Time Series Analyses of Groundnut (*Arachis Hypogaea L.*,) in the Selected Sites of Karnataka State

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Abstract
Background: India is one of the leading global producers of groundnut, with the states of Gujarat, Madhya Pradesh, and Tamil Nadu at the forefront. However, the area dedicated to groundnut cultivation and its production in India has experienced significant fluctuations over the years, leading to challenges in agricultural planning.
Methods: This research seeks to examine the trends in both area and production of groundnut in selected districts of Karnataka, specifically Tumkur and Chitradurga was major purposively selected for study, because due to production and productivity is more for last five years. The study employs various time series models, including linear, quadratic, cubic, exponential, and logistic regression models were formulated, utilizing a dataset spanning twenty-five years (1997- 2022).
Results: The results indicate that, the cubic model is the most appropriate for assessing the area under cultivation, while the quadratic model is deemed to be most robust for analyzing production trends of groundnut in different agro climatic zones. Additionally, the study addressed various challenges and risks associated with groundnut production in Karnataka. Linear, quadratic and exponential models were fitted. As per the results, the cubic and logistic models were found to be insignificant. Additionally, the Run's test and Shapiro-Wilk test statistics were found to be non-significant for quadratic model. Therefore, the data on groundnut production in Tumkur district during the study period was well-fitted by quadratic model as compared with rest of the study sites.
Conclusion: The findings aim to enhance the understanding of different oilseed production trends, thereby aiding farmers and government stakeholders in making informed decisions to ensure stable production across larger areas.
Keywords: Trend Model, Groundnut, Production, Parameters, Regression Model

Introduction

Groundnut serves as a significant oilseed crop in India, where it ranks first in terms of area cultivated and second in production, following soybean. In the global context, China leads in groundnut production with 17.57 million tonnes, while India follows with 6.73 million tonnes. Other notable producers include Nigeria with 4.45 lakh tonnes, Sudan with 2.83 million tonnes, and the United States with 2.49 million tonnes. These figures represent (36.01%), (13.79%), (9.12%), (5.80%), and (5.11%) of the total world production, which was 48.80 million tonnes in the 2019-20 period. As of the 2022-23 seasons, India's groundnut production is reported to be 102.97 lakh tonnes. As compared to national level, the Karnataka as one of the key states for groundnut cultivation

in India positioned sixth after Gujarat, Rajasthan, Tamil Nadu, Madhya Pradesh, and Andhra Pradesh. The state contributes a total of 5.80 lakh tonnes of groundnut annually. However, due to increasing risks and uncertainties, both the area dedicated to and the production of groundnut in Karnataka are experiencing a decline, with only slight improvements in crop productivity. Within Karnataka, Chitradurga district leads in both area and production of groundnut, representing 24.35% of the area and 15.46% of the production for the year 2022-23.

Many researchers have explored time series models to fill the existing research void at both national and international scales. (Ismail et al) investigated historical patterns in cherry production in Jammu and Kashmir using parametric, nonparametric, and semi-parametric regression techniques. The effectiveness of each approach was assessed through higher R² values and reduced residual criteria. The results revealed that, nonparametric and semi-parametric regression methods offer a better fit for cherry production trends than parametric regression. Additionally, the semi-parametric spline regression found to be most appropriate model for trend analysis, the study concluded that both the area under cultivation and productivity showed an upward trajectory, with the exception of a few recent years that experienced a decline.

In a separate study, (Sekhar and Umakrishna) aimed to forecast chilli yields in Andhra Pradesh by applying various growth models. The data series on Capsicum annuum (Chilli) yield was collected for a period of 25 years (1991-2015) from database. Cubic model was fitted for yield and it was identified as the best model for the observed. (Shah) estimated the growth trends in area, production, the productivity of apple fruit in Jammu and Kashmir. Secondary data on area, production and productivity of Malus pumil (apple) fruit in India and the State of Jammu and Kashmir were collected for the period from 1991-92 to 2017-18. The data were analysed through growth rate, trend analysis and co-efficient of variation techniques. The estimated linear growth model for J&K's apple cultivation area showed that the annual growth rate was 3.16 percent. Forecasting was done for seven years from 2018-19 to 2024-25 to know

the future trend in apple Area, Production and productivity in the state. This model estimated J&K's apple cultivation area to be at 1,77,258 hectares for the year 2020.

(Sivasankari) conducted the study to the trend analysis of area, production and productivity for pulse crops in select districts of Tamil Nadu. Time series data on area, production and productivity of black gram (Vigna mungo L. Hepper) and green gram (Vigna radiate) in select districts of Tamil Nadu, the data were collected from (1997-98) to (2015-2016). They have fitted different trend models (linear, non-linear and fuzzy time series models) for pulse crops like Black and Green gram for selected districts of Tamil Nadu. The best-fitted model for future projection was approximated based upon highest Theil's U Statistic, coefficient of determination (R²) and with least MAPE, MAE and RMSE values. Among all the linear and nonlinear models for black gram production, the quadratic model was best fitted model for Cuddalore district. For Nagapattinam and Trivarur districts, Cubic model was best fitted model. For green gram production, exponential model was shown more robust for Tuticorin district and Cubic model was well appropriate for Trivarur and Nagapattinam districts.

