TIME SERIES MODELLING FOR COMPARATIVE PERFORMANCE AND INFLUENCING FACTORS OF PRODUCTION ON PADDY AND COCONUT IN SOUTH INDIA

by

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DECLARATION

I, hereby declare that this thesis entitled **"TIME SERIES MODELLING FOR COMPARATIVE PERFORMANCE AND INFLUENCING FACTORS OF PRODUCTION ON PADDY AND COCONUT IN SOUTH INDIA"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

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SURESH A.

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LIST OF ABBREVATIONS

ADF	Augmented Dickey-Fuller
ADL	Autoregressive Distributed Lag
AIC	Akaike Information Criterion
APMC	Agricultural Produce Market Committee
BIC	Bayesian Information Criterion
CAGR	Compound Annual Growth Rate
CV	Coefficient of variation
et al.	Co-workers
FE	Fixed Effects
GOI	Government of India
GOK	Government of Karnataka
GOK	Government of Kerala
GOTN	Government of Tamil Nadu
HYV	High Yielding Variety
KAU	Kerala Agricultural University
LOP	Law of One Price
NEM	North East Monsoon
OLS	Ordinary Least Square
NSSO	National Sample Survey Organization
RAS	Regional Agricultural Research Station
RE	Random Effects
RH	Relative Humidity
RMSE	Root Mean Square Error
SE	Standard Error
VAR	Vector Auto Regression
VECM	Vector Error Correction Model
VIF	Variance Inflation Factor

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LIST OF SYMBOLS

%	Per cent
°C	Degree Celsius
D	Durbin – Watson value
ha	Hectare
i.e.	that is
kg ha^{-1}	Kilogram per hectare
mm	Millimetre
q	Quintal
Q1	1st Quarter (January to March)
Q2	2nd Quarter (April to June)
Q3	3rd Quarter (July to September)
Q4	4th Quarter (October to December)
ρ	Correlation Coefficient
R^2	Coefficient of Determination
$\overline{R}^2$	Adjusted Coefficient of Determination

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Introduction

1. INTRODUCTION

Rice (*Oryza sativa L.*) is the second largest cereal produced in the world. Asia is the biggest rice producer and consumer, accounted for 90 per cent of the world's production (Rani *et al.,* 2014). Rice crop is mainly cultivated wide range of areas viz., Asia, Africa, and America. Rice is the excellent source of carbohydrates, energy and a good source of vitamins and minerals such as thiamine, niacin, iron, riboflavin, vitamin D and calcium (Juliano, 1993).

In India, rice is the important staple food around 65 per cent of the population. It plays a vital role in country's exports accounting nearly 25 per cent of total agricultural export of the country. India contributes one third of world's rice cultivation area. Rice is cultivated in almost all the states of India but mainly cultivated in river valleys, delta regions and low lying coastal areas of North Eastern and Southern India. The major paddy producing states are West Bengal, Assam, Punjab, Bihar, Orissa, Madhya Pradesh, Maharashtra, Gujarat, Uttar Pradesh and South Indian states viz., Andhra Pradesh, Kerala, Karnataka and Tamil Nadu which together contributes around 95 per cent of production to India (Derekar and Reddy, 2017).

In India, rice is grown in 43.86 million ha, the production level is 104.80 million tones and the productivity is about 2390 kg ha-1 (GOI, 2015). Karnataka, Tamil Nadu and Kerala accounted for nearly 13 per cent production to all India production. Karnataka has contributed over 14 lakh hectare of land for rice cultivation with an average productivity of 2700 kg ha-1. The state Tamil Nadu also covers almost 19 lakh hectares of land for rice cultivation with an average yield of 3900 kg of rice per hectare. The state Kerala covers about 1.7 lakh hectares of rice area and production around 5.49 lakh MT with an average yield of 2424 kg per hectare.

Coconut (*Cocos nucifera L.*) is the most useful palm tree in the world because every part of the tree is useful for human life in many purposes.

Therefore, the coconut palm is affectionately called 'KALPAVRIKSHA' which means the tree of paradise. India ranks third on world coconut map next to the Philippines and Indonesia. In recent times India becomes the largest producer of coconut with the production of 22.17 billion nuts from acreage under plantation of about 2.09 million hectares. India contributes about 17.54 per cent in area and 33.02 per cent in terms of production of coconut in the world (APCC, 2015).

