Statistical Analysis on Area and Production of Onion Crop in Selected Districts of Karnataka State

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***Abstract*—This research study effectively attempted to estimate the trends in the area and production of onion in selected districts of Karnataka state. Onions are widely cultivated and used around the world. India is the second-largest onion producer in the world. For the present study the secondary data for 24 years dated from 19998-99 to 2021-22, collected on the area and production of onion for Vijayapura and Chitradurga districts of Karnataka from the official website of the Directorate of Economics and Statistics (2020), Department of Agriculture, Government of Karnataka. The data was analyzed through selected linear, quadratic, cubic, quartic, exponential and logistic models. The best-fit model was selected based on minimum Root Mean Square Error (RMSE), Mean Average Percentage Error (MAPE) values and highest R^2 Value. Results depicted that the quartic model was found best fit for the area of onion and the cubic model was found best fit for the production of onion in the Vijayapura district with fluctuation in trend. The quadratic model was found best fit for the area and production of onion in the Chitradurga district of Karnataka indicating an increasing trend.**

***Index Terms*—Quadratic, Cubic, Quartic, MAPE, RMSE, R^2 and MT**

I. INTRODUCTION

Agriculture is the primary and important source of income for around 58 percent of India's population. Horticulture also forms an integral and specific part of agriculture, dealing extensively with cultivated "Garden crops."

The most widely cultivated species of the genus Allium is the onion (*Allium cepa* L., from the Latin cepa meaning "onion"); also known as bulb onion or common onion. Onions are widely cultivated and used around the world. These vegetables can be cooked or made into pickles and chutneys. Generally, they are consumed raw as a vegetable or as part of cooked savory dishes. If chopped, they give off a pungent smell, and some of their fumes can cause eye irritation. Onions get their pungency from a substance called allyl-propyl disulfide.

The majority cultivated in 140 countries covering a land area of 54.8 lakh hectares, onions give a yield of 1045.54 lakh tons product, which would make them the third most valuable vegetable in the world after potatoes and tomatoes. The average productivity in the world stands at 23.06 tons per hectare. (FAOSTAT, 2020)

India is the second largest onion producer in the world. Onions, available throughout the year, are reputed for their pungency. India is the world's second largest country in terms of area and production, after China. The production figure for 2022 found and recorded as 1.94 million hectares of sowing and the resultant 31.69 million metric tons of onion harvest. The major onion-producing states are identified as Maharashtra, Karnataka, Gujarat, Uttar Pradesh, Orissa, Tamil Nadu, Madhya Pradesh, and Bihar. As far as the dimension (2.60 lakh hectares) and yield (126.46 lakh metric tones) are concerned, Maharashtra is leading and Gujarat leads in productivity with 25.50 tons of production per hectare. (National Horticulture Board, 2022)

The area under onion in Karnataka is 2.39 lakh hectares, with a production of 27.79 lakh tones. Various districts where the major production of onion crop is carried out are Vijayapura, Chitradurga, Bagalkot, Bellary, Gadag and Dharwad in Karnataka. The major onion-producing regions in Karnataka are Vijayapura (4,93,775 MT), Chitradurga (4,50,469 MT), Bagalkot (3,02,319 MT), Bellary (1,14,312 MT),

Gadag (94,004 MT) and Dharwad (29,717 MT). (Directorate of Economics and Statistics Bengaluru, 2020)

Most of the previous studies relating to the performance of agriculture in Karnataka have been made at the aggregate level. This study will provide information effectively regarding the trends with respect to the area and production of onion in selected districts of Karnataka. A district-level detailed study would be extremely beneficial to policymakers in formulating relevant and appropriate agricultural policies and programs for all the districts.

II. METHODOLOGY

A. Study area

The Karnataka state was delineated into 31 districts and 176 taluks spread over 27,481 villages. The selection of the district for the present research study is purely based on the existing ranking performance among the different districts existing in Karnataka state based on the important components of area and production of onion over a specified period. This study was carried out for the Vijayapura and Chitradurga districts of Karnataka state, to analyse the trend changes with respect to area and production of onion crop over the period of time.

B. Research Data:

This study was carried out for the Vijayapura and Chitradurga districts of Karnataka state. The secondary data pertaining to the area and production of onion in Vijayapura and Chitradurga districts of Karnataka for the period of 24 years i.e., from 1998-99 to 2021-22 collected from the official website of the Directorate of Economics and Statistics, Department of Agriculture, Government of Karnataka, Bangalore.

