Statistical Analysis of Jowar Production in Karnataka

THESIS

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In

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2020

CERTIFICATE – I

This is to certify that the thesis entitled **"*Statistical Analysis of Jowar Production in Karnataka*"** *submitted in partial fulfilment of the requirements for the degree of* ***Master of Science (Agriculture) in Agricultural Statistics*** *of the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bona-fide research work carried out by* ***Mr. Raghu K N*** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

All the assistance and help received during the course of the investigation have been acknowledged by him.

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CERTIFICATE – II

This is to certify that the thesis entitled **"*Statistical Analysis of Jowar Production in Karnataka*"** *submitted by* ***Mr. Raghu K N*** *to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfilment of the requirements for the degree of* ***Master of Science (Agriculture) in Agricultural Statistics*** *in the Department of Mathematics & Statistics has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.*

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Declaration and Undertaking by the Candidate

I, Raghu K N S/o Mr. Narayana Swamy K N Certify the work embodied in thesis entitled "***Statistical Analysis of Jowar Production in Karnataka*** " is my own first hand bona-fide work carried out by me under the guidance of Dr. H.L. Sharma, Professor and Head, Department of Mathematics & Statistics, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2019-2020.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol/Abbreviation		Stand for
R^2_{adj}	:	Adjusted R^2
α	:	Alpha
β	:	Beta
R^2	:	Coefficient of determination
CV	:	Coefficient of variation
CGR	:	Compound growth rate
ρ	:	Correlation coefficient
d.f.	:	Degrees of freedom
ε	:	Epsilon
=	:	Equal to
b	:	Estimated value of β
θ	:	Estimation of parameter
OLS	:	Ordinary least square
%	:	Percentage
RMS	:	Residual mean square
σ_x	:	Standard deviation of x
Σ	:	Summation

INTRODUCTION

Jowar is one of the important food and fodder crops grown mostly in arid and semi arid climates of the world as well as in India. The cereal plant of jowar came up in historic times in the present day Ethiopia and east central Africa. It was probably in the first millennium that jowar plants were brought from African countries into India. Jowar or sorghum belongs to the Graminae family and grows to a height of about 4 meters. Seeds are rounded and pointed at the base, the color being brownish, yellow, pink or white. The advantage of this cereal crop is that it can be cultivated in both Kharif and Rabi seasons under marginal conditions of soil fertility and moisture. Jowar is the fifth most important cereal crop in the world after rice, wheat, maize and barley. The nutritional value of jowar is same as that of corn and that is why it is gaining importance as livestock feed. Jowar is also used for ethanol production, producing grain alcohol, starch production, production of adhesives and paper. Jowar cultivation is gaining popularity due to its nature of extreme drought tolerance. Jowar is very nutritious just like corn and can be used as green fodder, dry fodder, hay or silage.

In India, Jowar is mainly grown in Maharashtra, Karnataka, Madhya Pradesh and Tamil Nadu. In 2017-18 India produced 4.95 million tonnes of Jowar from an area of 4.96 million hectares with an average productivity of 998 kg per hectare. Maharashtra tops the Indian Jowar production with a contribution of 36.45 per cent followed by Karnataka (22.87%), Madhya Pradesh (11.51%) and Tamil Nadu (8.49%). Andhra Pradesh is having the highest productivity of 2150 kg/ha, followed by Madhya Pradesh (2112 kg/ha), Uttar Pradesh (1272 kg/ha), Tamil Nadu (1089 kg/ha) and Karnataka (1048 kg/ha) which is higher than the country's average productivity of 998 kg/ha.

In Karnataka, jowar is mainly grown in Kalaburagi, Belagavi, Vijayapura, Bagalkot, Raichur, Ballari, Yadgir, Bidar and Gadag districts. In Karnataka, jowar is grown in an area of 10.9 lakh ha, with an annual production of 11.3 lakh tonnes and productivity of 1048 kg per hectare.

The observations pertaining to the different agricultural variables, which are recorded over different time periods (time sequences), are known as time series variables. These time series variables (temporal) are time dependent and thereby stochastic in nature. For acquiring the knowledge of the intrinsic behavior of these temporal variables and also to predict their future values, the support of time series models is of paramount importance.

A stochastic process is simply a collection of random variables indexed by time. It will be useful to consider separately the cases of discrete time and continuous time. We will even have occasion to consider indexing the random variables by negative time. That is, a discrete time stochastic process $X = \{ X_n, n = 0,1,2,\ldots \}$ is a countable collection of random variables indexed by the non-negative integers and a continuous time stochastic process $X = \{ X_t, 0 \le t < \infty \}$ is an uncountable collection of random variables indexed by the non-negative real numbers.

Simple correlation studies and path analysis are two effective methods, which have high potentiality in effectively diagnosing the important factors influencing the total jowar production. The study, brought under the purview of this endeavors, is undertaken to identity some of the factors (Pertaining to the jowar production scenario) which are related so and have direct and indirect effects on the total jowar production and productivity in Karnataka.

In view of above description, the present study on “Statistical Analysis of Jowar Production in Karnataka” was undertaken with following objectives:

1. To study the growth rate on time series production factors of jowar.
2. To determine the influential time series production factors governing total jowar production.
3. To fit statistical models on agricultural dynamic variables and asses for projecting the future values.

REVIEW OF LITERATURE

With a view to evaluating the objectives of the study, it was considered desirable to have an idea of the findings of some earlier researches and the methods adopted for arriving at the same. Such a review of literature connected with the main objective of the study, it is hoped, would provide a basis either for confirming the earlier findings or for contradicting the same and thereby to suggest points of departure for further studies.

Consistent with the objectives of the study, the review of literature is presented in this chapter under the following heads:

2.1 To study the growth rate on time series production factors of jowar.

2.2 To determine the influential time series production factors governing total jowar production.

2.3 To fit statistical models on agricultural dynamic variables and assess for projecting the future values.

2.1 To study the growth rate on time series production factors of jowar.

Singh *et al.* (1991) studied the growth patterns and factors affecting output of pigeon pea in Madhya Pradesh for the period of 1974-75 to 1983-84 and observed that in the absence of higher yield expectation from the crop, the area allotted to this both in actual and pattern declined overtime. Reduction in area emerged as the dominant factor for the same, but positive and significant growth rate of yield in the state off sent the negative impact of area. Further it was observed that the productivity of crop is the most important factor which influences production significantly.

Srivastava (1998) in his study indicated that the growth rates in area, production and productivity of potato in Bihar were (2.26%, 2.45% and 0.13%) higher than those in total food grains (-0.03%, 1.92% and 2.22%) during the period from 1970-71 to 1991-92. The decline in area was due to shift in acreage in favor of completing crops such as groundnut and potato.

Suhag *et al.* (2000) has proposed a method for estimating the source of growth of output in Haryana agriculture. The uneven rate of growth observed in the patten of production of different crops could be either due to one or two or several of the important factors such as expansion of cultivated area, irrigation, change in crop pattern, improvement in yield per hectare, etc. The growth in value of product on the other hand includes the price factor in addition to the aforementioned components. An attempt is, therefore made to measure the relative contribution of these components to the growth of agriculture production in the Haryana state both in absolute and value terms.

Singh *et al.* (2003) studied the growth and instability in Sugarcane area, production and productivity in Uttar Pradesh for different regions for the period from 1980-81 to 1998-99. Semi-log equations were fitted to estimate compound growth rates and coefficient of variation analysis to study the instability. Area, production and productivity under sugarcane registered a significant and positive growth rate in all the study regions and state as a whole.

Job and Nandamohan (2004) carried out a study on rice production in Kerala using trend and instability analysis. Though rice is the staple food of the people of Kerala, area and production of rice is dwindling from mid-seventies and the phenomenon is still continuing. Here an attempt is made to analyze the changes in the growth pattern of rice in Kerala across time and across seasons. Exponential trend, which approximate best uniform rate of growth and log quadratic trend which is an extension of an exponential equation by adding a quadratic term were used.

Mathur (2005) computed the compound growth rates of area, production and productivity of rice, during the high yielding variety period (1966-67 to 2000-01) in India by the least square technique of fitting of exponential function $y=ab^t$. He concluded that the average yield is low in the regions comprising Uttar Pradesh, Bihar, Assam, West Bengal, Orissa, Madhya Pradesh and Maharashtra when compared with other regions and production in general, has grown at a much faster rate than the area in all states.

Sadeesh *et al.* (2006) have attempted to analyze the growth and variability in area, production and yield of major oilseed crop in India by considering the time series data from the period 1971-72 to 2002-03. They have opined that there is an increase in area and productivity due to the implementation of technology mission on oilseeds.

Dhakre and Sharma (2010) studied growth analysis of area, production and productivity of maize in Nagaland. Maximum decrease in area under maize crop was 16.02% found in the year 1999-2000 and maximum increase in area under maize crop was 30.23% in the year 2000-01, whereas maximum increase in production and productivity of maize crop in Nagaland was 103.05% and 101.26% respectively in the year 1988-89.

Acharya *et al*. (2012), in their study, the growth in area under crops like jowar, bajra, finger millet and minor millets was observed negative, while growth rate in area under maize and rice was positive. They also observed that there was a significant decrease in area under finger millet due to low output price in the market.

Ramachandra *et al*. (2014) examined the performance of trends of agriculture growth and production in India. The paper had shown that the growth and production were significantly increased during the last three decades and also highlighted the performance of the Indian agriculture growth over the period of time.

Ahmad *et al.* (2015) examined the trends in area, production and productivity of cereals in India as well in Nigeria for period of 1982-2012. The computed growth trend for cereals in India was negative (-0.0750) for area, positive for production (0.84) and productivity (0.94). However, in Nigeria the computed growth was positive (1.056, 1.247 and 0.189) for area, production and productivity respectively.

Kaur *et al.* (2015) demonstrated the variations in area, production and yield of the crops (cotton, castor and banana). This analysis was done at different levels viz. country, state and district level. A time series data from 2000-01 to 2011-12 regarding the area, production and yield of selected crops viz. Cotton, Castor and Banana were collected. Results demonstrated the variations in area, production and yield of the selected crops. The study can aid the planners in deciding the growth rates to be achieved in accordance with the planned targets. Further, it can contribute towards basis for predicting the future supply.