In India, Kerala is the main coconut growing state with an area of 7.7 lakh hectares and production of 7429.39 million nuts, followed by Tamil Nadu (4.6 lakh hectares and 6171.06 million nuts), Karnataka (5.3 lakh hectares and 5128.84 million nuts). South India contributes about 89.57 per cent in area and 90.7 per cent in terms of production. Southern states of Kerala, Karnataka and Tamil Nadu states together accounts for 84.49 % of the total production of the country (GOI, 2016).

Climate change was reported to cause an increase in air temperature between 1.4^0C and 5.8^0C, increase in CO_2 concentration and significant changes in rainfall pattern (Houghton *et al.* 2001). Irregular pattern of rainfall and unpredictable high temperature may adversely be affecting the yield of the crops (FAO, 2004).

Time series analysis is a statistical methodology appropriate for an important class of longitudinal research designs. Area, production and productivity of coconut and paddy are measured repeatedly at regular intervals over a long period of time. This time series analysis can help us to understand the underlying naturalistic process, the pattern of change in area/production/productivity over time, or evaluate the effects of either a planned or unplanned intervention.

In view of the above emphasis, the present study is designed to estimate trend models for production, area and productivity, statistical models for analysing the price movement and also to assess the influencing factors of production with the following objectives:

1. To develop statistical models on trend in area, production and productivity of paddy and coconut across Kerala, Karnataka and Tamil Nadu

2. To develop different statistical models for analysing the price movement of these crops across the states over time

3. To develop models for analysing the influencing factors of production

1.4 SCOPE OF THE STUDY

From this study, we will come to know that changes in area, production and productivity of paddy and coconut in Karnataka, Kerala and Tamil Nadu. It helps in forecasting the future area, production and productivity. Co-integration helps to provide guidelines to policy makers and planners in formulating national production and price policies.

1.5 LIMITATIONS OF THE STUDY

The study is based on the secondary data collected from various sources. The study is restricted to Kerala, Karnataka and Tamil Nadu and results cannot be generalised for entire South India. In case of coconut, copra wholesale price was taken for the analysis. However, an attempt has been made to have an in depth analysis of the data by using suitable statistical tools and techniques to arrive at meaningful conclusions.

1.6 PLAN OF THE THESIS

The entire study has been presented in five chapters. The first chapter deals with the introduction and importance of paddy and coconut, objectives of the study and scope of the study. The second chapter provides an outline of the work by reviewing the relevant studies, related to the objectives of the present study. The third chapter deals with collection of materials and statistical methods used for the analysis. In fourth chapter, the results and discussions of the study are presented. The last chapter depicts the summary and conclusions drawn from the present study.

Review of Literature

2. REVIEW OF LITERATURE

In this chapter an attempt has been made to critically review the literature of the past research work relevant to the present study. The available literature on the subject has been reviewed and presented under the following headings.

2.1 Studies relating to trend analysis

2.2 Studies relating to growth rate

2.3 Studies relating to price movement

2.4 Studies relating to influencing factors of production

2.1 STUDIES RELATING TO TREND ANALYSIS

Abraham and Raheja (1967) fitted different trend models *viz.,* linear, Cobb-Douglass, semi-log and exponential functions. This study estimated the trend for the production of rice and wheat crops in India for the period 1951-52 to 1964-65. Among four different models Linear and Cobb-Douglass functions showed good fit in most of the states.

Sahu (1967) studied the growth rates of area, production and productivity of rice in major districts of Bihar during the second and third five year plan periods. This study fits linear and exponential trends for estimating trends in area, production and productivity of rice.

George *et al.* (1978) fitted various trend models to find out the pattern of growth in oilseeds area and productivity. This trend has been disaggregated at two levels *viz.,* area and yield instead of aggregate production and state level data instead of all India data. The following functional forms were used for estimating the trends.

1. Linear $Y = a + bt$

2. Semi log $\text{Log } Y = a + bt$

3. Log increase $\quad$ Log Y = a + b/t

4. Double log $\quad$ Log Y = a + b log t

Where, Y = Area/ productivity of oilseeds

t = Time

Indiradevi *et al.* (1990) studied the trends in area, production and productivity of banana in Kerala for 1970-71 to 1986-87 using three functional forms *viz.*, semi log, exponential and quadratic models. The quadratic model was found to be the best model as compared to others in explaining trend and coefficient of determinations. This model explained the trend in yield during the entire periods and area and production during 1980-87 periods.