C. Analytical Tools and Techniques:

For estimating long-term trends in the area and production of onion crop among selected Vijayapura and Chitradurga districts, the linear and nonlinear time series models were fitted i.e linear, quadratic, cubic, quartic, exponential and logistic models were utilized for the trend analysis.

1. Linear model: $Y_t=\beta_0+\beta_1 t + \varepsilon$ (1) (Choudhari et al. 2018)
2. Quadratic model: $Y_t=\beta_0+\beta_1 t +\beta_2 t^2+\varepsilon$ (2) (Satish et al. 2017)
3. Cubic model**:** $Y_t=\beta_0+\beta_1 t+\beta_2 t^2+\beta_3 t^3+\varepsilon$ (3) (Satish et al. 2017)
4. Quartic model**:** $Y_t= \beta_0+\beta_1 t+\beta_2 t^2+\beta_3 t^3+\beta_4 t^4+\varepsilon$ (4) (Prajneshu and Das, 2000)
   Where, β_0=Intercept β_1= Linear effect parameter, β_2= Quadratic effect parameter, β_3= Cubic effect parameter, β_4: Quartic effect parameter, Y_t = Area and Production of Onion in time t and ε = Error term
5. Logistic model: $Y_t = \frac{\beta_0}{1 + \beta_1 \exp(-\beta_2 t)} + \varepsilon$ (5) (Panghal et al. 2019)
   Where,
   Y_t = Area and Production of Onion in time t,
   β_0 = Carrying capacity,
   β_1 = Growth range and β_2 = Growth rate.
6. Exponential model: $Y_t = \beta_0 \exp(\beta_1 t) +\varepsilon$ (6) (Satish et al. 2017)
   Where, Y_t = Area and Production of Onion in time t, β_0 and β_1 are parameters, ε = Error term.
   Best model selected based on the significance of the coefficients and minimum Root Mean Square Error (RMSE) and Mean Average Percentage Error (MAPE) values and highest R^2 Value.

C. model adequacy checking

a) The coefficient of determination (R^2):

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

Where, ESS = Error sum of squares, RSS = Regression sums of squares and TSS = Total sum of squares.

b) Root Mean Square Error (RMSE):

$$RMSE=\sqrt{\frac{\sum_{i=1}^{n}(Y_t-\widehat{Y}_t)^2}{n}} \quad \text{……..(8)}$$

Where, Y_t= Observed value, $\widehat{Y}_t$= Predicted value and n= Number of observations.

c) Mean Average Percentage Error (MAPE):

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i-\hat{Y}_i}{Y_i}\right| X\ 100 \quad \text{…….(9)}$$

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

III. RESULTS AND DISCUSSION

A. Statistical Trend analysis of area and production of onion in Vijayapura district.

The research result found that the quartic model was the best fitted model for the area of onion in Vijayapura

district, with the calculated parameter values are β_0 = 19321.23, β_1 = -9786.53, β_2 = 1974.02, β_3 = -134.05 and β_4 = 2.96 with a minimum MAPE of 33.19, minimum RMSE of 4014.13 and per cent variation (86.82) explained for the area of onion. The trend for the area under onion in Vijayapura district of Karnataka gradually increased with time from 1998-99 to 2007-08, then from 2007-08 to 2008-09 the trend is gradually decreasing, then from 2008-09 to 2011-22 the trend is increasing, then from 2011-12 to 2017-18 the trend is gradually decreasing and from 2017-18 to 2021-22 the trend is increasing. The projected values of the trend, which display an increasing trend for the area in Vijayapura district (Fig. 1).

The research result found that the cubic model was the best fitted model for the production of onion in the Vijayapura district. The calculated parameter values are β_0 =-16583.94, β_1 = 45222.35, β_2 = -5693.08 and β_3 = 196.54 with a minimum MAPE of 53.42, minimum RMSE of 43039.36 and R^2 of 0.8869, cubic model was therefore found to be the best-fit model. The trend for the production of onion in Vijayapura district is gradually getting increased with time from 1998-99 to 2021-22. The projected values of the trend, which displays an increasing trend for the production in Vijayapura district (Fig. 2). Chukwujioke and Okiemute (2018) used linear, quadratic and cubic models to examine the trend in area and production for cashew in Nigeria. The results showed that the cubic model was the best fit model.

Table 1-Parameter estimates and model adequacy checking criteria by different models for area and production of Onion in Vijayapura district.

