Original Research Article

Performance Evaluation of Predictive Models for Coconut Crop Production in Karnataka Using Weather Parameters

ABSTRACT

In Karnataka, growing coconuts is one of the main industries supporting the state's farmers. The Directorate of Economics and Statistics reports that 3.38 billion nuts were produced on 0.42 million hectares of coconut agriculture in Karnataka in 2019–20, with an average yield of 8,095 nuts per hectare. After Tamil Nadu and Kerala in terms of coconut production and area, Karnataka comes in third place in India. In this study, the production and trends of the coconut crop in Karnataka were assessed using log-logistic, cubic, exponential, and linear models. The model that fit the data the best was the one with the lowest RMSE. The coconut crop showed cubic growth in area and linear growth in production between 1950 and 2019. Furthermore, an evaluation of the prediction model was analyzed with the following independent variables: area, rainfall, temperature (highest and lowest), relative humidity, and coconut production as the dependent variable. MLR and SMLR were used in this evaluation. Both the stepwise regression estimates and the MLR estimates for relative humidity (RH) and minimum temperature (T) were negative. These findings imply that the production of coconut crop is negatively or inversely affected by RH and T.

Keywords: Trends,Log-logistic, SMLR (Stepwise Multiple Linear Regression), Relative Humidity (RH),Temperature, Adverse, Inverse, Production.

1. INTRODUCTION

Coconut is an important crop in India, especially in the southern states. According to the Ministry of Agriculture and Farmers Welfare, India has an area of 2.15 million hectares under coconut cultivation, producing 19.31 billion nuts with an average productivity of 8,966 nuts per hectare [5]. India ranks third in the world in terms of coconut area and production, after Philippines and Indonesia [4]. Some of the major coconut producing states in India are Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Odisha, and West Bengal. Kerala alone accounts for 35.5% of the total area and 28.6% of the total production of coconut in India. Coconut cultivation provides livelihood to more than 12 million people in India. According to a study by the Coconut Development Board, the average cost of cultivation of coconut in India was Rs. 1,20,000 per hectare and the average net income was Rs. 1,44,000 per hectare in 2019-20. The study also found that the highest net income was obtained in Tamil Nadu and the lowest in Tripura [1].

Coconut is a versatile crop that can be used for various purposes such as food, oil, fiber, fuel, cosmetics, and medicine. Some of the by-products obtained from coconut are copra, coconut oil, coconut milk, coconut water, coconut shell, coir, coir pith, and activated carbon. These by-products have a high demand in the domestic and international markets and contribute to the income of the coconut farmers. Coconut cultivation in Karnataka is one of the major sources of income for the farmers in the state. According to the Directorate of Economics and Statistics, Karnataka has an area of 0.42 million hectares under coconut cultivation, producing 3.38 billion nuts with an average productivity of 8,095 nuts per hectare in 2019-20. Karnataka ranks third in India in terms of coconut area and production, after Kerala and Tamil Nadu [2].

The economics of coconut cultivation in Karnataka depends on various factors such as the cost of inputs, the yield of nuts, the price of nuts, and the by-products obtained from coconut. According to a study by the Coconut Development Board, the average cost of cultivation of coconut in Karnataka was Rs. 1,10,000 per hectare and the average net income was Rs. 1,60,000 per hectare in 2019-20. The study also found that the highest net income was obtained in Dakshina Kannada and the lowest in Chitradurga. Some of the by-products obtained from coconut in Karnataka are copra, coconut oil, coconut milk, coconut water, coconut shell, coir, coir pith, and activated carbon. These by-products have a high demand in the domestic and international markets, and contribute to the income of the coconut farmers [4].

Trend analysis and predictive modelling are important tools for agriculture production and area, as they help farmers and policymakers to make informed decisions based on data and evidence. Trend analysis is the process of examining historical data to identify patterns, changes, and relationships over time. Predictive modelling is the process of using statistical methods to create models that can predict the outcomes based on current and historical data. Trends and predictive modelling can help optimize the production and use of inputs, such as seeds, fertilizers, pesticides, water, and energy, by predicting the optimal amount, timing, and location of these inputs based on crop, soil, and weather conditions [6]. They can also improve the resilience and adaptation of agriculture to climate change, by forecasting the impacts of extreme weather events, such as droughts, floods, heat waves, and pests, on crop yields and quality, and suggesting mitigation and adaptation strategies. Enhancing the profitability and sustainability of agriculture, by estimating the market demand and supply of agricultural products, and predicting the prices and revenues of these products, and providing guidance on crop diversification, value addition, and risk management [9].