Singh and Chandra (2001) have proposed a method for estimation of growth trends in area, yield and production in Uttar Pradesh. The growth trends of area, production and productivity of food grains were expressed by the linear, quadratic, exponential, power, compound, growth and logarithmic functions and the best model was chosen on the basis of coefficient of determination and adjusted R^2.

Angles and Hosamani (2002) examined the performance of turmeric in terms of area, production and productivity in Tamil Nadu, Karnataka, Andhra Pradesh and Kerala during the period from 1979 to 1989. This study was based on exponential function used to analyse the growth rate. This study concluded that all the states registered a significant growth in area, production and productivity except area in Tamil Nadu and Kerala, production in Tamil Nadu and productivity in Karnataka.

Pradip and Krishna (2002) used different growth models to study the critical analysis with Andhra Pradesh and India. Linear and non-linear regression models were used for estimating the growth rate and fitting the best model, which will help in better future prediction. They have discussed the use of R^2 and adjusted R^2 as a measure of goodness of fit for choosing the best model and also criteria of randomness and normality of time-series data for choosing the best model. Power function was fitted as the best model for production of food grains in Andhra Pradesh because minimum RMS was exhibited by power function and also satisfied other assumptions. Gompertz and linear models were found to be the best fitted model for production and productivity of food grains in India because of least RMSE and also this model satisfied the assumptions of normality and independence of residuals.

Deka and Sarmah (2005) studied the growth trend in area, production and productivity of pineapple in Assam by fitting linear, quadratic and exponential regression. They observed 93.1%, 93.6% and 66.2% R^2 in case of area, production and productivity respectively in quadratic model. They also observed that the coefficients of quadratic term were found negative in case of area and production while it was positive in productivity.

The growth function models are:

i) Linear $y = a + bt$

ii) Quadratic $y = a + bt + ct^2$

iii) Exponential $Y = ae^{bt}$

Where, Y = Area/production/ productivity of pineapple

X = Time

Lathika and Kumar (2005) studied the growth and trends in area, production and productivity of coconut in India for the five decades during a period of 52 years from 1950-51 to 2001-02. Three trend equations namely, semi-log ($lnY_t = a + b.t + u_t$), log-quadratic ($lnY_t = a + b.t + c.t^2 + u_t$) and log-quadratic (modified) were worked out on the data of coconut. Trend models were fitted for area, production and productivity of coconut in all coconut producing states and

India. In case of area, the exponential model was found to be the best model for area in all the regions. Growth rate based on the exponential model was found to be best for area under coconut in all the regions. Whereas log-quadratic model (modified) was found to be the best fitted model for productivity of coconut among the three models tried. This study concluded that production of coconut in India was highly determined by the southern and coastal States of India. Positive growth rate was shown in area and production of coconut in India as well as at the state level.

Jose *et al.* (2008) proposed non-parametric methods to estimate the trend and relative growth rate. This method was based on the linear regression smoother. Also the extended method for handling quick changes in the trend or growth rate functions was studied by adding dummy variables. Simulation study indicated a sudden shift in trend and growth rate during 1967. This sudden shift in wheat production might be due to impact of green revolution started in India during the middle of the 1960.

Bhagyashree (2009) designed a technique to fit the trends in area, production and productivity of bajra crop during the period 1949-50 to 2006-07 in Gujarat state. Among the linear, non-linear and nonparametric regression models, the nonparametric regression model was evolved as the best fitted trend equation for area and production. Whereas, Gompertz model was evolved as the best fitted trend equation for productivity.

Rajarathinam *et al.* (2010) conducted a study on trend and growth rate in area, production and yield of tobacco in Anand, Gujarat during the period from 1949-50 to 2007-08. Trends and growth rate was calculated based on the parametric and non-parametric regression models. Different linear, non-linear and time-series models come from parametric models. Best suited models were selected based on adjusted R^2, significant regression coefficient and coefficient of determination (R^2). The results concluded that the entire parametric models were not suitable to fit the trends in area, production and productivity of tobacco.