2.2 To determine the influential time series production factors governing total jowar production.

Sun *et al.* (1993) found that quarterly milk supply response function is derived that account for biological and economics factors in a system of equations representing heifer numbers, cow numbers and cow in the U.S.A. The heifer and cow numbers are estimated simultaneously by observing the age composition of heifer and cows. Based on the results of a dynamic simulation, this model predicts the supply response components better than two other traditional specifications that ignore the biological processes. Short-intermediate and long run supply elasticity with respect to various exogenous variables justifies the dynamic adjustment of this model.

Srinath and Baruah (1994) studied tea plantation supply function model is constructed for Assam state, India. Nerlove's partial adjustment hypothesis is incorporated into the model. The explanatory variable are long-term expected profit, short-term expected profit, expected yield, rainfall and technological change.

Omezine and Jabri (1998) presented an empirical investigation of vegetables grower's responses to prices. However, these adjustments were rather low for some crops in the shorts and long run. Grower's production decisions had also shown a significant response to prices of other products competing for farm space and other production resources.

Mythili and Shanmugam (2000) done a study using the unbalanced panel data of 234 rice farms in Tamil Nadu state of India, Mythili and Shanmugam attempted to measure the farm level technical inefficiency in rice production by employing the stochastic frontier production technique. The technical efficiency ranged from 46.5 per cent to 96.7 per cent across the sample farms. The mean technical efficiency computed was 82 per cent which indicated that on an average, the realized output can be increased by 18 per cent without any additional resources.

Rajan *et al.* (2007) studied the direct and indirect effects of seed related characters on number of seeds in guava fruits. The data was subjected to path analysis to find out direct and indirect effects of different characters on a number of seeds in the fruits. They concluded that improvement in characters like seed weight per fruit (SWPF) will help in improving a number of seeds per fruit (NSPF) in guava both directly and indirectly and thus SWPF should be considered for NSPF in guava breeding programme. Seed content (SC) speaks the quality of fruit and is a consumer preference fixing scale. Therefore selection should be based on seed characters after assessing their correlation with NSPF.

Singh (2008) used the stochastic frontier function model to estimate the farm level TE and AE of the farmers in fish production in South Tripura district of Tripura state in India during the year 2004-05. The estimated mean TE, AE and EE were found to be lying in the range of 0.65 to 0.71, 0.51 to 0.61 and 0.35 to 0.45, respectively. The TE appeared to be more significant than AE as a source of gains in EE. The results also proved that the expansion in the use of any resource by the fish farmers would bring more than proportionate increase in their output, given the value of increasing returns to scale, obtained in production.

Kumawat and Prasad (2012) estimated the supply response function for sugarcane for all India as well as for Uttar Pradesh and Maharashtra. The results suggested that the area under cane is affected mainly by sugar prices during last one or two years. In addition to sugar prices, rainfall too affects the production, and this effect comes through factors other than area. The high explanatory power of cane arrears with requisite sign underlines the important role of payment practices in determining cane production. Finally, the equations for yield have low values of adjusted R^2 indicating the important role played by non-price factors, e.g., pest attacks, climatic factors etc.

Savabi *et al*. (2013) diagnosed the direct and indirect effect of soil properties, corn yield components and crop yield. Two fields of 1.54 and 1.62 ha in Berrien County, Georgia, USA (83° 21’ 09.96” W, 31° 22’ 37.89” N) were delineated into six management zones based on the “fuzzy-c means” cluster technique. Statistical analyses were combined and applied to the entire research site, then to each management zone. Crop yield was defined as a function of seven yield components and 27 soil, water and nutrient properties. Results from standard multiple regression procedures were compared to the results derived from three conceptual path analysis models, which separated yield components and soil properties into direct and indirect effects.

Grace *et al.* (2014) studied the supply response studies in the past were based on traditional econometric techniques (classic linear regression) and the nervolian framework. Results of traditional econometric techniques are reliable when the time series data are stationary. However, there can be a possibility of some macroeconomic time series data are non-stationary, thereby results and conclusion drawn from using those techniques are having the risk of invalidity. This paper specifically attempted to quantify the relationship between pulses production and price and non-price factors viz., land productivity, annual rainfall, irrigated area and revenue difference between cereals and pulses.

Akhter *et al*. (2016) analyzed the growth and trend in the area, production and yield of major crops of Bangladesh. They assessed the growth pattern in the context of the total cultivable area, gross production and yield rate of some economically important crops such as rice, wheat, pulse, rape and mustard, jute, sugarcane & tea for the period of 1969-74 to 2004-2009. The compound growth rate, as well as trend analysis, indicated that the production of rice was increased due to the corresponding increase in per hectare yield and the trend co-efficient of the area, production and yield of all other crops were positive.

2.3 To fit statistical models on agricultural dynamic variables and assess for projecting the future values.

Morant and Gnanasakthy (1989) Wood's model, Morant and Gnanasakthy model, Mitscherlich x Exponential model and proposed model were fitted to the average weekly milk yield of crossbred cows. The errors generated by the proposed and Mitscherlich x Exponential models followed first order autocorrelation scheme, whereas, the errors generated by the

Morant and Gnanasakthy and Wood's models followed second and third order autocorrelation scheme respectively.

Vasanth Kumar (2002) employed a multiplicative model of time series to know the trend of timber species in Teak, in all cases the trend was steadily increasing from 1987 till 2005. The single parameter exponential smoothing model was used to predict the price of teak, rosewood and yellow teak.

Venugopalan and Shamasundaran (2003) used nonlinear regression model to analyse data on fruit yield of Coorg mandarin trees. Four different methods of nonlinear regression were discussed and measures of goodness of fit were presented with a view to develop a suitable nonlinear model for describing data pertaining to the period from 1960-61 to 1976-77, on average fruit yield of Coorg mandarin trees. Using the Gompertz model, it was inferred that 94 per cent of the carrying capacity had already been achieved by year 1977 and hence there is little scope for its survival in Coorg region.

Panwar and Kumar (2004) have used the non-linear models viz., logistic, Gompertz, monomolecular, Morgan-Mercer-Flodin (MMF) for describing the state-wise yield data of apple during 1991-92 to 2000-2001. They considered five major apple growing states viz., Jammu and Kashmir, Arunachal Pradesh, Uttaranchal, Nagaland and Himachal Pradesh. They concluded that logistic model was best fitted for the apple productivity data and Nagaland showed good performance in yield compared to other states.

Chetana (2009) examined prediction models in teak based agroforestry systems in the northern transitional zone of Karnataka. Different prediction models 14 namely Linear, Quadratic, Cubic, Exponential, Growth, Sigmoid, vapour pressure, Hassel, MMF compound, Logarithmic, Logistic, Weibull, Gompertz, Power etc., have been tried to predict the diameter and height growth of the teak tree. MMF model was found better followed by Gompertz and Weibull for diameter prediction whereas for height growth prediction MMF model followed by logistic and Richards were found to be better.

Rajarathinam and Parmar (2010) estimated models for the area, production and productivity trends of castor crop for Anand region of Gujarat state based on parametric and non-parametric regression models. The statistically most suited parametric models were selected on the basis of adjusted R^2, significant regression co-efficients and co-efficient of determination (R^2). The statistically appropriate model was selected on the basis of various goodness of fit criteria viz., Akaike's Information Criterion, Bayesian Information Criterion, Root Mean Square Error, Mean Absolute Error, assumptions of normality and independence of residuals. None of the parametric models was found suitable to fit the trends in area, production and productivity of tobacco crop. The nonparametric regression model emerged as the best fitted trend functions for the area, production and productivity of castor crop.

Kakde *et al*. (2013) designed to measure resource use efficiency in gram production of Amravati division of Vidharbha region of Maharashtra state. In present investigation they used the double log type Cobb-Douglas production function.

Singh *et al*. (2013) studied statistical analysis of the linear models in soybean production and soybean oil production in Madhya Pradesh and India. Dataset used for this analysis was taken from soybean processor association, Indore. The following stochastic models were taken: Linear, Quadratic, Compound, Cubic, Power. Four comparison criteria viz., coefficient of determination (R^2), the sum of squares error, root mean square error and mean absolute prediction error were used for model fitting performance. The results indicated that Cubic, Quadratic and Power models are more useful than other models to estimate soybean production and soybean oil production in India and Madhya Pradesh.

Abid *et al.* (2014) focused on making forecast of maize area and production in Khyber Pakhtunkhwa province of Pakistan using time series data from 1980-81 to 2011-12. Five forecasting models such as Linear trend model, Quadratic trend model, Exponential growth model, Moving Average Model and Double exponential smoothing model were used to find the best fitted model for area and production of maize crop in Khyber Pakhtunkhwa.

Singh *et al*. (2014) analysed the non-linear stochastic models for describing growth of soybean oil production in India and also in Madhya

Pradesh. Eight nonlinear stochastic models were taken: Boltzmann, Gompertz, Logistic, Richards, Janoschek, Chapman, Morgan-Mercer-Flodin and Weibull. The results indicated that Chapman model is more useful than other non-linear models for describing growth of soybean oil production in India and Weibull model is more appropriate for describing the growth of soybean oil production in Madhya Pradesh.

Tripathi *et al*. (2014) forecasted the rice productivity and production of Odisha and India using Autoregressive Integrated Moving Average Models**.** The study showed that the trend analysis of the rice data showed an increasing productivity and production trend for both Odisha and India; the rate of increase was less in Odisha than all Indian average. Based on the forecasting and validation results, it may be concluded that ARIMA model could be successfully used for forecasting rice area, production, and productivity of Odisha as well as India for the immediate subsequent years.

Ali *et al*. (2015) attempted to forecast production and yield of sugarcane and cotton crops of Pakistan for 2013-2030 using Auto Regressive Moving Average (ARMA) and Auto Regressive Integrated Moving Average (ARIMA) models. Using data from 1948 to 2012, productions and yields of both crops were forecasted for 18 years starting from 2013 to 2030. ARMA (1, 4), ARMA (1, 1) and ARMA (0, 1) were found appropriate for sugarcane production, sugarcane yield, and cotton production respectively, whereas ARIMA (2, 1, 1) was the suitable model for forecasting cotton yield. Some diagnostic tests were also performed on fitted models and were found well fitted.

MATERIAL AND METHODS

This chapter elaborates the study area, nature and source of data, study period taken for analysis and the statistical tools and techniques employed for analyzing the data are presented under the following headings.