2. MATERIAL AND METHODS

The goal of this research is to identify existing patterns in the area and production of coconut agriculture in Karnataka, as well as to assess the performance of predictive models for coconut production based on area and meteorological characteristics. The following sections provide information about the materials and procedures used in the study.

2.1 Nature and source of the data

The secondary data on the area and production of Coconut crop in each district (Fig.1) for the years 1950–2019 were gathered from the "Karnataka at a Glance" reports that were released by the Government of Karnataka, Bangalore, through the Directorate of Economics and Statistics. The University of Agricultural Sciences, Bangalore's AICRP on Agrometeorology is the source of the data on numerous weather parameters.

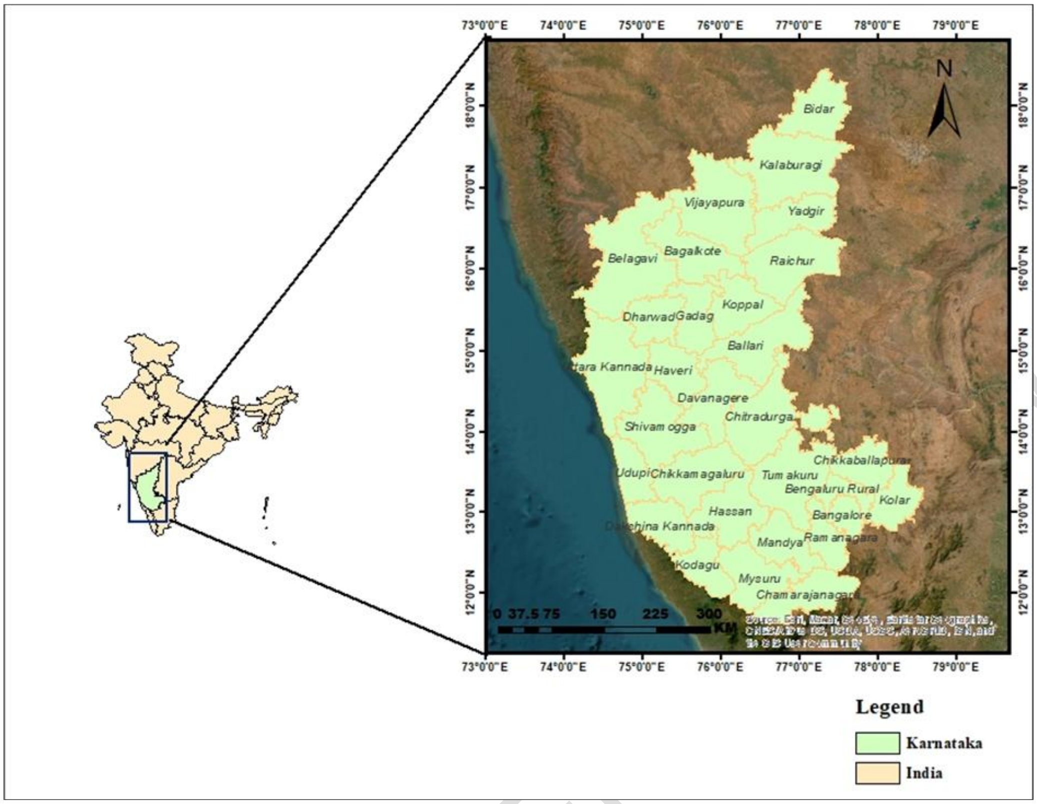

Fig.1. Geographical Map of Karnataka state (Study area)

2.2Methodologies used for the analysis of the data

2.2.1 Linear and Non-Linear Models

Less squares estimation is the method used to estimate the long-term trend of productivity, production, and area. Through the mathematical relationship that is established between time and the time-dependent response variable, this method measures the trend in area, production, and productivity. Here is one way to represent the mathematical expression:

Linear model (Straight line) $Y_t = \alpha + \beta t + \varepsilon$

Cubic model $Y_t = \alpha + \beta t + kt^2 + \gamma t^3 + \varepsilon$

Where,α: Intercept or Average effect

$\beta,\ k, \gamma$: Slope or Regression Coefficients (β= linear effect parameter,

k: Quadratic effect parameter and γ: cubiceffect 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.Coefficients α, β, k and $\gamma$are constant parameters 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[8].

