International Journal of Statistics and Applied Mathematics 2024; 9(1): 90-97

International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2024; 9(1): 90-97

https://www.mathsjournal.com
Received: 16-11-2023
Accepted: 19-12-2023

Ragini HR
Ph.D. Scholar, Department of Agricultural Statistics, Uttar Banga Krishi Viswavidyalaya, West Bengal, India

Harshith KV
Dept. of Agril. Statistics, Applied Mathematics & Computer Science, CoA, UAS, GKVK, Bengaluru, India

Corresponding Author:
Ragini HR
Ph.D. Scholar, Department of Agricultural Statistics, Uttar Banga Krishi Viswavidyalaya, West Bengal, India

Identifying existing pattern in area and production of major food grains in Karnataka using linear and non-linear statistical models

Ragini HR and Harshith KV

DOI: https://dx.doi.org/10.22271/maths.2024.v9.i1b.1615

Abstract
The study was carried out across all the districts of Karnataka. The secondary data on area and production of major food grains of all the districts for the duration from 1950-2019 will be collected from 'Karnataka at a Glance' published by the Directorate of Economics and Statistics, Government of Karnataka, Bangalore. To analyse the trends in area and production of major food grains (Paddy, Jowar, Bajra, Ragi) of Karnataka using linear, cubic, exponential and log-logistic model. The best fit model was selected based on the minimum value of RMSE. Exponential model was found to be the best fit model for area and production for Bajra, Ragi, area and production had linear growth for Paddy, Jowar had exponential growth over area and linear growth over production crops during 1950 to 2019.

Keywords: Cubic model, exponential model, linear model, log-logistic model, trends

1. Introduction
Karnataka's Department of Agriculture is devoted in servicing the farming community. The Department of Agriculture launched a variety of projects in 2018-19 to increase total agricultural productivity. Agriculture sector employs the vast majority of people in Karnataka. Rice is the most important food crop on the coastal plain, followed by jowar and ragi.
India is second in the world in terms of cereal production and consumption, including paddy. Paddy is sensitive to a wide range of illnesses and insect pests that cause significant losses. Karnataka is one of the country's top 10 paddy-producing states (Lamani and Thimmaiah, 2022) [5]. The largest paddy arrival markets in Karnataka are Gangavati, Sindhanur, Bhadravati, Davanagere, K R Nagar, Raichur, Shivamogga, and Siruguppa (Acharya *et al*., 2012) [1]. Jowar, also known as Sorghum, is an important food and fodder grain crop grown throughout India. After rice and wheat, it is the third most important sustenance crop in terms of both territory and output. Maharashtra, Karnataka, Madhya Pradesh, are the top three Jowar producing states in India. Maharashtra is the leading producer of Jowar in India, accounting for about half of total Jowar output (2109 thousand tonnes in 2014-15). Karnataka is India's second largest producer of jowar, with 1174 thousand tonnes produced in 2014-15. Bajra is the second most important millet, and it is used as a source of nutrition in the country's arid regions. It is also commonly used as fodder, since its stalks are given to cattle. Rajasthan is India's primary producer of Bajra. It produced 44.56 thousand tonnes in 2014-15. In the same crop year, Karnataka ranked seventh with 248 thousand tonnes, followed by Tamil Nadu (178 thousand tonnes). Ragi is popularly referred to as Finger Millet. It is a grain crop that grows alongside wheat, maize, and rice. This grain is used as a staple food. It is a dry land crop that is grown in both tropical and subtropical climates. It is largely farmed in Karnataka, Tamil Nadu, and Maharashtra in India. Karnataka was India's leading producer of Ragi in 2014-15, producing 1298 thousand tonnes. Tamil Nadu, which produces 350 thousand tonnes of ragi in 2014-15, is the second largest producer after Karnataka (Shamim, 2022) [9].
Trend analysis refers to methods for extracting an underlying pattern of behaviour in a time series that may otherwise be masked by noise (Mithiya *et al*., 2018) [7].