3.1 Description of the study area

3.2 Nature and source of data

3.3 The study period

3.4 Materials

3.5 Analytical tools and techniques

3.1 Description of the study area

The Indian State of Karnataka is located 11°30' North and 18°30' North latitudes and 74° East and 78°30' East longitude. It is situated on a tableland where the Western and Eastern Ghat ranges converge into the complex, in the western part of the Deccan Peninsular region of India. The State is bounded by Maharashtra and Goa States in the north and northwest, by the Arabian Sea in the west, by Kerala and Tamil Nadu States in the south and by the States of Andhra Pradesh and Telangana in the east. Karnataka extends to about 750 km from north to south and about 400 km from east to west.

Karnataka is the sixth-largest state in India by area (1,91,791 km^2) and eighth-most populous (61 million) state. The economy of Karnataka is the fourth-largest state economy in India with ₹15.35 lakh crore in gross domestic product and a per capita GDP of ₹2,10,000. Karnataka has the twelfth highest ranking among Indian states in human development index.

The present study was conducted in the state of Karnataka. In Karnataka, all the thirty districts were selected for making a detailed study.

3.2 Nature and source of data

The secondary data were collected for analysis from Directorate of Economics and Statistics and indiastat.com.

3.3 The study period

In accordance with the objective delineated, the time-series data pertaining to the total jowar production ('000 t) and productivity (kg/ha) for over a long span of 30 years, i.e., from 1989 to 2018 had been brought under the purview of the present analysis.

3.4 Materials

Data pertaining to five important factors related to jowar for the study purpose were collected both for Karnataka and India as a whole. The selected factors were as:

X_1	=	Jowar area	('000 ha)
X_2	=	Jowar production	('000 tonnes)
X_3	=	Jowar productivity	(kg/ ha)
X_4	=	Value of output	(Rs. in Lakh)
X_5	=	MSP	(Rs/q)

From Jowar statistics, five factors were screened which were found to have substantial effect on the total Jowar production (viz., area, production, productivity, value of output and minimum support price pertaining to the all agricultural sector).

3.5 Analytical tools and techniques

For the purpose of analyzing the objectives of the study, data were subjected to analyses through the following statistical techniques.

3.5.1 Growth rate study on time series production factors on jowar

A number of studies were undertaken to understand growth pattern of production and productivity under jowar crop in Karnataka and India. Statistical tools and techniques ranging from graphs to model fitting were employed.

The statistics, viz., Mean, Coefficient of variation (CV) and percentage figures were computed in respect of the above factors for both Karnataka and India. The coefficient of variation criterion was used for consistency of a factors over years. In order to study the growth rate, the well-known growth model was fitted with respect to each factor.

The model

$$X_{it} = \alpha \, \beta^{t} \, \varepsilon_{it} \qquad i = 1,2,\ldots,5; \quad t = 1,2,\ldots,30;$$

$$\log X_{it} = \log \alpha + t \log \beta + \log \varepsilon_{it}$$

Where,

X_{it} = the response of the i^{th} factor in the t^{th} year,

α, β = unknown parameters to be estimated in the model,

t = time element which takes the value 1, 2, 3,…,n

ε_{it} = multiplicative error

ε_{it} s ~ IID $N(0, \sigma^2)$

The above growth model was linearalised by using logarithmic transformation and the unknown parameters were estimated by the ordinary least squares (OLS) method. From the fitted model compound growth rate percentage was computed as:

Compound Growth Rate (%):

$$(\text{CGR } \%) = (\text{Antilog } b - 1) \times 100$$

Where, b = Estimated value of β.

Further, to examine the stability of all factors the coefficient of variation (CV) was estimated by using the formula:

$$CV = \frac{\sigma_X}{\bar{X}} \times 100$$

where,

σ_X = Standard deviation of x factor, and

$\bar{X}$ = Mean of x factor.

Simple correlation coefficients among the five factors were computed to study the strengths of their interrelationship in respect of Karnataka. To diagnose the important factors (appearing in the total production scenario) which have their direct and indirect influences on the total jowar production, the technique of path coefficient analysis has been employed.

3.5.2 A statistical diagnostic study for detecting the influential time series production factors governing total jowar production

3.5.2.1Path coefficient analysis

Correlation coefficients measure the absolute value of correlation between variables in a given body of data. Correlation does not say anything about the cause and effect relationship. Sewell Wright (1921) developed and applied the method of path analysis for the purpose of interpretation of a system of correlation coefficients in terms of paths of causation. The theory underlying path analysis is that a variable Y is represented and completely determined by a number of intermediate factors X_1, X_2, …, X_5 and R, all of which except the residual R is represented as inter-correlated.

The path diagram shows Y as either completely determined by certain other factors or as the ultimate factor. In this study Y, the dependent variable jowar production (X_2) is of various components like jowar area (X_1), jowar productivity (X_3), value of output (X_4), minimum support price (X_5), the independent variable, could be the jowar production components and are inter-correlated among themselves and also correlated to Y and R the residual factor is not included in the study when all the relations are linear *i.e.* when Y, jowar production (X_2) is treated as a linear function of a number of others, X_1, X_3, X_4, X_5 and the residual factors R. Then we have

$$Y = b_0+b_{01}X_1+b_{03}X_3+\ldots+ b_{05}X_5R$$

where b_{0i}'s are partial regression coefficients and which measure the concrete contribution that $X_1,X_3,\ldots,X_5$ make directly to Y. When these variables are standardized *i.e.* when they are measured from their means in units of standard deviation, the above equation takes the form as

$$Y=\rho_{01}X_1+\ldots+ \rho_{05}X_5+b_{0R}R$$

where,

ρ_{0i}'s are standardized path regression coefficients.

The correlation between $Y(=X_2)$ and the known variables $(X_1, X_3, \ldots, X_5)$ may be written as a series of simultaneous linear equations equal in number to the unknown path coefficients

$$r_{YX_1} = \rho_{01} + r_{X_1X_2}\rho_{02} + r_{X_1X_3}\rho_{03} + r_{X_1X_4}\rho_{04} + r_{X_1X_5}\rho_{05} \ldots\ldots\ldots\ldots\ldots 1$$

$$r_{YX_3} = r_{X_1X_3}\rho_{01} + r_{X_3X_2}\rho_{02} + \rho_{03} + r_{X_3X_4}\rho_{04} + r_{X_3X_5}\rho_{05} \ldots\ldots\ldots\ldots 2$$

$$r_{YX_4} = r_{X_1X_4}\rho_{01} + r_{X_4X_2}\rho_{02} + r_{X_3X_4}\rho_{03} + \rho_{04} + r_{X_4X_5}\rho_{05} \ldots\ldots\ldots\ldots 3$$

$$r_{YX_5} = r_{X_1X_5}\rho_{01} + r_{X_5X_2}\rho_{02} + r_{X_5X_3}\rho_{03} + r_{X_5X_4}\rho_{04} + \rho_{05} \ldots\ldots\ldots\ldots\ldots 4$$

where, r_{YX1}, r_{YX3}, r_{YX4}, and r_{YX5} are the simple correlation coefficients between each of the causal factors and the effect Y.

The correlation coefficient between variables is partitioned into (1) direct effect measured by path coefficient and (2) indirect effect. The path coefficients ρ_{01}, ρ_{03}, ρ_{04}, and ρ_{05} are the direct effects of the causal factors X_1, X_3, X_4 and X_5 on Y and $r_{x1x3}\rho_{03}$, $r_{x1x4}\rho_{04}$ and $r_{x1x5}\rho_{05}$ are the indirect effects of X_1 on Y through X_3, X_4 and X_5 respectively. Thus the method of path coefficient which is a form of multiple regressions can be applied to find the best linear expression of one variable in terms of a number of others from the knowledge of correlation coefficient. The above simultaneous equations can be written in the form of matrices as follows-

$$\begin{bmatrix} r_{YX_1} \\ r_{YX_3} \\ r_{YX_4} \\ r_{YX_5} \end{bmatrix} = \begin{bmatrix} r_{X_1X_1} & r_{X_1X_3} & r_{X_1X_4} & r_{X_1X_5} \\ r_{X_3X_1} & r_{X_3X_3} & r_{X_3X_4} & r_{X_3X_5} \\ r_{X_4X_1} & r_{X_4X_3} & r_{X_4X_4} & r_{X_4X_5} \\ r_{X_5X_1} & r_{X_5X_3} & r_{X_5X_4} & r_{X_5X_5} \end{bmatrix} \text{X} \begin{bmatrix} \rho 01 \\ \rho 03 \\ \rho 04 \\ \rho 05 \end{bmatrix}$$

A B C

The path coefficient values are estimated as

$$\begin{bmatrix} \rho 01 \\ \rho 03 \\ \rho 04 \\ \rho 05 \end{bmatrix} = \begin{bmatrix} r_{X_1X_1} & r_{X_1X_3} & r_{X_1X_4} & r_{X_1X_5} \\ r_{X_3X_1} & r_{X_3X_3} & r_{X_3X_4} & r_{X_3X_5} \\ r_{X_4X_1} & r_{X_4X_3} & r_{X_4X_4} & r_{X_4X_5} \\ r_{X_5X_1} & r_{X_5X_3} & r_{X_5X_4} & r_{X_5X_5} \end{bmatrix} \text{X} \begin{bmatrix} r_{YX_1} \\ r_{YX_3} \\ r_{YX_4} \\ r_{YX_5} \end{bmatrix}$$

This can be also written as $C=B^{-1}A$

3.5.2.2 Determination of residual variability

Considering the equation,

$$Y = X_1 + X_2 + X_3$$

It can be shown that

$$\sigma_Y^2 = \sigma_{X_1}^2 + \sigma_{X_2}^2 + \sigma_{X_3}^2 + 2\sigma_{X_1X_2} + 2\sigma_{X_1X_3} + 2\sigma_{X_2X_3}$$

Now, dividing both sides by σ_Y^2

$$1 = (\rho_{01})^2 + (\rho_{02})^2 + (\rho_{03})^2 + 2r_{X_1X_2}\rho_{01}\rho_{02} + 2r_{X_1X_3}\rho_{01}\rho_{03} + 2r_{X_2X_3}\rho_{02}\rho_{03}$$