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 rates 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 [7].
The following are the two nonlinear growth curves, which were used to describe the growth of present time-series.

Exponential $$Y_t = \alpha e^{ct} + \varepsilon$$

Where,

Y_t represents area, production or productivity in time period *t*
α and *c* are parameters,
e is theexponential term, and
ε denotes the error term.

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

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

Where,

Y_t represents area, production or productivity in time period *t*
α, *β* and $\gamma$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.

2.2.2 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:

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

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,

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

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 [11].Reject the null hypothesis if *W* is too small (near to zero).

2.2.3Multiple Linear Regression Model

Multiple Linear Regression is (MLR) is an extension of simple linear regression model. The data consist of *N* observations on a response variable *Y* and *p* regressor variables *viz.*X_1, $X_2, \dots, X_p$. The relationship between *Y* and X_1, $X_2, \dots, X_p$ is put together as a linear model,

$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_p X_p + \varepsilon$$

Where, $\beta_0, \beta_1, \dots, \beta_p$ are the parameters considered as the regression coefficients and ε represents the error in the model. It is assumed that *Y* is approximately a linear function of the *X*'s and ε measures the discrepancy in that approximation [3].

2.2.4Model Adequacy Checking

A.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.

$$R^2 = \frac{RSS}{TSS} = 1 - \frac{ESS}{TSS}$$

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.

B. 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^2can be negative, but it's usually not. It is always lower than the R^2.

$$Adjusted\ R^2 = \frac{RSS/_{df}}{TSS/_{df}}$$

Where,

RSS is regression sum of squares.
TSS is total sum of squares.
df is the respective degrees of freedom.

c. 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

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

Where,

Y_t = observed value.
$\widehat{Y_t}$ = predicted value.
n= number of observations

D. 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 most often used for model selection.
The formula for AIC is.

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

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.

E. 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.

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

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[10].

.

3. RESULTS AND DISCUSSION

This chapter presents and discusses the results of the study considering the objectives. The chapter is divided into two sections, each corresponding to one of the objectives. The first section aims to identify the existing patterns in the area and production of coconut crop in Karnataka.The second section evaluate the predictive models of coconut production based on area and weather parameters.

3.1 To identify the existing patterns in the area and production of coconut crop in Karnataka.

The time series components of area and production of coconut crop may show a clear trend of increasing or decreasing over time. This study examines the trends in the data from 1950 to 2019. Additionally, it conducts separate analysis for each district under investigation.

Table 1. Distribution of Coconut for area, production, and productivity in Karnataka

Coconut Crop			
	Area (ha)	Production (tonnes)	Productivity (Tonnes/ha)
1950-1985	419688	2836508	5.059
1986-2019	463548	3637416	4.973
Overall	441618	3236962	5.016

<u>3.1.1 Analysis of Trends in area and production for coconut crop of Karnataka</u>

For the crop period from 1950-2019, linear and nonlinear models were used to assess the changes in the area and production for Coconut crop in Karnataka. Statistical significance of the parameters of the linear, cubic, log logistic, and exponential models was determined by evaluating student t-tests, and the remaining models were determined by computing the 95% asymptotic confidence intervals of the estimated parameters. If the estimated parameter of the fitted model falls within the 95% asymptotic confidence interval, the model was considered statistically significant.The following is a summary of the findings.

3.1.1.1Trends in Area of Coconut crop in Karnataka for the period of 1950-2019: Parameters and Global Statistics of the models fitted

The parameters of the linear, cubic, log-logistic, and exponential models are determined to be significant at the five percent significance level, according to the data shown in Table 4.2.12. Additionally, the Shapiro-Wilk test statistic for the entire model was determined to be non-significant (*P*> 0.05), indicating that the residuals' normality was fulfilled, according to the results from the table below. The models were deemed well-fitted only if every parameter was discovered to be significant and the "normality of residuals" assumption was met. As a result, every model suited the data on the area of coconuts quite well. The log-logistic model outperformed the other models, according to the MAPE value of 5.33. The best-fitting model was thus determined to be the log-logistic model. As a result, the Coconut area data from 1950 to 2019 shows a log-logistic growth.