Trend analysis may be performed inside a formal regression analysis if the trend is linear, as stated in Trend estimate. Trend analysis is the process of collecting data and looking for patterns. In several fields of study, the phrase "trend analysis" has more precisely defined meanings. Although trend analysis is commonly used to anticipate future events, it may also be used to evaluate unclear past events. An attempt is made in this research to investigate the trend in area, production of major food grains in Karnataka.

2. Materials and Methods

The objective of this study is to identifying existing patterns in area and production of major food grains in Karnataka using linear and non-linear statistical models.

2.1 Description of the study area

Karnataka has a varied climate. The state encounters three sorts of environment: arid, semi-arid and humid tropical. The environment changes from one spot to another because of the area's elevation, geography and the separation from the ocean. The southwest monsoon provides most precipitation to the state.

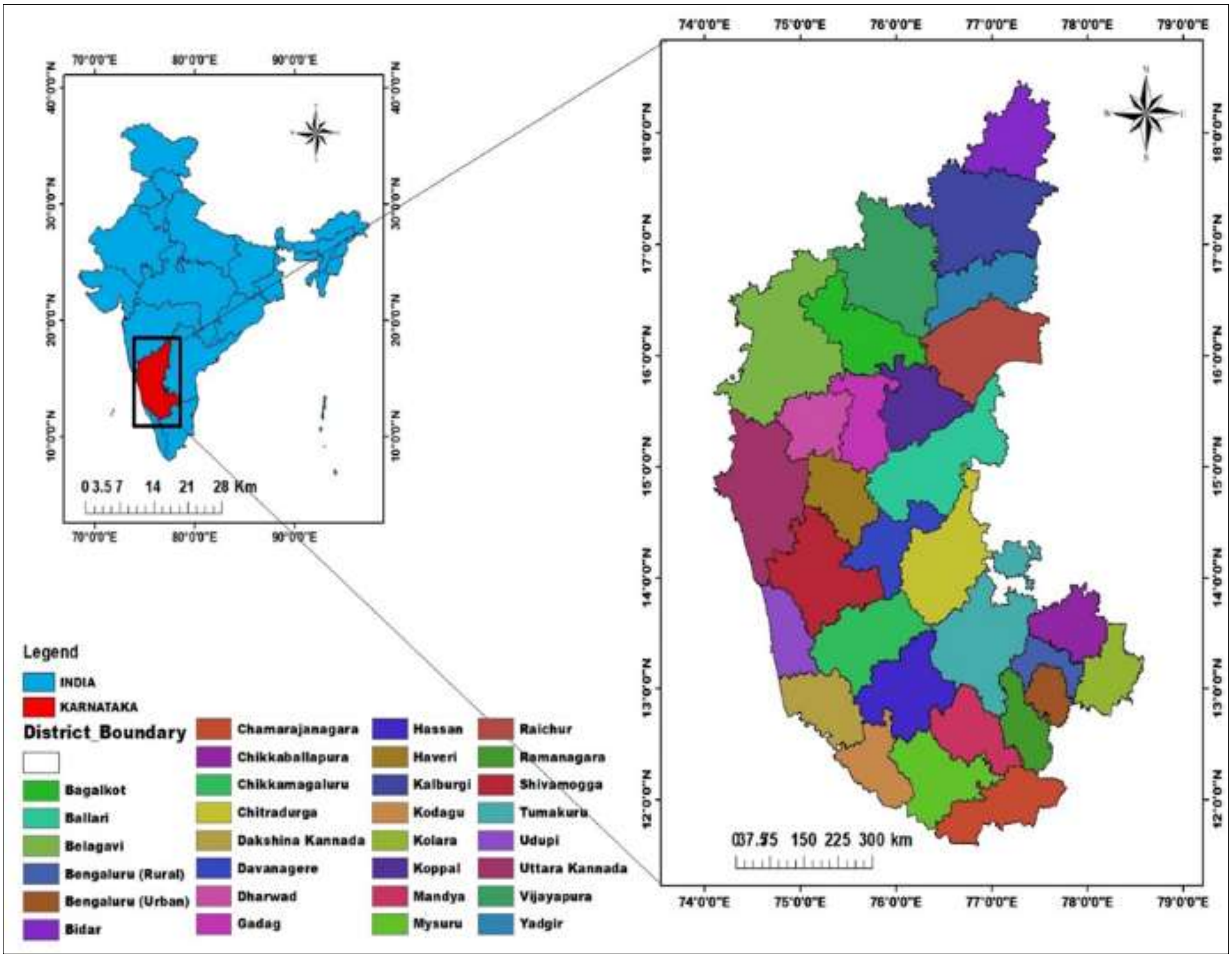

Fig 1: Geographical Map of Karnataka state (Study area)