Now extending the model to include residual R (= X_1+X_2+X_3+…+X_m +R), the determination of Y by the residual factors R, estimated from the following relationship.

$$R^2 = 1 - \sum_{i=1}^{m} \rho_{0i}^2 - 2\sum_{j,k=1}^{m} \rho_{0j}\rho_{ok}r_{jk}, \quad \mathrm{k} > j$$

3.5.3 Statistical model fitting on agricultural dynamic variables for projecting the future values

Jowar production ('000 t) and Jowar productivity (kg/ha) are given in Table 3 (apendix-3) have been taken for study. The production models of these two factors (production & productivity) were constructed following the advanced procedures elaborated in Montgomary and Peck (1992). The analysis has been performed by

The functional form of the above-mentioned models is

$$Y_t = f(\, t_i\ \beta_j\,) \qquad i = 1,2,\ldots,30; \quad j = 1,2,\ldots,p;$$

where,

Y_t = i^{th} year production of Jowar production/ productivity,

β_j = unknown parameter to be estimated,

p = parameter

ε_t = random error term satisfying strictly the assumptions of normality, independence with zero mean and a constant variance, i.e.

$$\varepsilon_t\text{'s} \sim \text{IID } N(0, \sigma^2)$$

The five models, viz. linear, quadratic, compound, cubic and power, were fitted on the first 26 years data and the sequentially adding one year datum at each stage up to the 30th year, being the last stage. The functional forms of these models are given as

Models		**Functional forms**	
Linear	:	$Y_t = \alpha + \beta_1 t + \varepsilon_t$	- - - - - - - - - - - (1)
Quadratic	:	$Y_t = \alpha + \beta_1 t + \beta_2 t^2 + \varepsilon_t$	- - - - - - - - - - - (2)
Compound	:	$Y_t = \alpha\ (\beta_1)^t \times \varepsilon_t$	- - - - - - - - - - - (3)
Cubic	:	$Y_t = \alpha + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \varepsilon_t$	- - - - - - - - - - - (4)
Power	:	$Y_t = \alpha\ (t)^{\beta} \times \varepsilon_t$	- - - - - - - - - - - (5)

(Johnson and Wichern, 2007)

Where,

Y_{it} = response of the i^{th} factor in the t^{th} year

α, β = unknown parameters of the model to be estimated,

ε_t = multiplicative error

The parameters of the linear models were estimated by ordinary least squares (OLS) method. The parameters of the non-linear models with multiplicative error term were linearalized by suitable transformation and OLS technique was applied to estimate the model parameters.

These models, also exhibit stability for predicting future values in respect of each factor. The results obtained from after fitting of these models was compared on the basis of criteria R^2, RMSE and Adjusted R^2 values.

The model represents the minimum RMS and highest R^2 was considered best for that particular factor on available data.

Validation of the econometric model

For checking the validity of the model as a dynamic system, stability of the model and its ability to stimulate historical data has been examined. The performance of the model had been examined through Coefficient of determination (R^2), Residual mean square error (RMSE) and Adjusted R^2.

(1) Coefficient of determination

The goodness of fit is examined by using the coefficient of determination (R^2).

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Yi - \hat{Y}i)^2}{\sum_{i=1}^{n}(Yi - \bar{Y}i)^2}$$

(2) Residual Mean Square Error

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(Yi - \hat{Yi})^2}{n}}$$

The smaller the value of RMSE the better is the model.

(3) Adjusted R^2

Adjusted R-square is nothing but the change of R-square that adjusts the number of terms in a model. Adjusted R square calculates the proportion of the variation in the dependent variable accounted by the explanatory variables. The adjusted R^2 always has a lower value than R^2.

The Adjusted R^2 defined as:

$$\bar{R}^2 = 1 - \frac{\sum_{i=1}^{n}(Yi - \hat{Y}i)^2/(\mathrm{n-k})}{\sum_{i=1}^{n}(Yi - \bar{Y}i)^2\,/(n-1)}$$

or $$R^2_{adj} = 1-(1-R^2)\,\frac{n-1}{n-k}$$

where,

k = the number of parameters of the model including the intercept term.

The above criteria were carried out with respect to data sets on production figures related to the factors under study, separately. The parameters of these models were estimated by OLS technique. By comparing and judging judiciously the estimates of the parameters, summary statistics, viz. coefficient of determination R^2; residual mean squares error (RMSE) and adjusted R^2 values, fitted better models were screened primarily. A best fitted parsimonious model was one which had the smallest RMSE with smaller number of parameters in a set of competing best fitted adequate models.

RESULTS

In consonance with the objectives of the study, the data collected from the different sources were analyzed and interpreted. The results of the study were presented in this chapter under the following headings.

4.1 Descriptive and growth rate study on time series production factors of jowar

4.1.1 Fitting the growth models and compound growth rate

4.1.2 Average and coefficient of variation with respect to jowar production factors

4.2 Statistical diagnostic study for detecting influential time series production factors governing total jowar production

4.2.1 Correlation of jowar production and jowar production factors

4.2.2 Path coefficient analysis between selected factors and jowar production

4.2.3 Direct and indirect influence of jowar factors

4.3 Statistical model fitting on jowar production and productivity.

4.1 Descriptive and growth rate study on time series production factors of jowar

4.1.1 Fitting the growth models and compound growth rate

The results emanated from the data considered under the purview of this investigation are presented in Table 4.1.

Table 4.1: Fitted growth models and Compound growth rates of factors of jowar during 1989 to 2018

Factors	Fitted growth models		CGR (%)	
	India	Karnataka	India	Karnataka
X1	$X1=14343.1x0.96^t$	$X1=2382.11x0.98^t$	-3.61	-2.25
X2=Y	$X2=11524.5x0.97^t$	$X2=1776.59x0.99^t$	-2.55	-1.03
X3	$X3=790.01x1.01^t$	$X3=704.86x1.01^t$	1.09	1.25
X4	$X4=199775.8x1.05^t$	$X4=14977.9x1.06^t$	4.81	6.45
X5	$X5=-139.55x1.09^t$	$X5=-139.55x1.09^t$	8.88	8.88

Table 4.1 reveals the growth dynamics of the jowar production factors for India and Karnataka during the period 1989 to 2018. From the table, it is seen that the maximum compound growth rate of MSP of jowar was observed in India as well as in Karnataka. Whereas negative CGRs were recorded for jowar production in India as well as Karnataka.

In case of India as a whole, the significant increase has been occurred in productivity (1.09%), value of output (4.81%) and Minimum support price (8.88%) and the decline in growth rate had occurred in area i.e. -3.61% and production i.e. -2.55%. Though the compound growth rates for Karnataka state record significant increase (per year) with respect to the factors jowar productivity (1.25%), value of output (6.45%) and Minimum Support Price (8.88%) yet surprisingly, the negative growth rates for the factors production (-1.03%) and area (-2.25%) has occurred. Both for India and Karnataka the factors are almost on par with each other. The growth rate scenarios for most of the factors with respect to India and Karnataka are quite satisfactory as, in these areas, positive significant growth rates loudly substantiate the theme of national advancement.

4.1.2 Average and coefficient of variation with respect to jowar production factors

Table 4.2: Averages, coefficient of variations with respect to Jowar factors and their percentage contributions to India from Karnataka during 1989 to 2018

Factors	INDIA		KARNATAKA		Percentage contribution of Karnataka to India
	Mean	C.V. (%)	Mean	C.V. (%)	
X1	9437.97	29.97	1658.43	25.38	17.57
Y=X2	7882.97	29.49	1451.97	20.96	18.42
X3	843.77	11.64	904.43	21.06	107.19
X4	574987.50	42.05	121279.60	56.74	21.09
X5	681.43	74.31	681.43	74.31	100

The table 4.2 indicated that Karnataka contributed 17.57% in area, 18.42% in production. The jowar productivity in Karnataka was 7.19% higher than the nation’s productivity and the value of output was lower than the India. Average values of factors corresponding to Karnataka and India as a whole were not comparable as percentage figures related to Karnataka in comparison to those of all India show significant contribution on the part of this state to the national scene for most of the factors which can be observed from this table.

Moreover, the values of the coefficients of variation revealed the existence of greater inconsistency (fluctuation) in the data. From the table, it was noted that the maximum coefficient of variation was observed for minimum support price both in India (74.31%) as well as in Karnataka (74.31%). The minimum coefficient of variation was observed for productivity in India (11.64%) and for production in Karnataka (20.96%). Hence, concluded that the most stable factors were productivity and production in India and Karnataka, respectively.

4.2 Statistical diagnostic study for detecting influential time series production factors governing total jowar production

The production of jowar was considered as dependent variable and the production factors were considered as independent variables. Further statistical analysis carried out using path coefficient analysis to know the direct and indirect effects of selected production factors on the production of jowar. The results of path analysis and correlation were described as under.

4.2.1 Correlation of jowar production factors

The correlation coefficients for the different pairs of variables were assessed (table 4.3). In this table the interrelationship among the total jowar production X_2 (Y dependent) variable and other production factors independent variables (jowar area, productivity, value of output and minimum support price) are represented in table 4.3 for Karnataka.

Table 4.3: Correlation of jowar production factors on the total jowar production in Karnataka

	X1	Y=X2	X3	X4	X5
X1	1	0.616*	-0.621*	-0.876*	-0.905*
Y=X2		1	0.221	-0.334	-0.623*
X3			1	0.767*	0.509*
X4				1	0.855*
X5					1

* Correlation is significant at the 0.01 level.

The results indicated that the production of jowar was positively and significantly correlated with jowar area (0.616) and productivity (0.221). Whereas, negatively correlated with the value of output (-0.334) and minimum support price (-0.623). From the table it was also noticed that area and minimum support price has the significant relationship with the jowar production. These components exhibited interrelationship with each other. This shows that the importance of these components as production attributing factors.

The correlation coefficients between X_2(Y) and other factors (area, productivity, value of output and minimum support price) are presented in table 4.4 for India.

Table 4.4: Correlation of jowar production factors on the total jowar production in India

	X1	Y=X2	X3	X4	X5
X1	1	0.914*	-0.300	-0.872*	-0.888*
Y=X2		1	0.096	-0.689*	-0.819*
X3			1	0.546*	0.243
X4				1	0.859*
X5					1

* Correlation is significant at the 0.01 level.