Finally, the nonparametric regression model was selected as best fitted model for area, production and productivity of tobacco based on least root mean square error (RMSE) and mean absolute errors (MAE). They made final statement that tobacco production had increased due to combined effect of increase in area and productivity.

Ramakrishna (2014) studied the trends in area, production and productivity of rice using linear and compound growth rates during 1970-09.Ten different models were used for fitting the area, production and productivity of rice in AP. The result revealed that area, production and productivity of rice in Andhra Pradesh had positive and significant growth. Coastal region of Andhra showed an increasing trend in area, production and productivity. Whereas, Rayalaseema region had positive and increasing trend in production and productivity and there was a decreasing trend in area. In Telangana, area, production and productivity showed a significant and upward trend.

Singh (2014) observed the growth rate in area, production and yield of wheat crop in Uttar Pradesh using linear and compound growth models. For this study ten different trend models were fitted to the area, production and yield of Wheat. The result revealed that the area, production and yield of wheat in UP marked a significant and increasing trend during the 1971-2010 periods. In the period of 1971-2010, area of wheat in India marked a significantly increasing trend but decrease in production and productivity.

Netam and Sahu (2017) reported that growth pattern in Chhattisgarh for area under rice showed a downward trend, regional and district level by fitting on exponential function. Production of rice showed an increasing trend in state and regional level and a downward trend in district level. Whereas in the yield, the growth pattern was upward trend at state, regional and district level during the study period.

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2.2 STUDIES RELATING TO GROWTH RATE

Rao (1965) studied the trend analysis in agricultural growth in the country and also different states during the period from 1949 – 1962. This study concluded that the growth rate of food grains was decreased 4.4 per cent in the period 1949 -1956 and 3.8 per cent during 1955-62. The growth rate for production of all crops was more or less constant at 4 per cent but production of non-food crops shows 3 to 4.5 per cent growth rate. The growth rate of productivity was positively associated with the irrigated area.

Sodhiya (1989) studied the growth rates in area, production and productivity of ten major crops (Cereals, Pulses and oil seeds) in Sagar division of Madhya Pradesh by using the linear regression model $y = a+bx$ using standard technique of method of least squares. Out of the five cereal crops, the regression coefficients for area were highly significant for all the cereals except jowar. Among oil seeds crops soybean had negative growth rate for area and production. However, regression coefficients for production of all the cereals were highly significant except in rice crop. The regression coefficients for productivity were negative for rice and jowar.

Singh et al. (1997) studied the trend in area, production and productivity of major food grains, coarse cereals, pulses, oilseeds, sugarcane and cotton at the state level in India. This study also analysed the factors responsible for determining yield of important food grain crops. This study calculated the compound annual growth rate of area, production and yield by using log linear model during the period 1960 to 1993. The causes of yield levels of important food grain crops were examined by fitting multiple regression equations using data for the period 1972-1993. The study reveals that for total food grains, as well as for all the individual food grain crops, yield witnessed a higher growth rate as compared to acreage during 1972-1993.

Mathur (2005) studied the compound growth rate of area, production and productivity of rice during the period of 1967-2001 in India by using least square

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method by fitting exponential function. The study concluded that the average yield was very low in the regions comprising Uttar Pradesh, Assam, Bihar, West Bengal, Madhya Pradesh, Orissa and Maharashtra as compared to other regions of India. Production has shown a much faster growth rate as compared to area in all states.

Tuteja (2006) has specified that all pulse production in India has grown at the rate of 0.7 per cent per year from 1980-1981 to 2001-2002. Growth in the area was almost stagnated, as production increased at a slow rate of around 1 per cent. The period prior to economic reforms with annual growth of 1.9 per cent in pulse production in India was significantly better than in the post-reform period. The post reforms period shows a negative growth rate of 0.3 per cent per year.

Chaudhari *et al.* (2010) conducted the study in the districts of Marathwada region to observe the performance of area, production and productivity in major cereals during the period 1985 to 2005. The compound growth was determined using Exponential model equation and significance was tested by correlation coefficient using the t test. The result of the study revealed that most of the districts showed a decreased growth rate in the area under kharif sorghum, rabi sorghum and total cereals. Whereas, growth rate in area and production was improved in pearl millet and wheat. Kharif sorghum productivity was stagnated during this study period, while pearl millet productivity, wheat and total cereal production has increased in the region as well as the state.

