture, it plays a vital role in evaluating historical trends, identifying influencing factors, and making data-driven decisions to improve production. By applying statistical Techniques, researchers can assess the impact of climatic, agronomic, and market variables on crop yields and develop reliable forecasts for future production.

Floriculture has witnessed significant growth in the Tumkur district of Karnataka, with Marigold emerging as one of the most important commercial flower crops. Marigold holds a prominent place in Karnataka's floriculture industry due to its vibrant color, long shelf life, and extensive use in religious ceremonies, festivals, and ornamental landscaping. Marigold, known for its vibrant colour and high demand during religious festivals and weddings, is one of the most extensively cultivated flowers in the state. It is suited to mild-to-warm climates and well-drained loamy soils. Karnataka accounts for approximately 18% of India's total Marigold output.

Tumkur district is a significant contributor, benefiting from favourable agro-climatic conditions and proximity to Bengaluru's urban markets. The crop thrives in sandy loam soils and warm temperatures (20-35°C), and local farmers have adopted modern practices such as drip irrigation and organic cultivation. Despite these advances, production is influenced by seasonal price volatility, climate variability, and pest infestations, which can affect farmer profitability.

Knowing Marigold's economic role, analysing its production trends is essential. Statistical analysis of historical data from 1981 to 2023 enables the identification of patterns, evaluation of growth rates, and forecasting of future production. This study focuses on Marigold production trends in Tumkur district, aiming to provide insights that can support policy formulation, enhance production, and promote sustainable growth in the region's floriculture sector.

Methodology
Tumkur district, located in the southeastern part of Karnataka at approximately 13°20′N latitude

and 77°06′E longitude, covers 10,597 sq. km. It is bordered by Chitradurga, Hassan, Chikkaballapur, Bengaluru Rural, Davanagere, and Ramanagara districts. The terrain is a mix of hills, valleys, rocky outcrops, and fertile plains, with agro-climatic zones ranging from Maidan (plains) to Semi-Malnad. Situated about 800 m above sea level, Tumkur has a tropical semi-arid climate with hot summers (30-40°C), a monsoon season (June-September), and mild winters (12-25°C). Rainfall ranges from 600 mm in drier areas to over 900 mm in parts of Sira and Madhugiri, mainly from the southwest monsoon, with some from the northeast monsoon.
This study is based on secondary data regarding the production (in Metric Tons) Tumkur from 1981-82 to 2022-23. The data was sourced from the District Statistical Office, Tumkur and the Directorate of Economics and Statistics, Bangalore.

Descriptive Analysis

a. Mean

The arithmetic mean is defined as the sum of all the observations divided by the total number of observations.

Arithmetic mean ($\bar{x}$) = $\frac{\sum_{i=1}^{n} x_i}{n}$,

where,
x_i = i^{th} observation and n = Number of observations.

b. Coefficient of Variation (%)

Coefficient of Variation:

$$CV = \frac{\sigma}{\bar{x}} \times 100,$$

where,
x = mean and σ = standard deviation.

Standard deviation:

$$\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2},$$

where,
x_i = i^{th} observation,
x = mean,
n = Number of observations.

Trend analysis

a) Linear model: The simple linear regression model for n observations can be written as

$$Y_t = \beta_0 + \beta_1 X_1 + \varepsilon, \ t=1, 2, 3, \ldots, n$$

where,
Y_t= dependent variable (Production),
X_1 = independent variable (Time),
β_0 = intercept,
β_1 = coefficient to be estimated,
ε = error term at time t.

b) Quadratic model: Here the model is

$$Y_t= \beta_0+ \beta_1X+ \beta_2X^2 + \varepsilon, \ t=1, 2, 3, \ldots, n$$

where,
Y_t= dependent variable (Production),
X = independent variable (Time),
β_0 = intercept,
β_1, β_2 = coefficients to be estimated,
ε = error term at time t.