The results indicated that the productivity and area of jowar had positive and significant correlation with jowar production in India, whereas jowar production of India had negative and significant correlation with value of output and minimum support price. These factors were found important for total jowar production of India.

4.2.2 Path coefficient analysis between selected factors and jowar production

Path analysis results aimed to diagnose the direct and indirect effect of important factors on the total jowar production which are summarized in table 4.5 to table 4.6 with respect to Karnataka and India as a whole respectively.

Table 4.5: Path coefficient between selected factors and jowar production in Karnataka

Parameters	X_1	X_3	X_4	X_5
X_1	**0.994**	-0.548	0.102	0.052
X_3	-0.617	**0.882**	-0.089	-0.029
X_4	-0.871	0.676	**-0.117**	0.049
X_5	-0.899	0.449	-0.100	**-0.057**

The diagonal elements represent direct effects and the off-diagonal elements represent indirect effects (Table 4.5). This indicates that area had a high positive effect of 0.994 followed by productivity (0.882).

Table 4.6: Path coefficient between selected factors and jowar production in India

Parameters	X_1	X_3	X_4	X_5
X_1	**0.984**	-0.118	0.159	-0.035
X_3	-0.294	**0.396**	-0.099	0.009
X_4	-0.858	0.216	**-0.182**	0.034
X_5	-0.874	0.096	-0.156	**0.040**

Table 4.6 represents the path coefficient analysis between selected factors and jowar production in India. This indicates that the area had high positive effect on jowar production (0.984) followed by productivity (0.396). It is found that the corresponding descending order with respect to the factors is jowar productivity via. Minimum support price via. Value of output.

Table 4.7 Direct and indirect influence of jowar factors on the total jowar production in Karnataka

Factors	Direct influence	Rank of direct influence	Total indirect influence	Rank of indirect influence
Jowar area	0.994	1	-0.394	2
Jowar productivity	0.882	2	-0.735	4
Value of output	-0.117	4	-0.146	1
Minimum support price	-0.057	3	-0.550	3

Table 4.7 portrays corresponding scenario prevailing with respect of Karnataka. In fact, it reveals that area was the most direct influential factor for jowar production with rank 1 followed by productivity with rank 2 followed by minimum support price and value of output. The total indirect effect of value of output had rank 1 followed by area with rank 2, minimum support price and productivity.

Table 4.8 Direct and indirect influence of jowar factors on the total jowar production in India

Factors	Direct influence	Rank of direct influence	Total indirect influence	Rank of indirect influence
Jowar area	0.984	1	0.006	1
Jowar productivity	0.396	2	-0.384	2
Value of output	-0.182	4	-0.608	3
Minimum support price	0.040	3	-0.934	4

All the factors had positive direct effects on jowar production in India except value of output (Table 4.8). The jowar area was on first position followed by jowar productivity and minimum support price. The highest total indirect effect of jowar area was observed in India.

The results obtained in course of building up to the best fitting parsimonious dynamic forecasting models on the total production of jowar and productivity are given in Table 4.9 to Table 4.12 (Fig-3 to Fig-6). The five models viz., linear, quadratic, cubic, compound and power, were fitted on the first 26 years data and the sequentially adding one year datum at each stage up to the 30th year, being the last stage. With their usual meanings as discussed in the selection “Methods”. The results obtained from these models is summarized in Table 4.9 to Table 4.12 by judicious comparison among the models with respect to R^2, RMSE and Adjusted R^2 values. The compound and Power models were screened to be the best fitting models. These models, also exhibited stability for predicting future values in respect of each factor.

The best fitting models with parameter R^2, RMSE, and Adjusted R^2, were found to be compound growth model and power growth model for jowar production in Karnataka. The value of compound model with parameter R^2, RMSE, and Adjusted R^2 is 15.2%, 0.034, 0.117 in year 2014 and the value of R^2, RMSE, Adjusted R^2 in year 2015 is 18.9%, 0.033, 0.157 and value of R^2, RMSE, Adjusted R^2 in year 2016 is 25.5%, 0.034, 0.226 and value of R^2, RMSE, Adjusted R^2 in 2017 is 32.4%, 0.037, 0.299 and value of R^2, RMSE, Adjusted R^2 in 2018 is 34.6%, 0.036, 0.322.

The value of power model with parameter R^2, RMSE, and Adjusted R^2 is 10.2%, 0.036, 0.065 in year 2014 and the value of R^2, RMSE, Adjusted R^2 in 2015 is 12.5%, 0.035, 0.090 and value of R^2, RMSE, Adjusted R^2 in 2016 is 16.1%, 0.039, 0.129 and value of R^2, RMSE, Adjusted R^2 in 2017 is 19.6%, 0.044, 0.167 and value of R^2, RMSE, Adjusted R^2 in 2018 is 21.5%, 0.043, 0.187.

Table 4.9: Different goodness of fit criteria for models on total jowar production in Karnataka

Time	Models	R^2 (%)	RMSE	Adjusted R^2
2014 (t=26)	Linear	17.8	61247.875	0.144
	Quadratic	18.0	63762.632	0.109
	Cubic	20.8	64407.810	0.100
	Compound	15.2	0.034	0.117
	Power	10.2	0.036	0.065
2015 (t=27)	Linear	21.8	59510.615	0.186
	Quadratic	22.4	61499.398	0.159
	Cubic	23.5	63220.966	0.136
	Compound	18.9	0.033	0.157
	Power	12.5	0.035	0.090
2016 (t=28)	Linear	27.9	60774.541	0.252
	Quadratic	30.2	61213.564	0.246
	Cubic	30.2	63748.390	0.215
	Compound	25.5	0.034	0.226
	Power	16.1	0.039	0.129
2017 (t=29)	Linear	34.2	63008.209	0.318
	Quadratic	38.8	60877.099	0.341
	Cubic	39.1	62988.533	0.318
	Compound	32.4	0.037	0.299
	Power	19.6	0.044	0.167
2018 (t=30)	Linear	36.7	60760.725	0.344
	Quadratic	40.5	59228.060	0.361
	Cubic	40.5	61489.187	0.336
	Compound	34.6	0.036	0.322
	Power	21.5	0.043	0.187

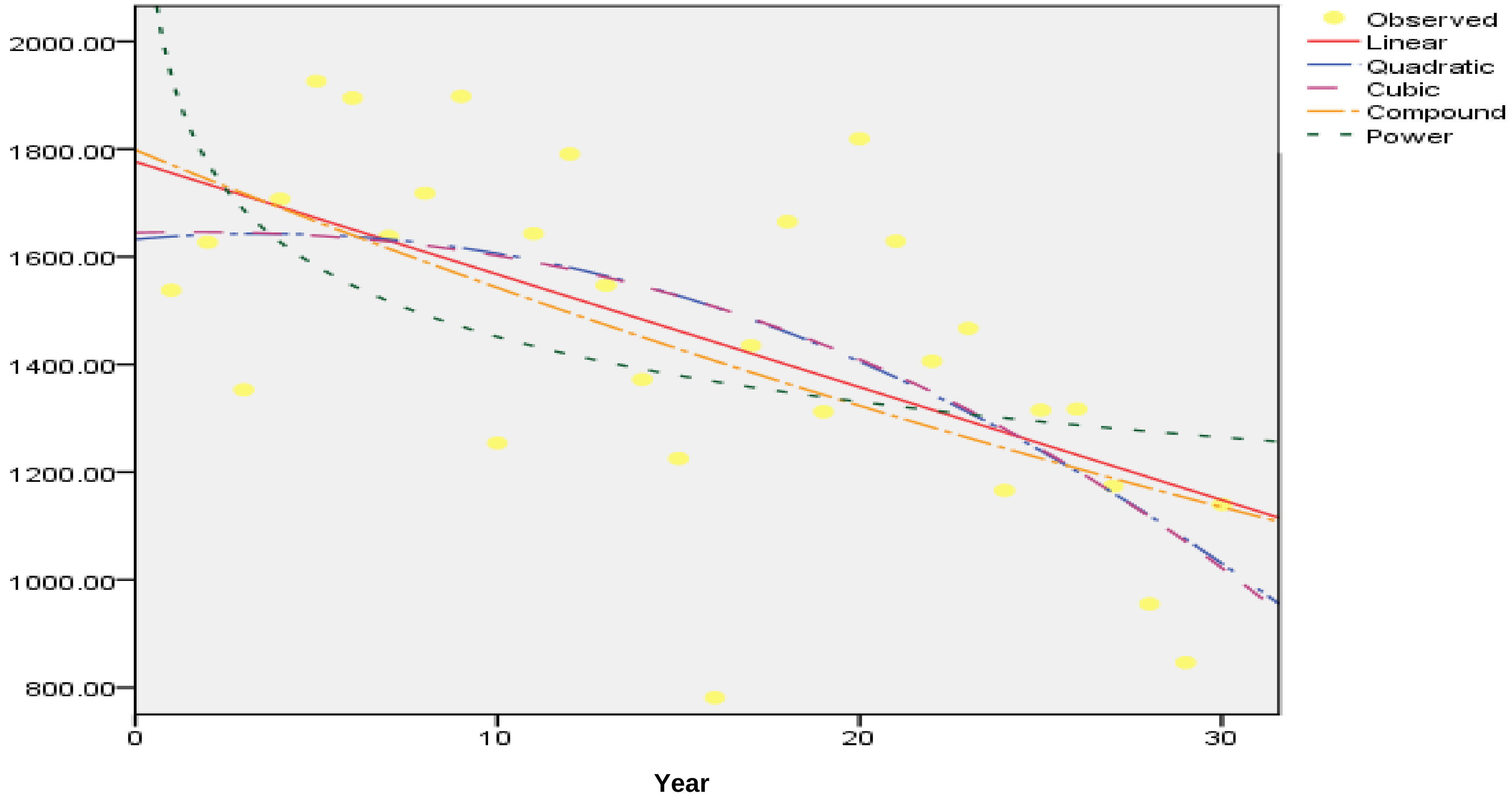

Fig. 4.1- Diagram showing the fitting of total jowar production in Karnataka.