Acharya *et al.* (2012) studied the compound growth rate of area, production and yield of different crops in Karnataka during the period 1882 to 2008. The results revealed that area of commercial crops showed a positive and not significant growth but production and productivity has shown a non-significant negative growth.

2.3 STUDIES RELATING TO PRICE MOVEMENT

Mahesh (2000) studied the relationship between domestic (Kolkata) and international (London) market price series of tea using the co-integration analysis. The results revealed that the tendency of the price series of both domestic and international market for tea move in-unison in the long-run confirming the law of one price (LOP).

Anwarul Huq and Alam (2006) analysed the integration of Potato markets in Bangladesh using Engle- granger co-integration technique. The empirical results suggest that regional potato markets in Bangladesh are highly co-integrated. The result indicated that the prices of potato tend to move uniformly across spatial markets and price changes were fully and immediately passed on to the other markets.

Bathla (2008) conducted the study on spatial analysis of food and non-food commodities based on Johansen co-integration and vector error correction model during 1980 to 2003. The result confirmed that greater spatial market integration in the post-liberalisation period for rice, wheat, sugar and groundnut prices in the selected states. Whereas cotton and soya bean seed wholesale markets showed a weak long-run equilibrium relationship. Further, in all commodity cases, vector error correction model revealed that slow speed of adjustment of prices towards equilibrium.

Ngbedge *et al.* (2009) explained equilibrium relationship among the variables like ground nut with producer price, rainfall, fertilizer etc. This study was conducted based on co-integration technique and error correction model. The result indicated the presence of co-integration between the variables, so parsimonious error correction model was set-up. The result of error correction model confirmed the existence of equilibrium relationship among all the variables.

Hossain and Verbeke (2010) analysed the co-integration for different rice markets in Bangladesh. Weekly wholesale coarse rice prices were used to test the market integration in Bangladesh using Johansen co-integration analysis and vector error correction model (VECM). The Johansen co-integration technique result showed that at least three co-integrating vectors are present in the rice markets in Bangladesh. The results showed that markets are linked together therefore the long-run equilibrium was stable.

Kaspersen and Foyn (2010) conducted the study on price transmission of Robusta coffee and sorghum prices between world markets and Ugandan market and to determine the impact of world market prices on Ugandan market using vector autoregressive (VAR) model. The results revealed that sorghum price transmission, were not integrated into world markets, and it was found different for Robusta coffee. In the period of 1990 high coffee prices in the world market and prices in Uganda were strongly connected.

Myint and Bauer (2010) studied the market integration using Engle-granger test and price causality using Granger causality in the Myanmar rice market. Monthly average price was collected from 2001 to 2004. Result of Engle-granger co-integration test stated that price co-integration did not exist between Myanmar and Thai market price.

Joseph (2011) analysed the co-movement of price in the domestic (Kerala) and international (New York) market of black pepper using Engle granger co-integration technique and error correction model. The results revealed that domestic (Kerala) and international (New York) markets were highly cointegrated with the extent of integration of markets in short run as 18 per cent and the speed of convergence as 72 per cent. This high level of speed of convergence shows that higher level of integration between domestic and international markets.

Ojo *et al.* (2013) examined the rice markets integration in Kwara and Niger States. Secondary data related to retail prices of rice were collected for the period of 60 months (2006-2010) and error correction model was applied for the determination of the degree of market integration between the two states using a four test procedures viz., ADF test used to detect stationarity in the series, Johansen co-integration test for long run equilibrium relationship among selected markets, vector error correction model (VECM) was used to find the short and long run variations in the movements of price and Granger casualty test used for the direction of influence between prices. The vector error correction estimates indicated that most of the markets in the two states were not well integrated in the short run. Co-integration results revealed that most of the markets in the two states were well integrated in the long run relationship. The results of granger causality indicated that there was a smooth transmission of price signals from Kwara state to Niger state.

Patil *et al.* (2013) studied the market integration of arecanut markets in Karnataka state based on monthly modal prices data which is collected through Agmarket from seven representative markets using Johansen co-integration technique and error correction model. The Johansen cointegration technique indicated that the arecanut markets were integrated. Error correction model result concluded that high speed of adjustment was found between Davangere and Shimoga in red boiled type (74%) and Bantwala and Kundapura in white chali type (72%). This study concluded that integrated arecanut markets are very efficient in price transmission from one market to another market.