2.2 Nature and source of data

The secondary data on area and production of selected Principal crops of all the districts of Karnataka for the duration 1950-2019 were collected from the reports of ‘Karnataka at a Glance’ published by the Directorate of Economics and Statistics, Government of Karnataka, Bangalore.

2.3 Methodologies used for the analysis of the data.

2.3.1 Linear and Non-Linear Models

For estimating the long-term trend of area, production and productivity, the method of least squares estimation has been employed. In this method, trend in area, production and productivity is measured by establishing mathematical relation between time and the response variable, which is depending on time. The mathematical expression can be represented by (Pázman, 2013) [8]:

1. Linear (Straight line) $Y_t = \alpha + \beta t + \varepsilon$ (1)
2. Cubic $Y_t = \alpha + \beta t + kt^2 + \gamma t^3 + \varepsilon$ (2)

Where, α: Intercept or Average effect
β, k, γ: Slope or Regression Coefficients (β= linear effect parameter, k: Quadratic effect parameter and γ: cubic effect parameter)
Y_t: Area, production or productivity in time period t
ε: Error term or disturbance term

The above linear models fitted by using ‘lm’ function of R studio
Coefficients α, β, k and γ are constant parameters are need to be estimated. Here, the relation is so derived that the sum of the squared deviations (errors) of the observed values from the theoretical values is least. 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 rate analyze are also widely employed to describing the long-term trend in variables over time in various agricultural crops. Growth models are generally 'mechanistic' and the parameters have meaningful biological interpretation (Das, 2000) [3].

The following are the two nonlinear growth curves, which were used to describe the growth of present time-series (Debnath, 2016) [4].

3. Exponential $Y_t = \alpha e^{ct} + \varepsilon$ (3)

where, Y_t represents area, production or productivity in time period *t*

α and *c* are parameters, *e* is the exponential term, and ε denotes the error term.

Here, α represents the value at *t* = 0, *c* represents the exponential rate

4. Log-logistic $Y_t = \frac{\alpha}{1+\exp[-\beta\{|\log(t)-\log(\gamma)|\}]} + \varepsilon$ (4)

where, Y_t represents area, production or productivity in time period *t*

α, β and γ are parameters and

ε denotes the error term.

The parameter 'γ' is the 'intrinsic growth rate', while the parameter 'α' represents the 'upper asymptote' and 'β' is the growth range.

It may be noted that both the above growth models are 'nonlinear', which involves at least one parameter in a nonlinear manner. Exponential model was fitted by using 'SSexpf' function of the package named 'nlraa' in R. The model loglogistic was fitted by using 'loglogistic' function of the package 'growth models' in R.

2.3.2 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:

$$W = \frac{\left[\sum_{i-1}^{n} a_i x_{(i)}\right]^2}{\sum_{i-1}^{n}(x-\bar{x})^2} \quad (5)$$

where, $x_{(i)}$is the i^{th}order statistic, *i.e.* the i^{th} smallest number in the sample;

$\bar{x}$is sample mean and the constants $a_i$is given by

$$(a_1, a_2, \cdots, a_n) = \frac{m^T V^{-1}}{\sqrt{(m^T V^{-1} V^{-1} m)}} \quad (6)$$

Where $m^T = (m_1, m_2, \cdots, m_n)^T$ and $m_1, m_2, \cdots, m_n$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 (Shapiro *et al*., 1968) [10]. Reject the null hypothesis if *W* is too small (near to zero).