Table 4.10: Different goodness of fit criteria for models on total jowar productivity in Karnataka

Time	Models	R^2 (%)	RMSE	Adjusted R^2
2014 (t=26)	Linear	41.6	23842.173	0.392
	Quadratic	45.1	23393.147	0.403
	Cubic	45.2	24387.655	0.378
	Compound	34.4	0.037	0.316
	Power	25.6	0.042	0.225
2015 (t=27)	Linear	44.4	22888.816	0.422
	Quadratic	47.2	22647.488	0.428
	Cubic	47.2	23632.029	0.403
	Compound	37.2	0.036	0.347
	Power	27.9	0.041	0.250
2016 (t=28)	Linear	38.4	24433.463	0.360
	Quadratic	38.7	25302.275	0.337
	Cubic	40.6	25500.762	0.332
	Compound	32.9	0.037	0.303
	Power	26.4	0.040	0.235
2017 (t=29)	Linear	34.3	25103.125	0.318
	Quadratic	34.4	26021.232	0.293
	Cubic	39.3	25041.155	0.320
	Compound	30.0	0.037	0.274
	Power	25.5	0.039	0.227
2018 (t=30)	Linear	35.4	24282.687	0.331
	Quadratic	35.6	25087.619	0.309
	Cubic	39.9	24313.255	0.330
	Compound	31.4	0.035	0.289
	Power	26.9	0.038	0.243

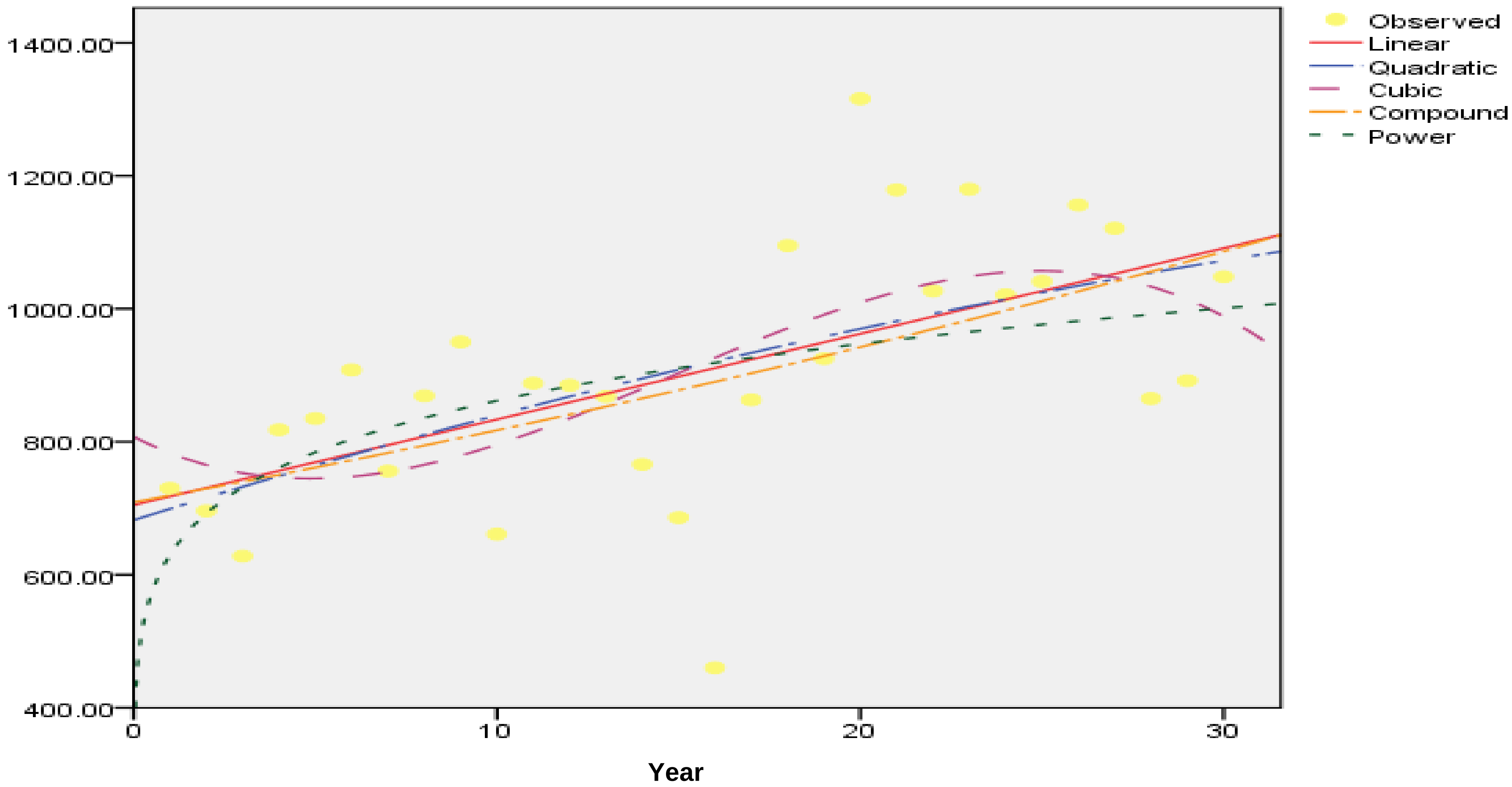

Fig. 4.2- Diagram showing the fitting of jowar productivity in Karnataka.

Table 4.11: Different goodness of fit criteria for models on total jowar production in India

Time	Models	R^2 (%)	RMSE	Adjusted R^2
2014 (t=26)	Linear	71.2	1331343.266	0.700
	Quadratic	72.5	1328343.842	0.701
	Cubic	72.5	1387523.195	0.688
	Compound	75.8	0.015	0.748
	Power	64.4	0.021	0.629
2015 (t=27)	Linear	73.2	1279770.609	0.721
	Quadratic	74.3	1276868.803	0.722
	Cubic	74.4	1328740.256	0.710
	Compound	78.1	0.014	0.772
	Power	65.9	0.022	0.645
2016 (t=28)	Linear	75.9	1251098.885	0.749
	Quadratic	76.3	1277916.114	0.744
	Cubic	76.8	1304683.247	0.739
	Compound	79.7	0.016	0.789
	Power	64.8	0.027	0.634
2017 (t=29)	Linear	77.8	1205173.423	0.770
	Quadratic	78.1	1234998.646	0.765
	Cubic	78.7	1252507.511	0.761
	Compound	81.7	0.015	0.810
	Power	65.6	0.029	0.643
2018 (t=30)	Linear	79.2	1166495.308	0.784
	Quadratic	79.5	1189400.157	0.780
	Cubic	79.9	1212694.951	0.776
	Compound	83.2	0.015	0.827
	Power	66.8	0.029	0.657

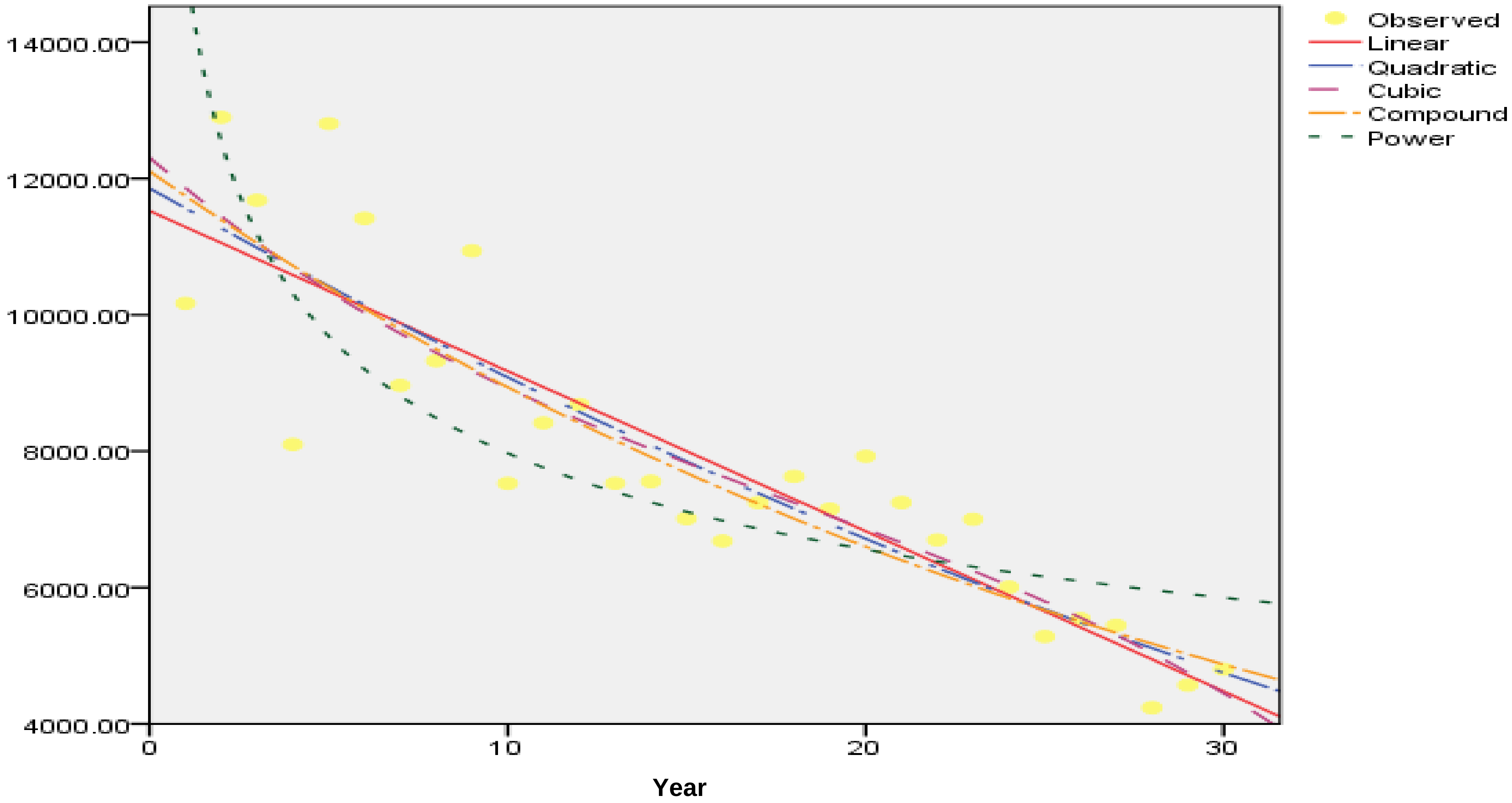

Fig. 4.3- Diagram showing the fitting of total jowar production in India.