Omar *et al.* (2014) conducted the study for understanding the current marketing system of banana in various hilly regions of Bangladesh. The objective of the study was to test market integration and price forecasting of Banana using Engle-granger cointegration test. The result of Engle Granger co-integration test has shown that Bandarban- Dhaka, Rangamati-Lasha and Rangamati- Cox'sbazar markets were integrated but Bandarban - Sylhet, Bandarban -Rangamati markets were not co-integrated. This co-integration study shows that banana markets in Bangladesh were well integrated except in hilly region.

Engle Granger co-integration is tested using the formula

$$\mathbf{Y_t = \alpha + \beta\, X_t + u_t}$$

Where,

β = Cointegrating coefficient

u_t = Residual term

Makhare and Tarpara (2015) examined co-movement and extent of co-integration of wholesale prices of cotton among major markets (Amreli, Rajkot, Gondal, Jamnagar and Junagadh APMC) of Saurashtra region by using Johansen test, examined the causality by granger causality test and also captures the speed of adjustment to deviations in long run equilibrium by using vector error correction model. Monthly wholesale price data were used in the study. The results of the Augmented dickey-fuller (ADF) test for cotton price were stationarity after the first differences. This suggested that all market price series were integrated of order 1 i.e. I(1). The Johansen co-integration test revealed that all the markets were integrated in the long run relationship. The vector error correction model (VECM) stated that there was long run relationship between the prices of all the markets *viz.*, Amreli, Rajkot, Gondal, Jamnagar and Junagadh. The results of pairwise Granger Causality test revealed that there was a bidirectional influence on prices of Junagadh and Amreli, Rajkot and Amreli, Jamnagar and Gondal, Junagadh and Gondal, Rajkot and Gondal and Rajkot and Jamnagar. But there was a unidirectional influence on prices was noticed between Gondal and Amreli, Jamnagar and Amreli, Junagadh and Jamnagar and Rajkot and Junagadh markets.

Wani *et al.* (2015) studied the price movement of apple markets through Johansen co-integration analysis on the wholesale weekly prices of commercial varieties (American, Delicious and Moharaji) and commercial grades (Super and Special) were collected from Sep, 2005 to Feb, 2013. The results revealed that apple markets were co-integrated and Delhi was dominated over other markets. In short run disequilibrium ranges from 2.1 to 96.9 per cent among all the varieties and grades of apple. However, the study stated that there is no co-integration within two pairs of markets viz., American Super variety in Delhi-Srinagar and Bangalore-Kolkata and within one pair of markets Bangalore-Kolkata for Moharaji Special. The Granger Causality Test revealed that there were 39 and 18 bi-directional and uni-directional causations respectively under different market situations. Further, vector Error Correction Model (VECM) results revealed a combination of positive and negative coefficients even though positive coefficients exceed the negative coefficients.

Habte (2016) studied the integration of papaya market, price transmission and price causality patterns with the help of Johansen co-integration test, vector error correction model and Granger causality test using 13 years average monthly prices of papaya. Johansen co-integration tests indicated that four papaya markets significantly co-integrated with each other. Vector error correction technique indicated that speed of price adjustment for Arbaminch market was statistically significant and fast compared to other papaya markets and equilibrium price were stable. Speed of price adjustment for Adama market was slow and insignificant as compared to other market prices and equilibrium price was unstable. The Granger causality test indicates that there was a bidirectional relationship with Merkato and Shashemenie markets.

Makama and Amruthat (2016) investigated the long-run and short run relationship between export price of Indian rice (non-basmati) and domestic price of Nigerian rice. The ADF test suggested that export price and domestic price series are integrated of order one. The Johansen co-integration test has established the long- run relationship between the export and domestic price of India and Nigeria respectively. Granger causality test has revealed a bidirectional causality between the two countries and error correction model confirmed that the domestic price of Nigeria have a long run relationship with export price of Indian rice.