c) Cubic model: Here model is

$$Y_t= \beta_0+ \beta_1X+ \beta_2X^2+ \beta_3X^3+ \varepsilon, \ t=1, 2, 3, \ldots, n$$

where,
Y_t= dependent variable (Production),
X = independent variable (Time),
β_0 = intercept,
$\beta_1, \beta_2, \beta_3$ = coefficients to be estimated,
ε = error term at time t.

d) Exponential Model

The exponential model represents

$$Y_t = \beta_0 e^{\beta_1 X_t + \varepsilon_t}, \ t=1, 2, 3, \ldots, n$$

where,
Y_t = dependent variable (Production),
X_t = dependent variable (Time),
β_0 = intercept,
β_1 = coefficient to be estimated,
ε_t = error term at time t.

e) Sinusoidal Model

The sinusoidal regression model is given by

$$Y_t = \beta_0 . \sin(\beta_1 . X_t + \beta_2) + \beta_3 + \varepsilon_t, \ t=1, 2, 3, \ldots, n$$

where:
Y_t - dependent variable (Production),
X_t - dependent variable (Time),
β_0 = amplitude of the wave (controls the height of oscillations),
β_1 = frequency (controls how frequently the oscillations occur),
β_2 = phase shift (controls the horizontal shift of the wave),
β_3 = vertical shift or baseline level,
ε_t = error term at time t.

Results and Discussion

A statistical model used to find the trends or patterns in data over time, which helps the variables in making predictions is trend analysis. In this study, an effort was made to apply various models and determine the best-fitting one for the production of Marigold in Tumkur district of Karnataka. The selection of the best model was based on its significance, R^2 value, and RMSE values. This approach helps avoid overfitting, which could compromise the accuracy of future data projections.
As presented in Table 1, in Tumkur district, the average production of Marigold was 1639.37 MT with a standard deviation of 640.85 MT, indicating moderate fluctuations in production across the study period. The coefficient of variation

(CV = 39.09%) reflects a moderate degree of variability, suggesting that while production levels fluctuated, they remained relatively stable compared to other flower crops. The skewness value (-0.87) indicates a negative skew, meaning that years with higher-than-average production were relatively fewer. The kurtosis value (-0.52) denotes a platykurtic distribution, implying a flatter spread with less concentration of data points around the mean. These results are on par with Dwivedi *et al.* (2024) [2].

Table 1: Descriptive Statistics of Marigold Production in Tumkur District of Karnataka

Parameter	Descriptive	Marigold
Production	Mean	1639.37
	SD	640.85
	CV (%)	39.09
	Skewness	-0.87
	Kurtosis	-0.52

Trend analysis is a statistical approach used to identify patterns or changes in data over time, aiding in predicting future values. Various linear and nonlinear models, including linear, quadratic, cubic, exponential and sinusoidal modes were applied for this purpose. Among these, the model that exhibited a higher R^2 value, a lower RMSE, and statistically significant coefficients was considered the best fit.

The trend in Marigold production in the Tumkur district was analyzed using different statistical models, including Linear, Quadratic, Cubic, Exponential, and Sinusoidal models, as presented in Table 2.

For production, the linear model recorded an R^2 of 0.23 and an RMSE of 554.30, with both coefficients (β_0 and β_1) statistically significant, indicating a modest linear trend over time. The quadratic model showed a slight improvement in fit (R^2 = 0.24, RMSE = 551.71), with β_0 and β_1 significant, while β_2 was not significant. The cubic model provided the best fit overall, achieving the highest R^2 (0.55) and lowest RMSE (424.69), with all coefficients statistically significant, capturing the non-linear fluctuations more effectively. The exponential model recorded an R^2 of 0.22 and RMSE of 557.97, showing a weaker fit compared to the cubic model, though both coefficients were significant. The sinusoidal model yielded a low R^2 (0.04) and a very high RMSE (77430.51), indicating poor model performance. Hence, the cubic model was identified as the best-fitted model for Marigold production in Tumkur district, effectively representing the complex temporal variations in production levels, and Table 3 represents the equation of the best-fitted model.