Further, (Manjula et al.) demonstrated growth model of egg production of poultry flocks by using different time series trend models. Asper the research findings, the poultry egg production in Karnataka have shown an increasing trend over the period with positive growth rates among the districts. This growth is not uniform across all the districts of the state. Hence, this modest attempts were made to explored statistical models separately by grouping the districts (clusters) on their production as high, medium and low egg producing districts as well as based on administrative divisions for obtaining the appropriate growth models. Various polynomial and exponential regression models were fitted and the best fitted model was selected based on Coefficient of determination (R²) and Root Mean Square Error (RMSE) criterion. In Kalaburagi division shows highest egg production followed by Mysuru, Belagavi and Bengaluru divisions. The quadratic model was best fitted model for low and medium egg producing districts and linear model was best suitable for high

egg producing districts. It was found that linear model was the appropriate model for the districts or division with higher egg production growth rates.

(Bhusanar et al.) analyzed groundnut output, area and productivity in Rajasthan. Secondary data was gathered from Rajasthan state between 1990-91 to 2019-20, the average groundnut area, production and productivity significantly ranged 352.12 thousand hectors, 513.40 thousand MT and 1351 kg/ha, respectively. The compound growth rates (CGR) of groundnut area, production and productivity were found to be positive and significantly produced ground nut production (R^2(%) = 0.652*, 0.940** and 0.603*) steepest ascent movement trend (CAGR of 3.2, 6.4 and 2.8 percent).

(Bhusanar and Meena) analyzed the area, production and productivity of groundnut in Rajasthan over the last thirty years and they have forecasted by using auto regressing integrated moving average (ARIMA) model. The descriptive statistics show that, there was a large fluctuation in the lowest and maximum values of area, production and productivity of groundnut in Rajasthan over the period of last thirty years. The parameter estimates of the ARIMA model were used to determine the model fit statistics, including the R-squared value, which indicates how well the model fits the data. These results indicate that there is a considerable upward trend in area, production and productivity of groundnut in Rajasthan over the last thirty years.

Above Trend models were hold considerable importance as they enable us to recognize patterns, forecast future results, and make well-informed decisions. By identifying and analyzing trends within data, these models contribute to improved resource allocation, effective risk management and enhanced strategic planning. An increased risk of agriculture production, the time series models is essential for making accurate cropping decisions at the appropriate time and with the right actions. In the current context, informed decision-making is consistently characterized by analytical methods. This study aims to address the existing research gap by demonstrating various time series models utilizing actual data related to groundnut cultivation.

Methods

The method of trend analysis refers to the general movement of data series, it was indicated upward or downward movement of real life time data over a massive period. This analysis was focused to study the behaviour of long-term changes within a agriculture time series, while ignoring any short-term fluctuations. In the field of agriculture, the extrapolation of productivity, crop production and price trends are crucial role for developing a new guidelines and making informed decisions. In this research gap we formulated the long-term trend models with respect to area and production of groundnut in the selected districts of Karnataka, by utilizing the least squares estimation and time series models. This technique was found to be effectively quantified trend movement in the current groundnut crop. The following mathematical equation was employed for the formulation of the trend models.

Linear Model

A linear model was characterized by the presence of all parameters in a linear form. The mean trajectory data points were represented by a linear straight line, which reflected a constant rate of changing the yield variable, it may precludes either increase or decrease over period of time as concordance study done by (Nini et al.).

$$Y_t = \alpha_0 + \alpha_t + \varepsilon \tag{1}$$

Quadratic Model

A quadratic function was generalized by the presence of either a maximum or minimum data points in the data, formed a parabolic shape. The overall trend of the data exhibits a curve that varied in the steepness, reflected changes were formulated by the following eqn (2)

$$Y_t = \alpha_0 + \alpha_t + \beta_t^2 + \varepsilon \tag{2}$$

Cubic Model

The cubic is unique model for extrapolation, there are two postulates in the data points. An average trajectory points for the bundle behaves quadratic until further curve appeared, which corresponded to the forward and backward movement with ambient degree of steepest degrees of freedom and likelihoods.

$$Y_t = \alpha_0 + \alpha_t + \beta_t^2 + \gamma_t^3 + \varepsilon \qquad (3)$$

Where, α_0 Intercept or average effect "α, β, γ" slope or regression Coefficients (α = linear effect parameter, (β) is quadratic effect parameter and (γ) cubic effect parameter), (Y_t) area or production of at time (t) and associated errors (ε).