Component	Model	β_0	β_1	β_2	β_3	β_4	RMSE	MAPE	R^2 Value
Area (ha)	Linear	1319.80^{NS}	1097.00**				8035.75	46.22	0.4717
	Quadratic	10919.85*	-1118.36^{NS}	88.62*			7086.92	42.66	0.5891
	Cubic	1484.78^{NS}	4291.61*	-441.49*	14.13*		6075.77	49.45	0.6980
	Quartic	19321.23**	9786.53**	1974.02**	134.05**	2.96**	4014.13	33.19	0.8682
	Exponential	3388.00*	0.09**				7054.85	42.60	0.7157
	Logistic	9.722e+06^{NS}	0.09^{NS}	80.85^{NS}			7057.48	42.56	0.5925
Production (Tonnes)	Linear	25804.00^{NS}	11934.00**				97796.20	87.64	0.4164
	Quadratic	155877.15*	29992.38*	1677.13**			66520.77	68.68	0.7299
	Cubic	16583.94^{NS}	45222.35**	-5693.08**	196.54**		43039.36	53.42	0.8869
	Quartic	79414.23^{NS}	19773.67^{NS}	5452.01^{NS}	-487.21^{NS}	13.67*	37543.91	47.27	0.9141
	Exponential	1166.00^{NS}	0.2541**				58686.6	65.55	0.7898
	Logistic	1.15e+08^{NS}	0.25*	45.21^{NS}			58715.25	65.57	0.7896

** Significant at 1 % level, *: Indicates significant at 5%, NS: Non-significant

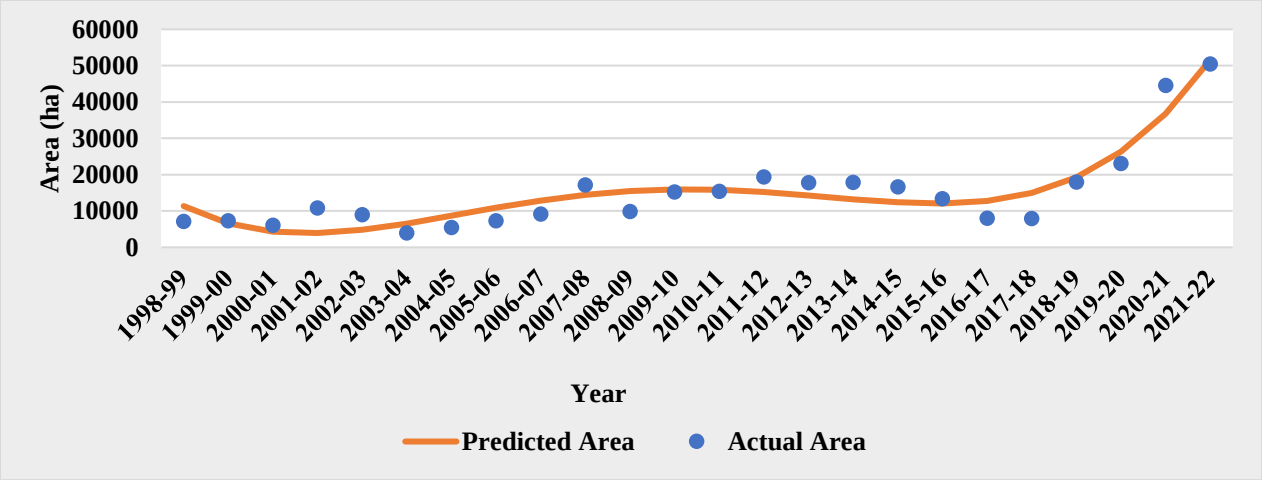

Fig. 1: Best fitted quartic model for the area of Onion in Vijayapura district.