Table 2. Trends in Area of Coconut in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	R^2	Adj. R^2
Linear	474.97**	24.95**			0.96	0.94
Cubic	639.27 **	0.85*	0.78 **	-0.006 **	0.97	0.96
Log Logistic	655.81**	54.94**	-2.13**	3101.21**	0.97	
Exponential	6.781e+02**	1.789e-02**			0.94	

Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	419.317	421.234	0.98 NS (0.36)	-5.77 NS (0.40)	93.68	5.84
Cubic	411.062	414.257	0.97 NS (0.26)	-6.26 NS (0.35)	80.76	4.95
Log Logistic	407.735	410.930	0.98 NS (0.40)	-6.01 NS (0.32)	83.91	5.33
Exponential	420.763	422.680	0.95 NS (0.008)	-6.50 NS (0.37)	117.57	7.64

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

3.1.1.2 Trends in Production of Coconut crop in Karnataka for the period of 1950-2019: Parameters and Global Statistics of the models fitted.

The data acquired in the table below showed that the parameters of the linear and cubic models were determined to be non-significant, whereas the parameters of the log-logistic and exponential models were found to be significant at the five percent significance level. Additionally, Table 4.25's results showed that the Shapiro-Wilk test statistic for the log logistic and exponential models was found to be non-significant (*P*> 0.05), indicating that the residuals' normality was fulfilled.

The models were deemed well-fitted only if every parameter was discovered to be significant and the "normality of residuals" assumption was met. Consequently, the production data for coconuts was well-fitted by log logistic and exponential models. The log-logistic model outperformed the exponential model with a MAPE value of 12.06, as demonstrated by its MAPE value of 10.89. The best-fitting model was thus determined to be the log-logistic model. As a result, the data on coconut production shows a log-logistic increase between 1950 and 2019.

Table 3. Trends in Production of Coconut in Karnataka for the period of 1950-2019

Model	α_0	α	β	γ	R^2	Adj. R^2
Linear	639.60	257.50**			0.81	0.395
Cubic	4781.04**	-126.13	7.04*	-0.025	0.89	0.667
Log Logistic	4673.54**	55.90**	-4.36**	26893.18**	0.90	
Exponential	3.04e+03**	2.83e-02**			0.88	

Model	AIC	BIC	Shapiro-Wilk Normality test (W)	Runs test	RMSE	MAPE
Linear	340.166	342.083	0.95^{NS} (0.22)	-6.74^{NS} (0.27)	2448	31.89
Cubic	333.223	336.419	0.87^{NS} (0.12)	-6.50^{NS} (0.24)	1873	12.07
Log Logistic	318.866	322.061	0.98^{NS} (0.21)	-6.50^{NS} (0.25)	1802	10.89
Exponential	339.830	341.747	0.85^{NS} (0.16)	-5.53^{NS} (0.12)	1941	12.06

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

3.1.1.3 Best fit models for Coconut crop of Karnataka over Area and Production

1950-2019	Coconut
Area	Cubic
Production	Linear

3.2 Evaluating the predictive models of coconut production based on area and weather parameters.

Modelling the linear relationship between a dependent variable (target) and one or more independent variables (predictors) is done using multiple linear regression (MLR). Ordinary least squares (OLS) form the basis of MLR; the model is fitted to minimize the sum-of-squares of the discrepancies between the observed and predicted values. Several presumptions underpin the MLR model, such as the normal distribution of errors with constant variance and zero mean. The regression estimators are optimal in the sense that they are impartial, effective, and consistent, provided that the assumptions are met**.**

Multiple Linear Regression (MLR)

Multiple Linear Regression is (MLR) is an extension of simple linear regression model. The relationship between Y and $X_1, X_2, \dots, X_p$ is put together as a linear model,

$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_p X_p + \varepsilon$$

Where, $\beta_0, \beta_1, \dots, \beta_p$ are the parameters considered as the regression coefficients and ε represents the error in the model.

Coconut crop was the Crop selected to forecast their production using area and weather parameters for the period from 1950 to 2019. Rainfall, Relative humidity, Min. Temperature and Max. Temperature are Weather Parameters considered as independent variables to forecast the production of Coconut crop in Karnataka.

Table 4. Descriptive Statistics for area, production of Coconut crop and weather parameters.