The above fitted linear models were fitted by using 'lm' function of 'R'. The Coefficients α_0, α, β and γ were constant parameters and it was estimated simultaneously. The process of minimization of the sum of the squared errors results in some equations called normal equations. The normal equations are the equations, which are used for finding the coefficients of the relation, which is fitted by the method of least square. In the above models, relationship between response variable and time period are assumed to be linear or curvilinear. However, the assumptions of linearity, curvilinear or exponential functional form may not hold for the real data in nature. Most of the time series relating to business and economic phenomena over long period of time do not exhibit sudden growth which is at a constant rate and in a particular direction over long period of time. Time-series are not likely to show either a constant amount of change or a constant ratio of change. The rate of growth is initially slow and then it picks up and becomes faster and get accelerated, then becomes stable for some time after which it shows retardation. The curves, which can be fitted to such data, are called Growth Curves. Growth models are generally 'mechanistic' and the parameters have meaningful biological interpretation (Das). The following are the two nonlinear growth curves, which were used to describe the growth of present time-series.

Exponential Model

If, when the values of 't' arranged in arithmetic series, the corresponding values of 'y' formed a geometric series, the relation was exponential type. The function of this type was given by

$$Y_t = \alpha e^{\beta t} + \varepsilon \qquad (4)$$

Where, (Y_t) represents area or production of groundnut in time period (t) (α) and (β) are parameters, (α) represents the value at (t = 0, β) represents the exponential rate (e) is the exponential term and (ε) denoted the error term.

Logistic Models

$$Y_t = [\beta_0 / \{1 + \beta_1 \exp(-\beta_2 X_t)\}] + \varepsilon \qquad (5)$$

Where, (Y_t) represents groundnut area or production in time period 't', (β_0) is the carrying capacity or upper asymptote, (β_1) shows the growth range and (β_2) is growth rate.

It was noted that, the above growth models are 'nonlinear', which involves at least one parameter in a nonlinear manner. Exponential model was fitted by using 'SS exp' function of the package named 'NLRAA' R -software. The logistic model was fitted by using 'NLSLM' function of the package 'minipack' in R Software. Once the parameters of the models were estimated, diagnostic check of residuals of the fitted models has to be analyzed to check any violations in the main assumptions of 'independence of residuals' and 'normality of residuals'. The main assumptions of 'independence of residuals' and 'normality of residuals' were examined by using respectively the 'Run-test' and 'Shapiro-Wilk test'.

Test for Independence (Randomness) of Residuals by Run Test

Non-parametric run test was used to test the randomness of residuals. Run was defined as 'a succession of identical symbols in which are followed and preceded by different symbols or no symbols at all'. If very few runs occur, a time trend or some bunching owing to lack of independence it was is suggested if many runs occur, systematic short period cyclical fluctuations were seem to be influencing the scores. Statement of null hypothesis (H_0): the sequence is random & alternative Hypothesis (H_1): Sequence is not random.

Let 'n_1', be the number of elements of one kind and 'n_2' be the number of elements of the other kind appeared in particular sequences of (N = $n_1 + n_2$) binary events. For small samples i.e. both n_1 and n_2 are equal or to less than 20, if the number of runs 'r' fall on the critical values, we accepted H_0 (null hypothesis), the sequence of binary events was random otherwise, we have reject the H_0. In a large samples i.e., if either n_1 or n_2 is larger than 15, a good approximation to the sampling distribution of r (runs) mean value theorem (MVT), it was formulated by the following eqn (6 to 8)

Mean $(\mu_r) = [(2n_1n_2) / (n_1+n_2)] + 1$ (6)

Variance $(\sigma_r^2) = \sqrt{[\{2n_1n_2(2n_1n_2-n_1-n_2)\} / \{(n_1 n_2)^2(n_1+n_2-1)\}]}$ (7)

Then H_0 can be tested using test statistic:

$Z = (r-\mu_r) / \sigma_r^2 \sim N(0,1)$ (8)

The significance of any observed value of 'Z' computed by using the above equation, it was determined from the normal distribution table.

Test for Normality of Residuals by Shapiro-Wilk's (W) Test

This is the standard test for normality. The test statistic W is the ratio of the best estimator of the variance (based on the square of a linear combination of the order statistics) to the usual corrected sum of squares estimation of the variance. W may be thought of as the correlation between given data and their corresponding normal scores. The values of W ranges from 0 to 1. When W=1 the given data are perfectly normal in distribution. When W is significantly smaller than 1, the assumption of normality is not met. A significant W statistic causes to reject the assumption that the distribution is normal. Shapiro-Wilk's W is more appropriate for small samples up to (n=50)

- NH (H_0): Samples $\{x_1............x_n\}$ is from a normality distributed population.
- AH (H_1): Samples $\{x_1.......x_n\}$ is not from a normality distributed population.

Test statistic is given by:

$W = [\sum_{i-1}^{n} a_i x_{(i)}]^2 / \sum_{i-1}^{n}(x-\bar{x})^2$ (9)

Where, $x_{(i)}$ is the ith order statistic, i.e., the ith smallest number in the sample, $\bar{x}$ is sample mean and the constants a_i is given by

$(a_1, a_2, ... ,a_n) = \{m^T V^{-1} / \{\sqrt{(m^T V^{-1}V^{-1}m)}\}$ (10)

Where $m^T = (m_1, m_2 ..., m_n)^T$ and $m_1, m_2, .. , m_n$ are the expected values of the order - statistics of independent and identically distributed random variables sampled from the standard normal distribution and V is the covariance matrix of those order statistics. Rejected the null hypothesis if W is too small (near to zero).