2.3.3 Model Adequacy Checking

2.3.3.1 The coefficient of determination (R^2):

The coefficient of determination (R^2) is a test statistic that will give information about the appropriateness of a model. R^2 value is the proportion of variability in a data set that is accounted for by the statistical model. It provides a measure of how well the assumed model explains the variability in dependent variable.

$$R^2 = \frac{RSS}{TSS} = 1 - \frac{ESS}{TSS} \quad (7)$$

Where,

ESS is error sum of squares.

RSS is regression sum of squares.

TSS is 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 of the fit of model.

2.3.3.2 Adjusted R^2

The adjusted R^2 is a modified version of R^2 that has been adjusted for the number of predictors in the model. The adjusted R^2 increases only if the new term improves the model more than would be expected by chance. It decreases when a predictor improves the model by less than expected by chance. The adjusted R^2 can be negative, but it's usually not. It is always lower than the R^2 (Basavaraj et al., 2020) [2].

$$Adjusted\ R^2 = \frac{RSS/_{df}}{TSS/_{df}} \quad (8)$$

Where,

RSS is regression sum of squares.

TSS is total sum of squares.

df is the respective degrees of freedom

2.3.3.3 Root Mean Square Error (RMSE)
The Root Mean Square Error (RMSE) (also called the root mean square deviation, RMSD) is used to assess the amount of variation that the model is unable to capture in the data. The RMSE is obtained as the square root of the mean squared error hence considered as the model prediction capability and is obtained as

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Y_t - \widehat{Y}_t)^2}{n}} \quad (9)$$

Where,
Y_t = observed value
$\widehat{Y}_t$ = predicted value
n= number of observations

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

$$AIC = 2K - 2\,ln(L) \quad (10)$$

where, K – Number of independent variables, L – Log-likelihood estimate
AIC is calculated for each model and then the model with lowest value is selected and considered as the best fit for the data.

2.3.3.5 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 is closely related to AIC. It is named after the field of study from which it was derived *i.e.*, Bayesian probability and inference. Like 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 in overfitting. The BIC resolves this problem by introducing a penalty term for the number of parameters in the model. The penalty term is larger in BIC than in AIC.
The formula for BIC is

$$BIC = Kln(n) - 2ln(L(\theta)) \quad (11)$$

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

The models are compared by calculating BIC for each model and then the model with lowest BIC is considered the best. Lower BIC value indicates lower penalty terms hence a better model (Lathika and Ajith Kumar, 2005) [6].
Though these two measures are 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.

3. Results and Discussion
To identifying existing patterns in area and production of major food grains of Karnataka. Time series components are likely to exhibit a distinct trend to rise or decrease over time. This is referred to as a trend. For the examination of trends in area and production of major food grains, data from 1950 to 2019 was used for the crops Paddy, Jowar, Bajra, Ragi respectively (Table 1). Furthermore, independent analysis is performed with regard to the selected food grains for the districts under investigation.

Table 1: Distribution of selected principal crops for area, production and productivity in Karnataka

Paddy Crop			
Study period	**Area (ha)**	**Production (tonnes)**	**Productivity (tonnes/ha)**
1950-1985	1409797	5768534	4.080
1986-2019	1342105	5194376	4.377
Overall	1375951	5481455	4.229
Jowar Crop			
1950-1985	1350117	1345065	0.996
1986-2019	1077065	1035382	0.963
Overall	1213591	1190224	0.979
Bajra Crop			
1950-1985	314360	195969	0.560
1986-2019	232288	234905	0.994
Overall	273324	215437	0.777
Ragi Crop			
1950-1985	778639	1252794	1.291
1986-2019	668773	1001680	1.457
Overall	723706	1127237	1.374

3.1 Trend analysis of the Area and Production of major food grains
The parameter estimates of all the fitted models and their standard errors for the area of major food grains i.e., Paddy, Jowar, Bajra, Ragi from the year 1950 to 2019. Statistical significance of the parameters of the linear, cubic. log logistic and exponential model was determined by evaluating student t-test, and remaining models were determined by computing the 95 per cent asymptotic confidence intervals of the estimated parameters. If the estimated parameter of the fitted model lies within the 95 per cent confidence interval indicates that the parameter values are significant at 5 per cent level of significance. The main assumption of normality of error terms of each model were examined by using "Shapiro-Wilk test",

and test statistic along with probability values are presented in tables given below Among all the good fit models, the best-fitted model was selected based on the minimum MAPE value. As measures of accuracy, the MAPE was computed for all the models presented in tables given below.