Measures	Dependent Variable	Independent Variable				
	Production (000' tones)	Area	Rainfall (mm)	Min Temp (^{0}C)	Max Temp (^{0}C)	RH
Mean	9780.8	1360.7	1282.5	11.0	38.9	60.3
Median	6573.5	1204.4	719.6	10.8	39.0	69.3
Standard Deviation	5791.7	516.4	1060.0	1.2	1.1	24.5
Kurtosis	0.046	-1.472	-0.481	-0.575	0.835	0.137
Skewness	1.005	0.096	1.088	0.267	-0.169	-1.372
Minimum	3281.7	626.5	321.6	8.6	35.4	11.8
Maximum	23904.1	2173.0	3698.7	14.1	41.6	82.6
CV	1380.9	123.1	252.7	0.2	0.2	5.8

The table shows estimates of the most essential SMLR parameters. Forecasting models for output explained 97.05 percent and an adjusted R2 of 96.88 percent of output variation, respectively. Other matching criteria, such as RMSE, MAPE, AIC, and BIC, are also shown in the Table 5.

Table 5. Parameter estimates and goodness of fit criteria by different models over production of Coconut.

Parameter estimates of MLR model					
Parameters		Estimates		SE	
Intercept		-1219.6		3298.7	
Area		8.9**		0.2	
Rainfall		0.3*		0.1	
RH		-17.7**		4.3	
Max Temp		41.9		86.2	
Min Temp		-295.4**		90.6	
R^2	Adj. R^2	RMSE	MAPE	AIC	BIC
0.97	0.97	36335.5	0.7	856.67	870.7

Parameter estimates of MLR using Stepwise selection					
Parameters		Estimates		SE	
Intercept		1870.4		866.0	
Area		8.5**		0.2	
Rainfall					
RH		-23.5**		3.8	
Max Temp					
Min Temp		-315.9**		89.6	
R^2	Adj. R^2	RMSE	MAPE	AIC	BIC
0.97	0.96	6983.2	0.4	860.0	870.0

** Significant at 1% level. * Significant at 5% level.

Table 6 presents the observed and predicted values for the variables over the years 2005 to 2017. The second column shows the observed values for each year, and the third and fourth columns show the predicted values using two different methods: MLR (Multiple Linear Regression) and SMLR (Sparse Multiple Linear Regression). The table allows for a comparison between the observed values and the predicted values obtained from the two methods.

Table 6. Prediction performance of the fitted model for Coconut crop.

Years	Observed Value	Predicted value	
		MLR	SMLR
2005	14811.1	13477.4	13340.0
2006	15840.4	12693.0	12644.2
2007	14743.6	12629.9	12480.1
2008	15729.8	12658.9	12584.9
2009	16918.4	12382.7	12354.5
2010	16942.9	12197.4	12127.2
2011	23351.2	13799.1	13575.2
2012	22680	14718.5	14477.9
2013	21665.2	14508.3	14295.7
2014	20439.6	13200.8	12940.3
2015	22167.5	13920.2	13641.9
2016	23904.1	14296.1	13993.2
2017	23798.2	14412.5	14094.9
2018	14682	14295.0	14046.0

2019	14006	14609.3	14425.2

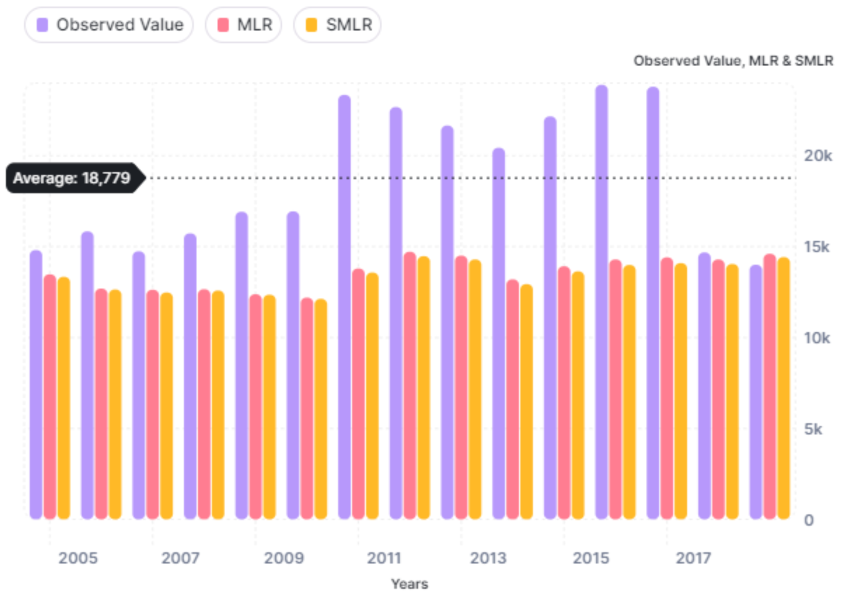

Fig.2. Prediction performance of MLR and SMLR models for Coconut Crop

In Fig. 2. The observed value of coconut crop has a wider range compared to MLR and SMLR predictions.