Model Adequacy Checking
The Coefficient of Determination R^2 (%)

The coefficient of determination (R^2) is a test statistic that gives an information about the robustness

of the model. R^2 value is the proportion of variability in a data set that accounted by the fitted model. It provides a measures of explained variability in the dependent variable.

R^2 (%) = RSS/TSS = (1-{ESS/TSS})   (11)

Where, ESS: Error sum of squares; RSS: Regression sum of squares and TSS: Total sum of squares, Computed R^2 value lies between zero and one. If R^2 value is closer to 1 indicates that the model fits the data. Adjusted R^2 and Root Mean Square Error (RMSE) are also used for the checking goodness of model fit.

Adjusted R^2 (%)

The adjusted R-squared value are modified version of R-square, that has been adjusted for the number of predictors in the fitted model. The adjusted R-squared increases only if the new term improves the model it more than what would be expected by chance factor. It shows downward movement when a predictor improves the model by less than expected by chance.

Adjusted R^2 (%) = 1 - [(ESS⁄df) / (TSS⁄df)]   (12)

Where, ESS: Error sum of squares, TSS: Total sum of squares and df: Respective degrees of freedom

Mean Average Percentage Error (MAPE)

Mean Absolute Percentage Error (MAPE) is the most widely used measure for checking forecasting accuracy. It represented under percentage errors, scale independent and it was used for comparing series on different scales. The model with the lowest MAPE value was considered to be the good fit. MAPE is very oftenly used as a loss function (LOF) for regression, because its intuitive interpretation in terms of relative error.

MAPE = $1/n \sum_{i=1}^{n} |(Y_i-\hat{Y}_i) / Y_i|$ x 100   (13)

Where, Y_i = Actual values, $\hat{Y}_i$ = Predicted values and n= number of observations

Root Mean Square Error (RMSE)

The Root Mean Square Error (RMSE) (also called the root mean square deviation, RMSD) was used to assessed the amount of variation that the model will unable to captured real data. The RMSE will obtained as the square root of the mean squared error.

$$RMSE=\sqrt{\{(\sum_{i=1}^{n}(Y_t-\hat{Y}_t)^2)/n\}} \qquad (14)$$

Where, (Y_t) Observed value, $(\hat{Y}_t)$ Predicted value and (n) number of observations

Akaike Information Criterion

The Akaike Information criterion (AIC) is a mathematical method for evaluating how well a model fits the data. AIC was used to compared different possible models and determined which one is the best fit. AIC was calculated from the number of independent variables used to build the model and the maximum likelihood estimates of the model. The best fit model evaluated based on AIC which explains the maximum amount of variation using the fewest possible independent variables. The formula for AIC is

$$AIC = 2K-2\ln(L) \qquad (15)$$

Where, (K) is the number of independent variables, (L) is log-likelihood estimates and AIC was calculated for each model with lowest value was selected as the best fit for the data.

Bayesian Information Criterion

The Bayesian Information Criterion (BIC) is a method for scoring and selecting a model. BIC is a criterion for model selection among a finite set of models. It was closely related to AIC. it is appropriate for models fit under the maximum likelihood estimation (MLE) method. When fitting models, it is possible to increase the likelihood by adding parameters, but doing so may result by way of overfitting. The BIC resolved this problem by introducing a penalty term for the number of parameters included in the model. The penalty term is larger in BIC than in AIC. The formula for BIC is

$$BIC = K\ln(n)-2\ln(L(\theta)) \qquad (16)$$

where, (n) sample size, (K) Number of independent variables, θ – set of all the parameters, $L(\theta)$ – Log likelihood estimate

The models were compared by calculating BIC for each model and then the model with lowest BIC was considered the best. Lower BIC value indicates lower penalty terms hence a better model. Though, these two measures were derived from a different perspective, they are closely related. Apparently, the only difference is BIC considers the number of observations in the formula, which AIC does not. In fact, BIC is always higher than AIC, lower the value of these two measures, better the model.

Results

Time-series data often shows a consistent pattern of increasing or decreasing over time, known as a trend. To determine the trends in groundnut production in Karnataka, annual data were collected from the Directorate of Economics and Statistics (DES), covering the 25-year period from 1997 to 2022. To estimate these trends, models such as linear, quadratic, cubic, exponential and logistic were applied. The statistical significance of the parameters for the linear, quadratic and cubic models was assessed using the student t-test, while the significance for the exponential and logistic models was evaluated based on the parameters within the 95 percent asymptotic confidence intervals. Parameter values were deemed significant at the 5 percent level if the estimated parameter of the fitted model fell within the 95 percent confidence range. The "Runs test" and the "Shapiro-Wilk test" were utilized to check the assumptions of independence or randomness and normality of residuals, respectively. Only those models where all parameters were significant and both assumptions were met were considered well-fitted. Among these well-fitted models, the best model was selected based on the minimum MAPE value. As a measure of accuracy, the MAPE was computed for all the models presented in the tables below. Data spanning 25 years, from 1997 to 2022, was used for this analysis. Both linear and nonlinear models were applied to evaluate the trend in groundnut production in selected districts of Karnataka. The results obtained are detailed in the following subsections. Table 1 presents the parameter estimates and their standard errors (in parentheses) for the five fitted models of groundnut area in Tumkur district. Table 2 provides the test statistics, probability values and model adequacy criteria. The results indicate that the calculated parameters for the linear, cubic, exponential and logistic models were significant at the given level of significance. Whereas, quadratic model found to be non-significant. Additionally, the Run's test and Shapiro-Wilk test statistics were found to be non-significant for all fitted models. Therefore, the data on groundnut area in Tumkur