3.1.1 Trends in Area of Paddy crop in Karnataka for the period of 1950-2019- Parameters and Global Statistics of the models fitted.

The results obtained in Table 2 revealed that parameters of linear and exponential models are found to be significant at 5 per cent level of significance, and some of the parameters of log logistic was found to be non-significant. Further, results from Table 2 also revealed that for the models linear and exponential, the Shapiro-Wilk test statistic was found to be non-significant (*p*>0.05) indicating normality of residuals being satisfied. Only for those models, in which all the parameters are found to be significant and assumptions of 'normality of residuals' are satisfied were considered as good, fitted models. Therefore, linear and exponential were well fitted to the data on area of paddy. The lowest value of MAPE (7.49) indicated that linear model performed better than the exponential model with MAPE value (7.55). Hence, the data of paddy area has linear growth over the years from 1950 to 2019.

Table 2: Trends in area of paddy crop in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	R^2	Adj. R^2
Linear	1522811**	-29105**			0.485	0.442
Cubic	1431912**	9149	-3419	65.94	0.513	0.367
Log Logistic	1.074e+06	1.077e+01	2.413e+01	1.387e+06	0.564	
Exponential	1.531e+06**	-2.186e-02**			0.475	
Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	373.366	375.28	0.94^{NS} (0.46)	0.00^{NS} (1)	120729	7.494
Cubic	376.586	379.78	0.92^{NS} (0.22)	0.55^{NS} (0.57)	117409	7.221
Log Logistic	375.033	378.22	0.92^{NS} (0.26)	0.55^{NS} (0.57)	111075	6.556
Exponential	373.631	375.54	0.95^{NS} (0.58)	0.00^{NS} (1)	121874	7.552

**Significant at 1%, *Significant at 5%, Values in the parenthesis indicate p-value, NS-Non-Significant

3.1.2 Trends in Area of Jowar crop in Karnataka for the period of 1950-2019 - Parameters and Global Statistics of the models fitted

The results obtained in Table 3 revealed that parameters of linear and exponential models are found to be significant at 5 per cent level of significance, and some of the parameters of cubic and log logistic models were found to be non-significant. Further, results from Table 4.6 also revealed that for the models linear and exponential, the Shapiro-Wilk test statistic was found to be non-significant (*p*>0.05) indicating normality of residuals being satisfied. Only for those models, in which all the parameters are found to be significant and assumptions of 'normality of residuals' are satisfied were considered as good fitted models. Therefore, linear and exponential were well fitted to the data on area of Jowar. The lowest value of MAPE (4.22) indicated that exponential model performed better than the linear model with MAPE value (4.48). Therefore, exponential model was found to be the best-fitted model. Hence, the data of Jowar area has an exponential growth over the years from 1950 to 2019.

Table 3: Trends in Area of Jowar crop in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	R^2	Adj. R^2
Linear	1514929**	-40178**			0.884	0.875
Cubic	1526627.2**	-28907.2	-4018.4	247.8	0.906	0.879
Log Logistic	2.0656e+00	7.8269e+00	1.4944e+06**	8.4741 e+05*	0.903	
Exponential	1.546e+06**	-3.352e-02**			0.895	
Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	353.059	354.976	0.95^{NS} (0.67)	0.5^{NS} (0.57)	58455	4.482
Cubic	354.069	357.264	0.95^{NS} (0.59)	0.11^{NS} (0.26)	52535	3.931
Log Logistic	354.626	357.821	0.97^{NS} (0.95)	0.55^{NS} (0.57)	53591	3.905
Exponential	351.628	353.545	0.95^{NS} (0.59)	1.11^{NS} (0.26)	55544	4.224