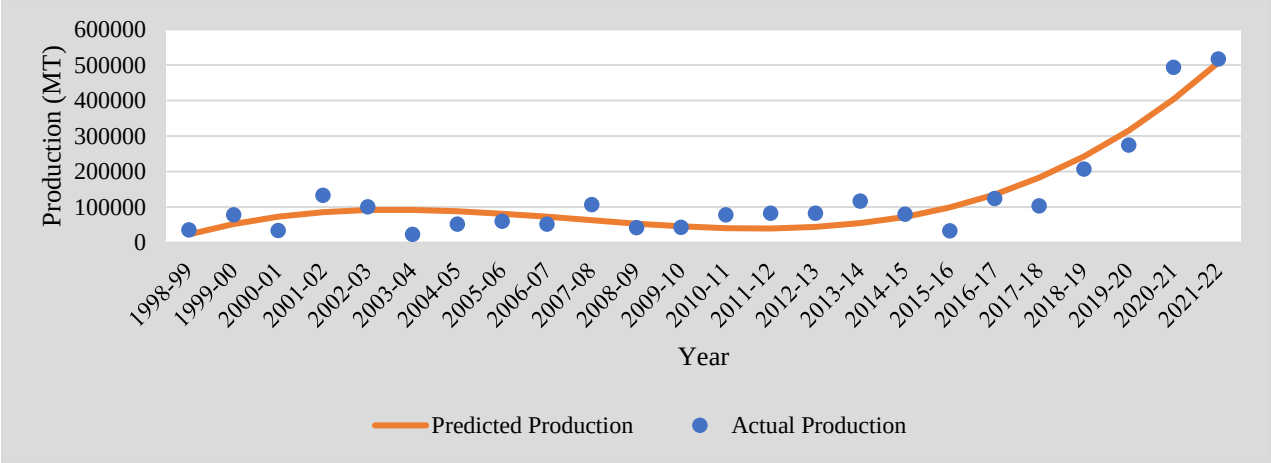

Fig. 2: Best fitted cubic model for the production of Onion crop in Vijayapura district.

IV. STATISTICAL TREND ANALYSIS OF AREA AND PRODUCTION OF ONION CROP IN CHITRADURGA DISTRICT.

It was found that the quadratic model was the best fitted model for the area and production of onion in the Chitradurga district. The calculated parameter values for the area are β_0 =16644.79, β_1 = -1161.92 and β_2 = 89.12 with a minimum MAPE of 14.81, minimum RMSE of 3389.95 and R^2 of 0.8572, the quadratic model was therefore found to be the best-fit model. The trend for the area under onion crop in Chitradurga district is gradually getting increased with time from 1998-99 to 2021-22. The projected values of the trend, display an increasing trend for the area in Chitradurga district.

The calculated parameter values are β_0 = 157968.00, β_1 = -20674.21 and β_2 = 1335.80 with a minimum MAPE of 27.28, minimum RMSE of 48834.46 and R^2 of 0.8220, the quadratic model was therefore found to be the best-fit model. The trend for the production of onion in the Chitradurga district gradually increased with time from 1998-99 to 2021-22. The projected values of the trend, display an increasing trend for the production in Chitradurga district. To track the trend, Choudhury and Kalita (2018) employed linear, quadratic and exponential growth models that were fitted to the area, productivity, and production of turmeric in Assam. The results showed that the quadratic model was the best fit model.

Table 2-Parameter estimates and model adequacy checking criteria for area and production of onion in Chitradurga district.

Component	Model	β_0	β_1	β_2	β_3	β_4	RMSE	MAPE	R^2 Value
Area (ha)	Linear	6990.50**	1066.00**				5099.31	23.74	0.6768
	Quadratic	16644.79**	-1161.92*	89.12**			3389.95	14.81	0.8572
	Cubic	15245.49**	-551.66^{NS}	29.317^{NS}	1.59^{NS}		3394.88	14.92	0.8522
	Quartic	14429.87*	0.22^{NS}	-65.37^{NS}	7.40^{NS}	-0.12^{NS}	3360.13	14.22	0.8597
	Exponential	8550**	0.06**				4162	18.56	0.7845
	Logistic	4.53e+06^{NS}	0.06^{NS}	101.8^{NS}			4166.76	18.54	0.7841
Production (Tonnes)	Linear	13255^{NS}	12721**				75135.01	46.77	0.5786
	Quadratic	157968.0**	-20674.2**	1335.8**			48834.46	27.28	0.8220
	Cubic	136591.02*	-11351.19^{NS}	422.26^{NS}	24.36^{NS}		48428.07	26.40	0.8249
	Quartic	47764.22^{NS}	48752.41^{NS}	9890.25^{NS}	657.03^{NS}	12.65^{NS}	44341.05	26.52	0.8533
	Exponential	3.975e+04**	9.751e02**				58172.88	34.69	0.7474
	Logistic	6.037e+07^{NS}	9.786e-02^{NS}	7.489e+01^{NS}			58198.09	34.71	0.7472