district during the study period was well-fitted by the linear, cubic, exponential and logistic models (Table 2). The optimal model was selected based on the lowest MAPE value among the four well-fitting models. The cubic model emerged as the best fit, with the lowest MAPE value of 17.87. This model outperformed the others not only in terms of MAPE but also according to several other criteria, indicating its robustness. Specifically, the cubic model demonstrated a strong fit with an R^2 value of 0.7074 and an Adjusted R^2 of 0.6656. Additionally, the model had an AIC (Akaike Information Criterion) value of 583.20 and a BIC (Bayesian Information Criterion) value of 589.29, both of which are used to assess the relative quality of statistical models for a given dataset. The RMSE was 23042, further confirming the model's accuracy. Consequently, the data on the groundnut area in Tumkur from 1997 to 2022 exhibited a cubic growth pattern, as evidenced by the comprehensive evaluation of these statistical criteria. (Sudha et al.) in their study also noticed the cubic model was the best fitted model for forecasting the area, production and productivity of maize in Guntur district of Andhra Pradesh. The cubic model in Figure 1 shows a rise and then a decline in the groundnut area in Tumkur district from 1997-98 to 2021-22, closely matching the actual data, reflecting shifts in land use and agricultural practices.

Table 1 Parameter Estimates by Different Models for the Area under Groundnut in Tumkur District

Parameters	Models				
	Linear	Quadratic	Cubic	Exponential	Logistic
Intercept (β_0)	174872.61** (11010.51)	165670.65** (17605.31)	130082.68** (23552.34)	1.824e+05** (1.471e+04)	1.777e+05** (3.587e+04)
β_1	-4721.01** (740.62)	-2676.09 (3120.27)	12300.69* (7691.69)	-3.932e-02** (7.158e-03)	-1.347e-01* (6.094e-02)
β_2	-	-78.65 (116.50)	-1490.87* (680.34)	-	1.811e+01** (3.597e+00)
β_3	-	-	36.21* (17.22)	-	

**Significant at 1% level; *Significant at 5 % level, values in parentheses indicate standard errors (SE)

Table 2 Test for Randomness, Normality of Residuals and Goodness of Fit Criteria of Different Models for the Area under Groundnut in Tumkur District

Criteria	Models				
	Linear	Quadratic	Cubic	Exponential	Logistic
Runs test (p-value)	-0.54 (0.58)	-0.60 (0.54)	1.03(0.30)	-0.60(0.54)	0.21(0.83)
Shapiro-Wilk (p-value)	0.95(0.30)	0.94(0.23)	0.96(0.19)	0.93 (0.22)	0.91(0.21)
RMSE	25613.99	25352.71	23042.94	26710.74	24834.74
MAPE	20.62	21.29	17.87	20.84	20.39
AIC	584.49	585.97	583.20	586.58	584.94
BIC	588.15	590.85	589.29	590.24	589.82
R^2 (%)	0.63	0.65	0.71	0.61	0.66
Adjusted R^2 (%)	0.62	0.61	0.66	0.59	0.61

P<0.05 Significant, Values in parentheses indicate Probability value.

Table 3 presents the parameter estimates and their standard errors (in parentheses) for the five fitted models of groundnut production in Tumkur district. Table 4 provides the test statistics, probability values and model adequacy criteria. The results indicate that the calculated parameters for the linear, quadratic and exponential models were significant at the given level of significance. Whereas, cubic and logistic model found to be non-significant. Additionally, the Run's test and Shapiro-Wilk test statistics were found to be non-significant for quadratic model. Therefore, the data on groundnut production in

Tumkur district during the study period was well-fitted by the quadratic model (Table 4). The optimal model was selected based on the lowest MAPE value among the four well-fitting models. The quadratic model emerged as the best fit, with the lowest MAPE value of 46.41. This model outperformed the others not only in terms of MAPE but also according to several other criteria, indicating its robustness. Specifically, the quadratic model demonstrated a strong fit with an R^2 value of 0.3863 and an Adjusted R^2 of 0.3304. Additionally, the model had an AIC (Akaike Information Criterion) value of 616.025 and a BIC (Bayesian Information Criterion) value of 621.025, both of which are used to assess the relative quality of statistical models for a given dataset. The RMSE (Root Mean Square Error) was 46336, further confirming the model's accuracy. Consequently, the data on the groundnut production in Tumkur from 1997 to 2022 exhibited a quadratic growth pattern, as evidenced by the comprehensive evaluation of these statistical criteria. (Karim et al.) in their study also noticed the quadratic model was found most appropriate for overall wheat production in Bangladesh. The quadratic model in Figure 3 indicates a steady decline in groundnut production during the same period, aligning with actual data and highlighting the impact of reduced cultivation area and other influencing factors.