Table 7 shows the correlation between the area and production of coconut and various weather parameters, including rainfall, maximum temperature, minimum temperature, and relative humidity (RH). The values in the table represent the correlation coefficients, which range from -1 to 1. A value close to 1 indicates a strong positive correlation, while a value close to -1 indicates a strong negative correlation. The table also includes significance levels, with "**" indicating significance at the 1% level and "*" indicating significance at the 5% level. According to Table 7, there is a significant positive correlation between the area of coconut and rainfall, minimum temperature, and relative humidity, while there is a significant negative correlation between the area of coconut and maximum temperature. Similarly, there is a significant positive correlation between the production of coconut and minimum temperature and relative humidity, while there is a significant negative correlation between the production of coconut and rainfall and maximum temperature.

Table 7. Correlation between Area, Production and Weather parameters

Parameters	Area	Production
	Coconut	Coconut
Rainfall	0.732**	-0.541**
Max. Temp	-0.400**	-0.489**
Min. Temp	0.713**	0.684**

RH	0.678**	0.544**

** Significant at 1% level. * Significant at the 5% level.   Other values are non-Significant

4. CONCLUSION

Analysis of trend in area and production of Coconut crop in Karnataka showed the cubic model with a minimum MAPE value of 5.33 for area and a linear model with a minimum MAPE value of 10.89 for production were found to be the best-fitted models for coconut area and production. The parameters of both the linear and cubic models were significant and met the residual assumptions. The results showed that the area and production of coconuts increased over the study period from 1950 to 2019.

On evaluating the predictive models of coconut production based on area and weather parameters the MLR results showed that the contribution to the production of coconut crop from 1950 to 2019 has an R2 of 97.42 percent and an adjusted R2 of 97.16 from all 31 districts of Karnataka, while the stepwise regression R2 value is 97.05 percent with an adjusted R2 of 96.88 for the state. The MLR estimates for RH and min. temperature are negative (-17.712) and (-295.416), respectively, and the Stepwise regression estimates are negative (-23.549) and (-315.9793), respectively, implying that RH and min. temperature have a negative or inverse effect on sugarcane crop production.

A good agreement has been found between estimated and observed yields for crops with a comparable pattern of deviation. This allowed us to estimate the yield of major crops in Karnataka state.

CONSENT (WHEREEVER APPLICABLE)

"All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images".

ETHICAL APPROVAL (WHEREEVER APPLICABLE)

"All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee."

REFERENCES

1. Agriculture coconut Statistics and Growth Figures Year-wise of India.Available :Indiastat.
2. Ashwini M, Lokesha H. Growth Dynamics of vegetable crops in Eastern Dry Zone of Karnataka, India: An Economic Analysis. Asian Journal of Agricultural Extension, Economics & Sociology. 2024;42(2):47-55.
3. Berger PD, Maurer RE, Celli GB, Berger PD, Maurer RE, Celli GB. Multiple linear regression. Experimental Design: With Application in Management, Engineering, and the Sciences.2018:505-32.

4. CDB – Statistics. Available (coconutboard.gov.in).
5. Coconut | Official website of Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. Available: (desagri.gov.in).
6. Coconut Statistics and Growth Figures Year-wise of India. Available :Indiastat
7. Kishore MS, Murthy C. Growth in area, production and productivity of coconut in Karnataka. International Journal of Commerce and Business Management. 2016;9(2):156-62.
8. Kurumatani K. Time series forecasting of agricultural product prices based on recurrent neural networks and its evaluation method. SN Applied Sciences. 2020;2(8):1434.
9. Majumdar J, Naraseeyappa S, Ankalaki S. Analysis of agriculture data using data mining techniques: application of big data. Journal of Big data. 2017;4(1):20.
10. Pandis N. Linear regression. American journal of orthodontics and dentofacial orthopedics. 2016 ;149(3):431-4.
11. Shapiro SS, Wilk MB, Chen HJ. A comparative study of various tests for normality. Journal of the American statistical association. 1968 ;63(324):1343-72.