Table 4.12: Different goodness of fit criteria for models on total jowar productivity in India

Time	Models	R^2 (%)	RMSE	Adjusted R^2
2014 (t=26)	Linear	18.1	8294.952	0.147
	Quadratic	21.8	8261.112	0.150
	Cubic	23.6	8445.639	0.131
	Compound	18.4	0.012	0.150
	Power	15.0	0.012	0.114
2015 (t=27)	Linear	18.2	8004.804	0.149
	Quadratic	20.4	8114.739	0.137
	Cubic	20.6	8443.604	0.102
	Compound	18.7	0.012	0.154
	Power	15.6	0.012	0.122
2016 (t=28)	Linear	08.7	9337.574	0.052
	Quadratic	08.8	9698.904	0.016
	Cubic	11.4	9814.924	0.004
	Compound	08.8	0.014	0.052
	Power	09.4	0.014	0.059
2017 (t=29)	Linear	06.9	9200.832	0.034
	Quadratic	07.7	9472.787	0.006
	Cubic	11.6	9432.234	0.010
	Compound	07.1	0.013	0.037
	Power	08.4	0.013	0.050
2018 (t=30)	Linear	09.7	9029.195	0.064
	Quadratic	09.8	9353.904	0.031
	Cubic	10.8	9599.647	0.005
	Compound	09.8	0.013	0.066
	Power	10.3	0.013	0.071

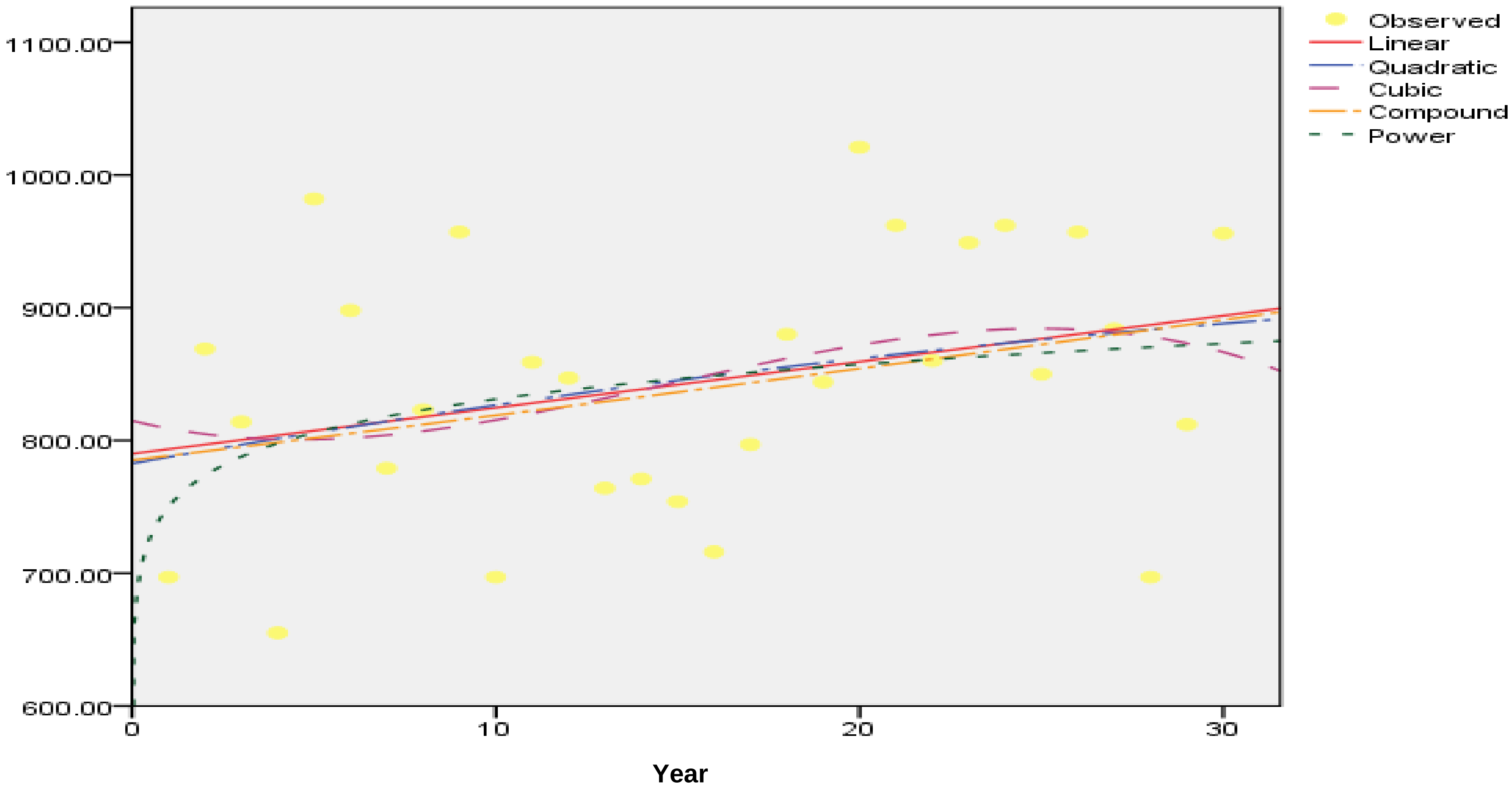

Fig. 4.4- Diagram showing the fitting of jowar productivity in India.

The best fitting models with parameter R^2, RMSE, and Adjusted R^2, is found to be compound and power for jowar productivity in Karnataka. The value of compound model with parameter R^2, RMSE, and Adjusted R^2 is 34.4%, 0.037, 0.316 in year 2014 and the value of R^2, RMSE, Adjusted R^2 in 2015 is 37.2%, 0.036, 0.347 and value of R^2, RMSE, Adjusted R^2 in 2016 is 32.9%, 0.037, 0.303 and value of R^2, RMSE, Adjusted R^2 in 2017 is 30.0%, 0.037, 0.274 and value of R^2, RMSE, Adjusted R^2 in 2018 is 31.4%, 0.035, 0.289.

The value of power model with parameter R^2, RMSE, and Adjusted R^2 is 25.6%, 0.042, 0.225 in year 2014 and the value of R^2, RMSE, Adjusted R^2 in year 2015 is 27.9%, 0.041, 0.250 and value of R^2, RMSE, Adjusted R^2 in 2016 is 26.4%, 0.040, 0.235 and value of R^2, RMSE, Adjusted R^2 in 2017 is 25.5%, 0.039, 0.227 and value of R^2, RMSE, Adjusted R^2 in 2018 is 26.9%, 0.038, 0.243 (Table 4.10).

The best fitting models with parameter R^2, RMSE, and Adjusted R^2, is found to be compound and power for jowar production in India. The value of compound model with parameter R^2, RMSE, and Adjusted R^2 is 75.8%, 0.015, 0.748 in year 2014 and the value of R^2, RMSE, Adjusted R^2 in 2015 is 78.1%, 0.014, 0.772 and value of R^2, RMSE, Adjusted R^2 in 2016 is 79.7%, 0.016, 0.789 and value of R^2, RMSE, Adjusted R^2 in 2017 is 81.7%, 0.015, 0.810 and value of R^2, RMSE, Adjusted R^2 in 2018 is 83.2%, 0.015, 0.827.

The value of power model with parameter R^2, RMSE, and Adjusted R^2 is 64.4%, 0.021, 0.629 in the year 2014 and value of R^2, RMSE, Adjusted R^2 in 2015 is 65.9%, 0.022, 0.645 and value of R^2, RMSE, Adjusted R^2 in 2016 is 64.8%, 0.027, 0.634 and value of R^2, RMSE, Adjusted R^2 in 2017 is 65.6%, 0.029, 0.643 and value of R^2, RMSE, Adjusted R^2 in 2018 is 66.8%, 0.029, 0.657 (Table 4.11).

The best fitting models with parameter R^2, RMSE, and Adjusted R^2, is found to be compound and power for jowar productivity in India. The value of compound model with parameter R^2, RMSE, and Adjusted R^2 is 18.4%, 0.012, 0.150 in year 2014 and the value of R^2, RMSE, Adjusted R^2 in 2015 is 18.7%, 0.012, 0.122 and value of R^2, RMSE, Adjusted R^2 in 2016 is 08.8%, 0.014, 0.052 and value of R^2, RMSE, Adjusted R^2 in 2017 is 07.1%, 0.013, 0.037 and value of R^2, RMSE, Adjusted R^2 in 2018 is 09.8%, 0.013, 0.066.

The value of power model with parameter R^2, RMSE, and Adjusted R^2 is 15.0%, 0.012, 0.114 in year 2014 and the value of R^2, RMSE, Adjusted R^2 in 2015 is 15.6%, 0.012, 0.122 and value of R^2, RMSE, Adjusted R^2 in 2016 is 09.4%, 0.014, 0.059 and value of R^2, RMSE, Adjusted R^2 in 2017 is 08.4%, 0.013, 0.050 and value of R^2, RMSE, Adjusted R^2 in 2018 is 10.3%, 0.013, 0.071 (Table 4.12).

Forecasting for jowar production and jowar productivity in India and also in Karnataka, compound and power stochastic models were suitable.

DISCUSSION

In order to appraise the jowar production, the associated factors of production were to be identified and growth behavior of different factors over time need be critically assessed. In this study growth trends in respect of some important factors related to jowar production have been extensively studied for the case of Karnataka state and India as a whole. The jowar productivity in India result has been found the minimum growth rate, it indicates that farmers may divert their lands for another crops so there is need to increase the yield by the use of high yielding varieties and other crop management practices.

The growth rate of production of jowar crop was found to be negative in Karnataka as well as India. The similar result has been observed by Rajarathinam and Parmar (2010), Singh *et al*. (2012). It is further pointed out that the major factors influencing the productivity for jowar in Karnataka were area under crop and minimum support price. The growth rate for area and productivity of jowar were found significant.

The maximum instability had been seen in the value of output of jowar in India as well as in Karnataka. The coefficient of variation in the minimum support price of jowar was inconsistent and the growth rate was maximum therefore the growth rate can be made stable by changing the minimum support price and other contribution factors. (Ahmad *et al.,* 2015). They examined growers production decisions and have also shown a significant response to prices of other products competing for farm space and other production resources. These results will support efforts aimed at market development and crop enhancement programmed.