Table 3 Parameter Estimates by Different Models for the Production (in MT) of Groundnut in Tumkur District

Parameters	Models				
	Linear	Quadratic	Cubic	Exponential	Logistic
Intercept (β_0)	127589** (21450)	174175.62** (32189.11)	169879.83** (47360.94)	1.620e+05** (3.229e+04)	1.475e+07 (3.631e+09)
β_1	-4409** (1443)	-14761.71* (5705.02)	-12953.86 (15467.07)	-7.703e-02** (2.384e-02)	-7.746e-02 (1.096e-01)
β_2		398.22* (213.03)	227.70 (1368.07)		-5.814e+01 (3.289e+03)
β_3			4.37 (34.63)		

**Significant at 1 % level; *Significant at 5 % level; values in parentheses indicate standard errors

Table 4 Test for Randomness, Normality of Residuals and Goodness of Fit Criteria of Different Models for the Production (in MT) of Groundnut in Tumkur District

Criteria	Models				
	Linear	Quadratic	Cubic	Exponential	Logistic
Runs test (p-value)	0.28 (0.77)	1.70 (0.08)	1.71 (0.09)	-0.60 (0.54)	-0.65 (0.56)
Shapiro-Wilk (p-value)	0.85* (0.03)	0.89 (0.05)	0.89* (0.03)	0.91* (0.04)	0.93* (0.03)
RMSE	49900.08	46336.18	46354.61	47661.36	47666.75
MAPE	60.95	46.40	46.49	55.20	55.12
AIC	617.84	616.15	618.13	615.54	617.54
BIC	621.49	621.02	624.22	619.19	622.42
R^2 (%)	0.28	0.38	0.38	0.35	0.35
Adjusted R^2 (%)	0.25	0.33	0.29	0.32	0.25

**Significant at 1 percent; *Significant at 5 percent; Values in parentheses indicate Probability value.

Table 5 presents the parameter estimates and their standard errors (in parentheses) for the five fitted models of groundnut area in Chitradurga district. Table 6 provides the test statistics, probability values and model adequacy criteria. The results indicate that the calculated parameters for the linear, cubic and exponential models were significant at the given level of significance. Whereas, quadratic and logistic models found to be non-significant. Additionally, the Run's test and Shapiro-Wilk test statistics were

found to be non-significant for all fitted models. Therefore, the data on groundnut area in Chitradurga district during the study period was well-fitted by the linear, cubic and exponential models (Table 6). The optimal model was selected based on the lowest MAPE value among the four well-fitting models. The cubic model emerged as the best fit, with the lowest MAPE value of 13.58. This model outperformed the others not only in terms of MAPE but also according to several other criteria, indicating its robustness. Specifically, the cubic model demonstrated a strong fit with an R^2 value of 0.5155 and an Adjusted R^2 of 0.4463. Additionally, the model had an AIC (Akaike Information Criterion) value of 576.36 and a BIC (Bayesian Information Criterion) value of 582.45, both of which are used to assess the relative quality of statistical models for a given dataset. The RMSE (Root Mean Square Error) was 20097, further confirming the model's accuracy. Consequently, the data on the groundnut area in Chitradurga from 1997 to 2022 exhibited a cubic growth pattern, as evidenced by the comprehensive evaluation of these statistical criteria. (Mishra et al.) in their study also noticed the cubic model was best fitted in area, production, yield and export of tea in India. The cubic model in Figure 2 shows fluctuations in the groundnut area in Chitradurga district from 1997-98 to 2021-22, with an initial rise followed by a decline and a slight recovery towards the end. The model fits the actual data well, reflecting variability in land use over time.

Table 5 Parameter Estimates by Different Models for the Area under Groundnut in Chitradurga District

Parameters	Models				
	Linear	Quadratic	Cubic	Exponential	Logistic
Intercept (β_0)	158599.81** (10677.01)	176464.91** (16531.42)	133512.04** (20541.57)	1.617e+05** (1.179e+04)	3.563e+06 (5.919e+08)
β_1	-2041.61** (718.22)	-6011.61* (2929.91)	12064.57* (6708.44)	-1.612e-02** (5.449e-03)	-1.673e-02 (1.080e-01)
β_2		152.71 (109.43)	-1551.79* (593.37)		-1.821e+02 (1.157e+04)
β_3			43.70** (15.02)		

**Significant at 1% level; *Significant at 5 % level values in parentheses indicate standard errors.

Table 6 Test for Randomness, Normality of Residuals and Goodness of Fit Criteria of Different Models for the Area under Groundnut in Chitradurga District