**Significant at 1%, *Significant at 5%, Values in the parenthesis indicate p-value, NS-Non-Significant

3.1.3 Trends in Area of Bajra crop in Karnataka for the period of 1950-2019 - Parameters and Global Statistics of the models fitted

The results obtained in Table 4 revealed that parameters of exponential model is found to be significant at 5 per cent level of significance, and of the parameters of linear, cubic and log logistic were found to be non-significant. Further, results from Table 4 also revealed that for the fitted exponential model, the Shapiro-Wilk test statistic was found to be non-significant (*p*>0.05) indicating normality of residuals were satisfied. Only for the model, in which all the parameters are found to be significant and assumptions of 'normality of residuals' are satisfied was considered as good fitted models. Therefore, exponential was well fitted to the data on area of Bajra. The value of MAPE (13.31) indicated that exponential model performed better. Therefore, exponential model was found to be the best-fitted model. Hence, the data of Bajra area has exponential growth rate over the years from 1950 to 2019.

Table 4: Trends in Area of Bajra crop in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	**R²**	**Adj. R²**
Linear	352925**	-10614			0.387	0.336
Cubic	227912.5*	64893.6	-11006.9	453.0	0.525	0.382
Log Logistic	1.927e+05	4.810e+00	8.701e+00	3.249e+05	0.446	
Exponential	3.571e+05**	-3.705e-02*			0.370	
Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	350.738	352.655	0.92^{NS} (0.29)	0.55^{NS} (0.57)	53805	12.953
Cubic	351.170	354.365	0.97^{NS} (0.94)	0.55^{NS} (0.57)	47368	13.734
Log Logistic	353.311	356.506	0.95^{NS} (0.67)	0.55^{NS} (0.57)	51132	12.701
Exponential	351.121	353.038	0.93^{NS} (0.31)	0.55^{NS} (0.57)	54547	13.317

**Significant at 1%, *Significant at 5%, Values in the parenthesis indicate p-value, NS-Non-Significant

3.1.4 Trends in Area of Ragi crop in Karnataka for the period of 1950-2019 - Parameters and Global Statistics of the models fitted

The results obtained in Table 5 revealed that parameters of linear and exponential models are found to be significant at 5 per cent level of significance, and some of the parameters of cubic and log logistic model were found to be non-significant. Further, results from Table 4.8 also revealed that for the models linear and exponential, the Shapiro-Wilk test statistic was found to be non-significant (p>0.05) indicating normality of residuals being satisfied. Only for those models, in which all the parameters are found to be significant and assumptions of 'normality of residuals' are satisfied were considered as good fitted models. Therefore, linear and exponential were well fitted to the data on area of Ragi. The lowest value of MAPE (9.20) indicated that exponential model performed better than the linear model with MAPE value (9.23). Therefore, exponential model was found to be the best-fitted model. Hence, the data of ragi area has a exponential growth over the years from 2005 to 2018.

Table 5: Trends in Area of Ragi crop in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	**R²**	**Adj. R²**
Linear	834708**	-14800*			0.335	0.279
Cubic	891845.8**	-48997.2	4944.3	-202.1	0.347	0.152
Log Logistic	6.6876e+05	3.1727e+01**	6.5036e+00**	7.9665e+05**	0.360	
Exponential	8.416e+05**	-2.058e-02*			0.337	
Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	363.226	365.143	0.95^{NS} (0.64)	1.11^{NS} (0.26)	84048	9.232
Cubic	366.956	370.151	0.94^{NS} (0.50)	1.11^{NS} (0.26)	83241	9.180
Log Logistic	366.672	369.868	0.95^{NS} (0.70)	0.00^{NS} (1)	82403	8.479
Exponential	363.184	365.101	0.95^{NS} (0.62)	1.11^{NS} (0.26)	83921	9.209

**Significant at 1%, *Significant at 5%, Values in the parenthesis indicate p-value, NS-Non-Significant

3.1.5 Trends in Production of Jowar crop in Karnataka for the period of 1950-2019 - Parameters and Global Statistics of the models fitted