The stability observed that productivity was most stable factor followed by production and area in India. The similar result was found by Chahal and Kataria (2003). They observed that production can be stable by price and other controllable factors in crazy manner.

The study of diagnoses for factors affecting the jowar production in Karnataka and in India was done by adopting the technique of correlation and path analysis. The result obtained most direct influential factor for total jowar production is area and the indirect influential factor is also area under crop in India. And the most direct influential factor for total jowar production is area and the indirect influential factor is value of output in Karnataka.

In the present study compound and power are the most suitable models for the forecasting of two influential factors such as production and productivity by using the three comparison criteria, coefficient of determination (R^2), residual mean square error (RMSE), Adjusted R^2. The similar type of model fitting procedure was used by Singh (2013) they also suggest that compound and power are best statistical models on the basis of various goodness of fit criteria.

In Karnataka, as jowar is one of the most important millet crop contributing 18.42% to India. During the 1989 to 2018 for 30 consecutive years, the area and production have registered negative growth rate, with the area decreasing from 2.25% and production by 1.03% and productivity has registered positive growth rate of 1.25% in Karnataka. Measures should be taken to increase the area, production and productivity of jowar. Karnataka is the second largest producer of jowar with the contribution of 18.42% of the national jowar production. Similarly, area and production have registered negative growth rate, with the area decreasing from 3.61% and production from 2.55% and productivity has registered positive growth rate of 1.09% during the period in India. Measures should be taken to increase the area, production and productivity of jowar. To achieve this goal statistical tools and techniques should be used to accurately determine the scope of expansion. The results obtained by the proposed work might be beneficial for the farmers and researcher to determine or increase the trend of jowar production and productivity in Karnataka and India.

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

Jowar is one of the important food and fodder crops grown mostly in arid and semi arid climates of the world as well as in India. The cereal plant of jowar came up in historic times in the present day Ethiopia and east central Africa. It was probably in the first millennium that jowar plants were brought from African countries into India.

The botanical name of jowar is *Sorghum bicolor* is a species of monocotyledonous plant belongs to the Graminae family and grows up to a height of about 4 meters. Seeds are rounded and pointed at the base, the color being brownish, yellow, pink or white.

In India, Jowar is mainly grown in Maharashtra, Karnataka, Madhya Pradesh and Tamil Nadu. In 2017-18 India produced 4.95 million tonnes of Jowar from an area of 4.96 million hectares with an average productivity of 998 kg per hectare. Maharashtra tops the Indian Jowar production with a contribution of 36.45 per cent followed by Karnataka (22.87%), Madhya Pradesh (11.51%) and Tamil Nadu (8.49%).

Jowar is the fifth most important cereal crop in the world after rice, wheat, maize and barley. The nutritional value of jowar is same as that of corn and that is why it is gaining importance as livestock feed. Jowar is also used for ethanol production, producing grain alcohol, starch production, production of adhesives and paper. Jowar cultivation is gaining popularity due to its nature of extreme drought tolerance. Jowar is very nutritious just like corn and can be used as green fodder, dry fodder, hay or silage.

The thesis contains five chapters besides a list of bibliography at the end.

Chapter one is introductory, which describes the importance of jowar crop, its status in India and Karnataka. In brief, we describe the stochastic model and its importance in forecasting the future values and the objectives have been delineated.

Chapter two assimilate the previous works within the framework of this study which are helpful for interpretation of results obtained during the statistical analysis. This part also includes the literature in the study of growth rate analysis in agricultural production, Diagnostic study for detecting the influential time series production factors governing total jowar production, Various statistical models on agricultural dynamic variables for projecting the future values.

Chapter three deals with the materials and methods used in this thesis. The objective wise summary of this chapter is given as follows:

1. For the first objective of this thesis, the information regarding five time series factors has been taken and a functional relation $X_{it}=\alpha\beta^{t}\varepsilon_{it}$ has been established and the compound growth rate has been explained.
2. For the second objective path coefficient analysis has been conceded out and direct and indirect effects have been discussed.
3. For the third objective, the five types of time series stochastic models (Linear, Quadratic, Cubic, Compound, Power) have been employed for forecasting the future values.

Chapters four and five deals with the results and discussion of the present study. From the fitted five factors it reveals that the maximum growth rate has been observed in minimum support price in Karnataka and minimum growth rate in jowar area. The maximum coefficient of variation is observed in minimum support price in Karnataka and minimum coefficient of variation was in production. The most direct influential factor is jowar area followed by productivity and indirect effective factor was value of output. For forecasting, the most suitable models are compound and power.

Chapter six deals with summary, conclusions and suggestions for further research work.

6.2 Conclusions

From the present investigations, it is concluded that

- The Maximum growth rate has been obtained in minimum support price in Karnataka followed by value of output.
- Minimum support price has been found the most unstable factor followed by value of output and area in Karnataka.
- Productivity has been found the most stable factor in India where as in Karnataka, the production represents for the same.
- The most direct and indirect influential factor for jowar production is area and value of output respectively.
- The compound and power are the most suitable models for forecasting production and productivity in Karnataka as well as India.

6.3 Suggestions for Further Work

The suggestions for further research work on the basis of the present investigation are as follows:

- Compound and power models are better fitted models to find the prediction of jowar production over a long period of time.
- A forecasting situation based on compound and power models is to be developed and transferred to farming community well in advance.
- By studying the path coefficient analysis, we came to know which all major factors are influencing more to the jowar production and help to sustainable jowar production with improved productivity to ensure energy security in the country.
- Some non-linear stochastic models should be fitted for the predictions of jowar production.
- Since the data related to time, hence time series analysis may be performed and forecasting may be done using time series models.

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APPENDIX - 1

Data of Jowar area, production, productivity, value of output and minimum support price in Karnataka from 1989 to 2018

Year	X_1 ('000 ha)	X_2 ('000 t)	X_3 (kg/ha)	X_4 (Rs. in Lakh)	X_5 (Rs/q)
1989	2106	1538	730	40959	145
1990	2339	1627	696	32925	165
1991	2155	1353	628	32953	180
1992	2086	1707	818	68010	205
1993	2306	1926	835	55075	240
1994	2086	1895	908	56088	260
1995	2165	1638	756	80453	280
1996	1976	1718	869	90082	300
1997	1999	1898	950	86586	310
1998	1897	1254	661	60719	360
1999	1850	1643	888	104951	390
2000	2024	1791	885	128375	415
2001	1782	1547	868	67507	445
2002	1790	1372	766	73984	485
2003	1786	1225	686	76899	490
2004	1698	781	460	49256	505
2005	1662	1435	863	90524	515
2006	1520	1665	1095	168781	525
2007	1419	1312	925	94961	548
2008	1382	1819	1316	165800	610
2009	1382	1629	1179	152022	850
2010	1369	1406	1027	130771	850
2011	1243	1467	1180	252729	890
2012	1142	1166	1021	222671	990
2013	1263	1315	1041	206823	1510
2014	1139	1317	1156	216923	1510
2015	1047	1174	1121	206718	1540
2016	1104	955	865	187841	1580
2017	948	846	892	186128	1638
2018	1088	1140	1048	250873	1712

Source: Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India.

APPENDIX - 2

Data of Jowar area, production, productivity, value of output and minimum support price in India from 1989 to 2018

Year	X_1 ('000 ha)	X_2 ('000 t)	X_3 (kg/ha)	X_4 (Rs. in Lakh)	X_5 (Rs/q)
1989	14599	10170	697	236031	145
1990	14838	12898	869	270738	165
1991	14357	11681	814	270459	180
1992	12360	8099	655	325998	205
1993	13041	12806	982	448712	240
1994	12711	11415	898	380526	260
1995	11514	8965	779	409269	280
1996	11326	9327	823	453488	300
1997	11431	10939	957	521727	310
1998	10801	7528	697	358755	360
1999	9794	8415	859	532225	390
2000	10251	8685	847	562131	415
2001	9856	7529	764	368792	445
2002	9795	7557	771	394393	485
2003	9300	7012	754	409827	490
2004	9331	6681	716	380464	505
2005	9092	7244	797	451410	515
2006	8667	7630	880	556553	525
2007	8473	7151	844	516560	548
2008	7764	7926	1021	749573	610
2009	7531	7246	962	651037	850
2010	7787	6698	860	685180	850
2011	7382	7003	949	1041983	890
2012	6245	6006	962	980657	990
2013	6214	5282	850	813294	1510
2014	5793	5542	957	907331	1510
2015	6161	5445	884	991654	1540
2016	6077	4238	697	781158	1580
2017	5624	4568	812	877452	1638
2018	5024	4803	956	922249	1712

Source: Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India.

APPENDIX - 3

Data of total jowar production and productivity in Karnataka and India

Year	Jowar Production ('000 t)		Jowar Productivity (kg/ha)	
	Karnataka	India	Karnataka	India
1989	1538	10170	730	697
1990	1627	12898	696	869
1991	1353	11681	628	814
1992	1707	8099	818	655
1993	1926	12806	835	982
1994	1895	11415	908	898
1995	1638	8965	756	779
1996	1718	9327	869	823
1997	1898	10939	950	957
1998	1254	7528	661	697
1999	1643	8415	888	859
2000	1791	8685	885	847
2001	1547	7529	868	764
2002	1372	7557	766	771
2003	1225	7012	686	754
2004	781	6681	460	716
2005	1435	7244	863	797
2006	1665	7630	1095	880
2007	1312	7151	925	844
2008	1819	7926	1316	1021
2009	1629	7246	1179	962
2010	1406	6698	1027	860
2011	1467	7003	1180	949
2012	1166	6006	1021	962
2013	1315	5282	1041	850
2014	1317	5542	1156	957
2015	1174	5445	1121	884
2016	955	4238	865	697
2017	846	4568	892	812
2018	1140	4803	1048	956

Source: Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India.

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Name of Degree	Subject(s) Major	Name of Institution	Year of passing	Percentage of marks/ CGPA obtained
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- Demographical Research

Awards and Grants:

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For the partial fulfillment of the master's degree programme, he was allotted a research problem on **"Statistical Analysis of Jowar Production in Karnataka"** which is successfully conducted by him and being submitted in the form of this thesis.