Criteria	Models				
	Linear	Quadratic	Cubic	Exponential	Logistic
Runs test (p-value)	-1.27(0.20)	-0.42(0.66)	0.69(0.48)	-0.60(0.54)	-0.65(0.55)
Shapiro-Wilk (p-value)	0.96(0.53)	0.97(0.55)	0.98(0.66)	0.96(0.60)	0.96(0.62)
RMSE	24838.09	23806.26	20097.29	24644.43	24650.19
MAPE	17.41	16.34	13.58	17.13	17.14
AIC	582.95	582.83	576.36	582.56	584.57
BIC	586.61	587.71	582.45	586.22	589.45
R^2(%)	0.25	0.32	0.51	0.27	0.27
Adjusted R^2(%)	0.23	0.26	0.45	0.21	0.18

Note: Values in parentheses indicate Probability value

Table 7 presents the parameter estimates and their standard errors (in parentheses) for the five fitted models of groundnut production in Chitradurga district. Table 8 provides the test statistics, probability values and model adequacy criteria. The results indicate that the calculated parameters for the linear,

quadratic and exponential models were significant at the given level of significance. Whereas, cubic and logistic model found to be non-significant. Additionally, the Run's test and Shapiro-Wilk test statistics were found to be non-significant for all fitted models. Therefore, the data on groundnut production in Chitradurga district during the study period was well-fitted by the linear, quadratic and exponential models (Table 8). The optimal model was selected based on the lowest MAPE value among the four well-fitting models. The quadratic model emerged as the best fit, with the lowest MAPE value of 32.86. This model outperformed the others not only in terms of MAPE but also according to several other criteria, indicating its robustness. Specifically, the quadratic model demonstrated a strong fit with an R² value of 0.4027 and an adjusted R² of 0.3290. Additionally, the model had an AIC (Akaike Information Criterion)

value of 601.92 and a BIC (Bayesian Information Criterion) value of 606.8, both of which are used to assess the relative quality of statistical models for a given dataset. The RMSE (Root Mean Square Error) was 34367, further confirming the model's accuracy. Consequently, the data on the groundnut production in Chitradurga from 1997 to 2022 exhibited a quadratic growth pattern, as evidenced by the comprehensive evaluation of these statistical criteria. (Sharma) in their study also noticed the quadratic model was best fitted model for area, production, productivity of food grains in India. The quadratic model in figure 4 shows a decline and then a slight recovery in groundnut production in Chitradurga district from 1997-98 to 2021-22, closely following the actual data and reflecting changes in production practices and external factors.

Table 7 Parameter Estimates by Different Models for the Production (in MT) of Groundnut in Chitradurga District

Parameters	Models				
	Linear	Quadratic	Cubic	Exponential	Logistic
Intercept (β_0)	124485** (17056)	172198.51** (24218.72)	152211.22** (35126.94)	1.389e+05** (2.113e+04)	1.262e+07 (5.074e+09)
β_1	-2784* (1147)	-13387.61** (4292.41)	-4976.20 (11471.71)	-3.821e-02** (1.338e-02)	-3.845e-02 (1.140e-01)
β_2		407.81* (160.31)	-385.33 (1014.68)		-1.170e+02 (1.091e+04)
β_3			20.34(25.69)		

**Significant at 1 percent level; *Significant at 5 percent level, values in parentheses indicate standard errors

Table 8 Test for Randomness, Normality of Residuals and Goodness of Fit Criteria of Different Models for the Production (in MT) of Groundnut in Chitradurga District

Criteria	Models				
	Linear	Quadratic	Cubic	Exponential	Logistic
Runs test (p-value)	1.03(0.30)	1.94(0.05)	1.66(0.09)	1.03(0.30)	1.02(0.40)
Shapiro-Wilk (p-value)	0.95(0.35)	0.96(0.32)	0.95(0.25)	0.97(0.64)	0.96(0.63)
RMSE	39678.61	34367.41	34876.21	38600.44	38607.81
MAPE	50.14	32.86	33.26	48.71	48.64
AIC	606.37	601.92	603.18	604.99	607.01
BIC	610.03	606.80	609.28	608.65	611.88
R² (%)	0.20	0.40	0.38	0.24	0.25
Adjusted R² (%)	0.16	0.32	0.31	0.21	0.13

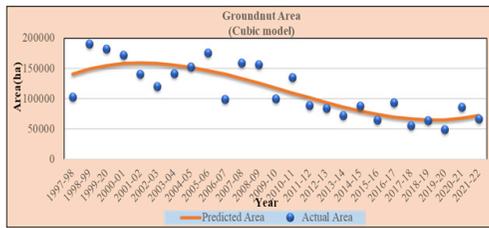**Note**: Values in parentheses indicate Probability value

Figure 1 Best Fitted Model for Area of Groundnut in Tumkur District
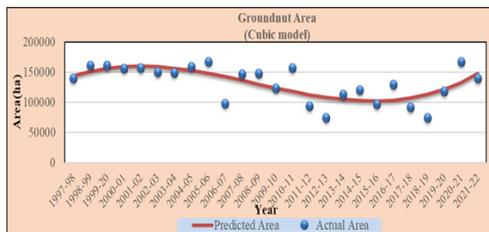