** Significant at 1 % level, * Significant at 5 % level, NS: Non-significant

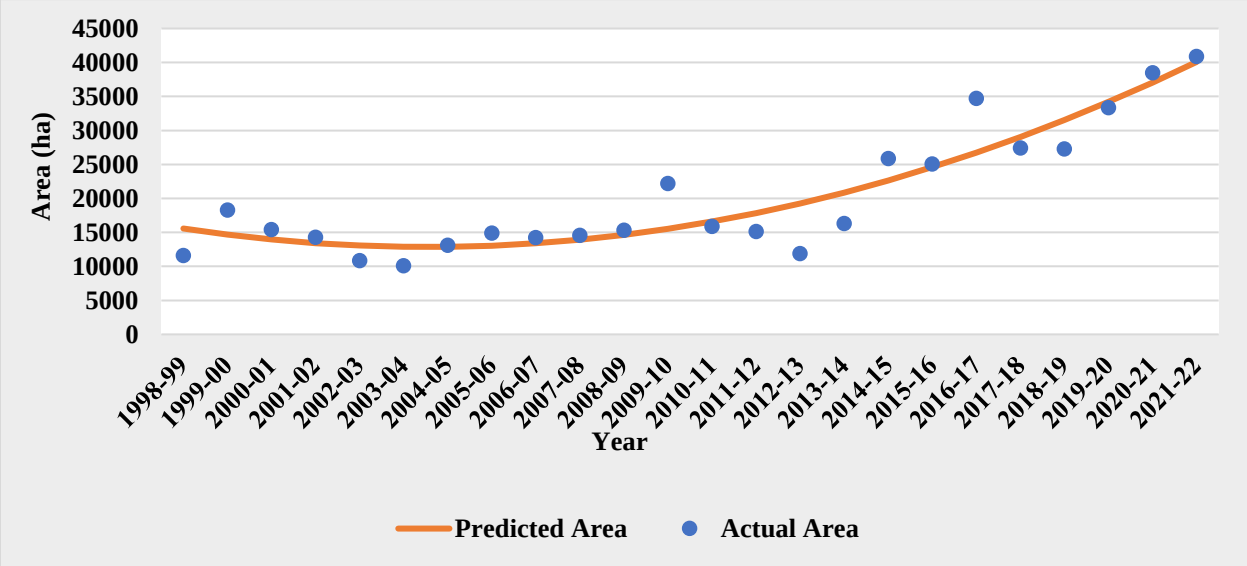

Fig. 3: Best-fitted quadratic model for the area of Onion in Chitradurga district.

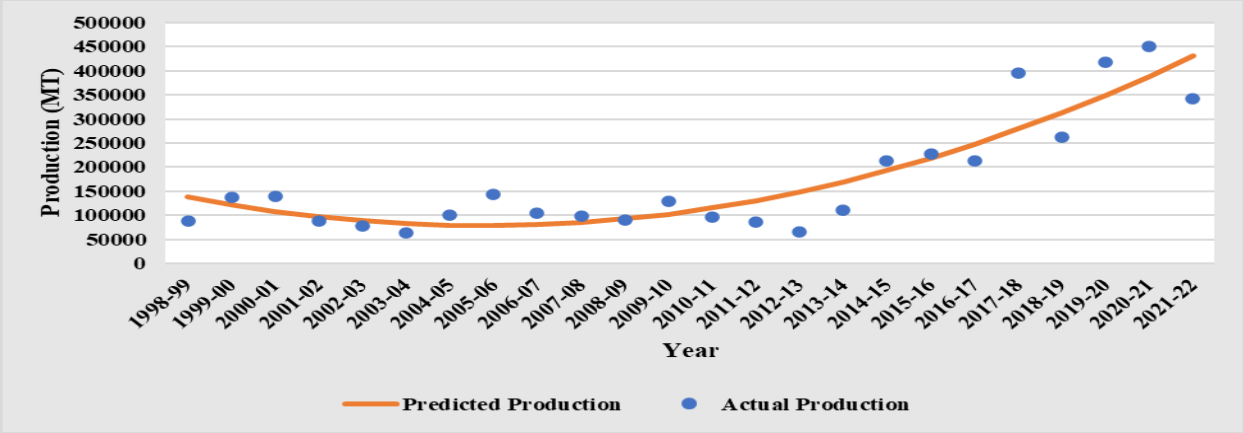

Fig. 4: Best-fitted quadratic model for the production of Onion in Chitradurga district.

V. CONCLUSION

The analysis of onion area and production trends in Vijayapura and Chitradurga districts of Karnataka reveals significant insights. In Vijayapura, a quartic model provided the best fit for the area indicating a cyclical pattern over the study period and the cubic model was found best fit for production. The area under onion cultivation showed phases of increase and decrease, while production increased.

In Chitradurga, the quadratic model provided the best fit for both the area and production of onion crop, indicating an upward trend in both area and production. These findings can assist policymakers in tailoring agricultural strategies to the region's unique trends and challenges.

A. Policy Recommendations

- Promote yield increasing technology like high yielding varieties, and expansion area under irrigation.
- Large scale promotion of stabilization measures like crop insurance which can enhance the per unit production as well as stabilize the area and yield of onion.
- Government agencies like State Agricultural Universities, Extension units, etc., have to provide timely and accurate climate related information to the farmers.

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