The results obtained in Table 6 revealed that parameters of linear and exponential models are found to be significant at 5 per cent level of significance, and the parameters of cubic and log logistic models was found to be non-significant. Further, results from Table 6 also revealed that for the models linear and exponential, the Shapiro-Wilk test statistic was found to be non-significant (p>0.05) indicating normality of residuals being satisfied. Only for those models, in which all the parameters are found to be significant and assumptions of 'normality of residuals' are satisfied were considered as good fitted models. Therefore, linear and exponential models were well fitted to the data on production of Jowar. The value of MAPE (10.99) indicated that linear model performed better than the exponential model with MAPE value (11.03). Therefore, linear model was found to be the best-fitted model. Hence, the data of Jowar production has a linear growth over the years from 1950 to 2019.

Table 6: Trends in Production of Jowar in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	R^2	Adj. R^2
Linear	1515320**	-43346**			0.517	0.477
Cubic	1301700.2**	111193.6	-25832.9	1177.7	0.578	0.451
Log Logistic	9.7448e+05**	5.4664e+00	6.7077e+00**	1.4360e+06**	0.576	
Exponential	1.547e+06**	-3.643e-02**			0.518	
Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	382.722	384.639	0.94^{NS} (0.53)	0.00^{NS} (1)	168625	10.991
Cubic	384.849	388.044	0.95^{NS} (0.64)	1.11^{NS} (0.26)	157715	11.643
Log Logistic	384.895	388.091	0.95^{NS} (0.65)	0.55^{NS} (0.57)	157975	11.653
Exponential	382.706	384.628	0.95^{NS} (0.70)	0.55^{NS} (0.57)	168530	11.038

**Significant at 1%, *Significant at 5%, Values in the parenthesis indicate p-value, NS-Non-Significant

3.1.6 Trends in Production of Bajra crop in Karnataka for the period of 1950-2019 - Parameters and Global Statistics of the models fitted

The results obtained in Table 7 revealed that parameters of exponential model is found to be significant at 5 per cent level of significance, and the parameters of linear, cubic and log logistic models was found to be non-significant. Further, results from Table 7 also revealed that for the exponential model, the Shapiro-Wilk test statistic was found to be non-significant (p>0.05) indicating normality of residuals being satisfied. Only for those models, in which all the parameters are found to be significant and assumptions of 'normality of residuals' are satisfied were considered as good fitted models. Therefore, exponential model was well fitted to the data on production of Bajra. The value of MAPE (33.32) indicated that exponential model performed better. Therefore, exponential model was found to be the best-fitted model. Hence, the data of Bajra production has an exponential growth over the years from 1950 to 2019.

Table 7: Trends in Production of Bajra in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	R^2	Adj. R^2
Linear	159760*	7424			0.106	0.031
Cubic	-40269.1	116012.9	-14245.4	531.3	0.319	0.115
Log Logistic	9.6161e+03	-1.8811e+01	1.9227e+00**	2.3701e+05***	0.433	
Exponential	1.704e+05**	3.037e-02*			0.093	
Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	364.108	366.025	0.96^{NS} (0.87)	-0.55^{NS} (0.57)	86739	33.208
Cubic	364.286	367.481	0.95^{NS} (0.61)	0.55^{NS} (0.57)	75670	31.127
Log Logistic	361.732	364.927	0.96^{NS} (0.83)	-0.55^{NS} (0.57)	69074	22.907
Exponential	87352.801	366.223	0.97^{NS} (0.94)	-0.55^{NS} (0.57)	87352	33.322

**Significant at 1%, *Significant at 5%, Values in the parenthesis indicate p-value, NS-Non-Significant

3.1.7 Trends in Production of Ragi crop in Karnataka for the period of 1950-2019 - Parameters and Global Statistics of the models fitted

The results obtained in Table 8 revealed that parameters of exponential model found to be significant at 5 per cent level of significance, and the parameters of linear, cubic and log logistic models was found to be non-significant. Further, results from Table 8 also revealed that for the exponential model, the Shapiro-Wilk test statistic was found to be non-significant (p>0.05) indicating normality of residuals being satisfied. Only for those models, in which all the parameters are found to be significant and assumptions of 'normality of residuals' are satisfied were considered as good fitted models. Therefore, exponential models were well fitted to the data on production of Ragi. The value of MAPE (23.85) indicated that exponential model performed better. Therefore, exponential model was found to be the best-fitted model. Hence, the data of Ragi production has an exponential growth over the years from 1950 to 2019.