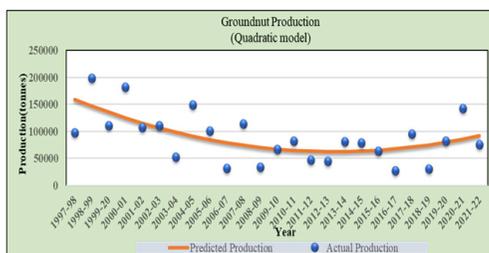**Figure 2 Best Fitted Model for Area of Groundnut in Chitradurga District**

Figure 3 Best Fitted Model for Production of Groundnut in Chitradurga District

Discussion

(Senthilnathan et al.) fitted compound annual growth rates for production, area, and yield are -0.14 percent, 1.05 percent, and 1.2 percent, respectively, groundnut production and yield are increasing and the area in India has changed throughout time. The decomposition of groundnut production in area, yield, and interaction effect showed that the yield effect was responsible for increasing the production of groundnut in India followed by the interaction effect and area effect. The results revealed that the level of instability was high in yield while it was lowest in area. The findings showed that the annual growth rate of productivity of groundnuts also shows an increasing trend during the recent period due to the availability of high-yielding cultivars and the deployment of innovative cultivation technologies. Therefore, the present study, groundnut production in

Chitradurga district showed to be better performance as correlated by the linear, quadratic and exponential models MAPE (32.86). Similar study reported by (Teja et al.) explored the performance of total oilseeds in India, using times series data, collected from 1949-50 to 2014-15. Nine annual oilseeds, which included seven edible oilseeds (groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger along with two non-edible crops). The total period from 1949-50 to 2014-15 was divided into four sub-periods (I, II, III and IV). They have fitted trend models of Compound Annual Growth Rate (CAGR), decomposition analysis model and instability analysis in the area, production, yield of total oilseeds. The model depicted on the performance of oilseeds is well, it was concluded that, there was a noteworthy performance in yield aspect of total oilseeds at the national level. Though there was an upward and significant growth in terms of the area, production and yield of total oilseeds over the study period. There exists a gap between domestic demand and supply of oilseeds, which obligates us to import edible oils. The present shows concordant results as cited in the above study. One more recent study reported by (Jayasudha and Sheela). The results clearly showed that the growth rate performance of area, production and yield of oilseed in the region declined sharply from period 1 to 3. The study witnessed that more than half of the area under the crop in the State suffered from low growth rate in area. The comparison of production growth rates of all the major oilseeds revealed that Sunflower showed better performance followed by rapeseed and mustard, During the study period from 1990-91 to 2019-20, only yield (2.02%) showed positive growth rate whereas area (-2.6%) and production (-0.62%) showed negative growth rate. The decomposition analysis of growth suggests that sources of output growth in Bihar state was the same in all the three periods as the major contribution was yield effect followed by area effect. Reduction in yield gap and adoption of new technology can improve Bihar as well as India's oilseeds production and make India self-sufficient in oilseeds production and consumption (Ujwala Rani, et al.). They have undertaken to analysed the growth rate performance of area, production, productivity of selected crops in

Karnataka from year 1997 to 2019. At state level, it was found that, the productivity of cereals showed positive growth with 1.22 percent. The area under maize increased by 5.30 percent by displacing Jowar, Bajra, minor millets. The rice and maize became stable crops in cultivation due its assured support prices and procurement from government. The production of pulses increased by 4.17 percent. The area under oil seeds showed negative trend with -5.87 percent which may be due to its high cost of production and unremunerative prices where as the commercial crops has recorded positive growth rates of production (2.69 percent) and productivity (2.43 percent) despite of its 0.24 percent area growth. The farmers prioritised sugarcane, cotton because of less labour requirements, good market prices. The Technology mission on oilseeds and Pulses in post 1990's could be reason for increased production and productivity of pulses. Fitted trend models were shows more robust and served as pragmatic tool for taking right decision at the right time by the researchers.

Conclusion

This study successfully examined the trends in area, production, and productivity of groundnut in the selected districts of Karnataka (Tumkur and Chitradurga districts). By employing various statistical models on secondary data collected over 25 years, the analysis identified that the cubic model was the best fit for predicting the area under cultivation in Tumkur and Chitradurga districts. In contrast, the quadratic model was more suitable for predicting production trends across these districts, though with moderate R² values and considerable variability. The findings highlight key challenges, such as fluctuations in area and production, that affect groundnut farming in Karnataka. Despite being major contributors, these districts face uncertainties that need focused attention. This study underscores the importance of stabilizing production by addressing these fluctuations to ensure consistent productivity. These insights will aid in future agricultural strategies aimed at enhancing the long-term sustainability of groundnut farming in the state.

Future Line of Research and Recommendation

This study aims to facilitate informed policy decisions regarding the implementation of innovative agricultural policies to enhance production and productivity. Based on these findings, the researcher will be equipped to undertake future research projects at a multicentric level. It is advisable for policy decisions regarding groundnut producers, supported by a substantial number of studies.

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