Table 2: Comparison of models for predicting the production of Marigold in Tumkur

Models	Production		
	β	R^2	RMSE
Linear (β_0)	1639.37**	0.23	554.30
(β_1)	-24.69**		
Quadratic (β_0)	1699.32**	0.24	551.71
(β_1)	-24.69**		
(β_2)	-0.39		
Cubic (β_0)	1699.32**	0.55	424.69
(β_1)	-89.86**		
(β_2)	-0.39		
(β_3)	0.24**		
Exponential (β_0)	1615.29**	0.22	557.97
(β_1)	-0.01**		
Sinusoidal (β_0)	-23645.05	0.04	77430.51
(β_1)	-1.78**		
(β_2)	-3794.35**		
(β_3)	151417.80**		

Note: ** Significant at 1 per cent

Table 3: Suitable model for the production of Marigold in Tumkur district of Karnataka

Crop	Best Model	Equation	R^2
Production			
Marigold	Cubic	$y = 0.24x^3 - 89.86x + 1699.32$	0.55

In Tumkur (Figure 1), in actual Marigold production from 1982-2001 there was a increase in production due to integrated management by traditional or Indigenous technology knowledges (ITK's) between 2006 and 2010, fluctuations in the production due to a shift toward high-value crops and urbanization pressures near Tumkur town, which reduced farmland (Anon., 2011, NABARD) [1]. Then there was an increase in the production values due to integration of the National Horticultural Mission. Again in 2021 decrease in production due to post-COVID reasons and the cubic model (R^2 = 0.6248) provided a slightly better fit, capturing the trend in production.

This study is consistent with the findings of Sudha *et al.* (2013) [7], Manasa *et al.* (2024) [3], and Nikhil *et al.* (2023) [4], who also identified the cubic model as the best fit for analyzing trends in area, production of crops such as maize and cotton in Karnataka. Similarly, the results are in agreement with Rao and Srinivasulu (2006) [5] and Rashmi *et al.* (2024) [6], who reported that the linear model provided the best fit for capturing production trends in turmeric and potato, respectively.

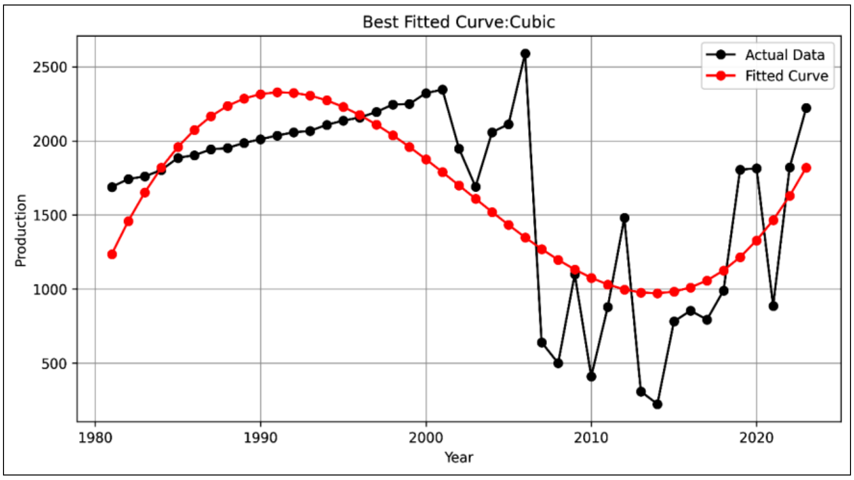

Fig 1: Plot of the best-fitted models for the production of Marigold in Tumkur

Conclusion

The trend analysis of Marigold production in Tumkur district over the 43 years (1981-82 to 2022-23) revealed significant variations across the study period. Among the models tested, the cubic model provided the best fit, as indicated by its higher R^2 (0.55) and lower RMSE (424.69) values compared to other models. This suggests that Marigold production exhibited a non-linear trend, influenced by fluctuations in cultivation practices, market demand, and climatic conditions over time. The superior performance of the cubic model highlights its effectiveness in capturing these complex variations and provides a reliable basis for forecasting future production trends of Marigold in the district.

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