Table 8: Trends in Production of Ragi in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	R^2	Adj. R^2
Linear	1357736**	-30733			0.117	0.043
Cubic	1390984.7*	-78602.5	10577.7	-560.1	0.129	-0.131
Log Logistic	-3.0556e+05**	2.8331e-01	2.4381e+01*	2.0973e+06**	0.108	
Exponential	1.369e+06**	-2.662e-02*			0.114	
Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	402.38	404.25	0.93^{NS} (0.38)	1.11^{NS} (0.26)	339886	23.32
Cubic	406.14	409.33	0.94^{NS} (0.48)	1.11^{NS} (0.26)	337468	22.80
Log Logistic	406.42	409.68	0.91^{NS} (0.19)	1.11^{NS} (0.26)	341641	24.28
Exponential	402.33	404.30	0.93^{NS} (0.35)	1.11^{NS} (0.26)	340427	23.85

**Significant at 1%, *Significant at 5%, Values in the parenthesis indicate p-value, NS-Non-Significant

4. Summary and Conclusion

The analysis identifies the linear model as the best fit for Paddy's area and production, with minimum MAPE values of 7.49 and 11.04, respectively. Additionally, the linear and exponential models for Paddy and Jowar show significant parameters and meet residual assumptions. Over the study period from 1950 to 2019, Paddy exhibits a constant trend in area and a decreasing trend in production, while Jowar displays decreasing trends in both area and production. For Jowar, the exponential model with a minimum MAPE value of 4.22 for area and the linear model with a minimum MAPE value of 10.99 for production are deemed the best fits. Similar to Paddy, the parameters of the models for Jowar meet assumptions, and the trends over the study period remain consistent. Moreover, the analysis highlights the exponential models as the best fits for Bajra and Ragi, with varying MAPE values. Bajra shows decreasing trends in area and increasing trends in production, while Ragi demonstrates decreasing trends in both area and production from 1950 to 2019. The parameters of the exponential models for both crops satisfy residual assumptions.

The present investigation scrutinized the trends and patterns in the area and production of key food grains on a state-wide scale. Over time, the cropping patterns in Karnataka have undergone significant transformations. Enhanced practices in soil and water management, profitable crop rotation techniques, innovative marketing strategies, advancements in genetic engineering, and substantial investments in farm education and rural infrastructure collectively possess the capacity to amplify agricultural output.

5. Reference

1. Amin AA, Gergis MF. Integrated management strategies for control of cotton key pests in middle Egypt. Agron Res. 2006;4:121-128.
2. Anonymous. Area, Production and Productivity of cotton in India. The Cotton Corporation of India [Internet]. Available from: https://cotcorp.org.in/statistics.aspx. Accessed on 20/4/21.
3. Anonymous. Top 10 Cotton Producing Countries. [Internet]. Available from: https://en.wikipedia.org/wiki/Cotton#Leading_producer_countries. Accessed on 22/4/21.
4. Banerjee SK. Estimation of losses due to major pest of cotton. CICR, Annual Report 2001-2002; c2002. p. 54-55.
5. Davidson RH, Lyon WF. Insect pests of farm, garden and orchard; c1978. p. 112-113.
6. Kaushik UK, Rathor VS, Sood NK. Incidence of bollworms and losses caused to cotton in Madhya Pradesh. Indian J Entomol. 1987;31(2):175-177.
7. Patil VN. Assessment of avoidable field losses caused by sucking pest and bollworm of cotton [M.Sc. Thesis]. Akola: Dr. P.D.K.V.; c1987. p.87-88.
8. Pradhan S. Insects pests of crops. New Delhi, India: National Book Trust; c1969. p.80.