Naveena *et al.* (2016) made an attempt to analyse the impact of world coffee price on Indian coffee price by considering monthly wholesale price of Arabica coffee and Robusta coffee seeds and monthly indicator price of world market prices of Arabica coffee and Robusta coffee from 1999 to 2013. Before applying the co-integration test stationarity of the individual wholesale coffee price series were tested using the Augmented Dickey-Fuller (ADF) test. The results of ADF test showed that all the price series were non-stationary but first differences of the series were became stationary. Johansen's cointegration test was carried out to find the long run relationship between Indiana coffee market and world coffee market. The results of study revealed that there was a long run association between Indian Arabica coffee price and world Arabica coffee price as well as Indian Robusta coffee price and world Robusta coffee price.

Singh *et al.* (2018) examined co-integration and causality between retail and wholesale market prices of pigeon pea crop in Karvi district of Uttar Pradesh and Satna district of Madhya Pradesh by using Johansen co-integration technique and Granger causality test. The result of the analysis confirmed the presence of co-integration among retail and wholesale markets prices of tur in Karvi market indicating the long-run price association between them. Further Granger causality gave additional evidence about direction of price transmission between retail and wholesale market price in Karvi district. The test confirmed the presence of bidirectional causality or price transmission. The wholesale price of tur in both i.e. Karvi and Satna market were cointegrated which shown that long term and spatial association of wholesale prices.

Johansen co-integration approach can be written as,

$$\lambda_{trace} = -T \sum_{t=r+1}^{n} \text{In}\ (1 - \lambda t)$$

$$\lambda_{max} = T\ \text{In}\ (1 - \lambda_{r-1})$$

where

r = rank of the coefficient matrix (r = 0, 1, 2,3…n-1)

2.4 STUDIES RELATING TO INFLUENCING FACTORS OF PRODUCTION

Rao (1986) conducted the study on impact of rainfall on productivity of coconut in Pilicode, Kerala. The result of the study concluded that high rainfall during monsoon season of June, July and August and absence of post and pre monsoon rainfall would adversely affect the successive year's productivity of coconut.

Rao (1991) has indicated the necessity of further studies for the climatic requirement of the coconut. These studies revealed that the crop response to major climatic variables, especially rainfall had to be further investigated and it should be based on distribution of rainfall and also on soil type. An identification of degree of influence of climatic factors for a given location would assist in short term yield forecasting and consequently in determining the potential yield in a given agro-climatic region.

Vijayakumar *et al.* (1991) collected fortnightly weather data and annual yields of arecanut (*Areca*) and cocoa (planted in a mixed cropping trial in 1970) for 1977-88. Seven weather variables were correlated with yield for both the current year and a one-year lag period. Arecanut yield was significantly correlated with rainfall and maximum RH of the previous year, and with minimum RH, maximum temperature, pan evaporation and rainfall of the current year. Cocoa yield was significantly correlated with the number of rainy days in the previous year, and sunshine hours and maximum and minimum temperatures of the current year. Stepwise regression analysis to eliminate non-contributing variables gave maximum RH of the previous year and pan evaporation and rainfall of the current year as the most contributing variables for arecanut yield, maximum and minimum temperatures of the current year as contributing variables for cocoa yield. The regression equation for arecanut explained approximately 84 per cent of variations in yield, whereas the regression equation for cocoa had very little predictive value.

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Peiris and Peris (1993) studied the influence of climatic factors on coconut yield in Sri Lanka and the analysis showed a considerable fluctuation between years mainly due to variation in the distribution of major climatic parameters such as rainfall, solar radiation and relative humidity. An attempt was made to study the influence of intensity and distribution of rainfall in two-monthly sub-periods of the previous year on nut yield. The estimated multiple regression model explained 89 per cent. The results of the study concluded that rainfall during January to April had a positive impact on coconut yield.

Joshi (1999) studied the dependence of area and production of lead crops (pearl millet, ground nut and rain fed cotton) on rainfall in dry farming area in Gujarat, India. The study examined whether any relationship can be established to suggest optimum period of planting these crops and also forecast expected area and production. Data were collected from 1961-62 to 1991-92. The study shows that the time of onset of monsoon becomes the deciding factor for area under covering and later on production of many lead crops. Adequate rainfall in the early period of monsoon increases area of cash crops like ground nut in Saurastra region, whereas with inadequate rainfall in this period, farmers opt for cultivation of coarse cereals like pearl millet. The adequate rainfall during the early growth period of cotton has a positive influence on its production. The forecast of area can‘t be based on periodical rainfall received during the season of a crop.

Saseendran *et al.* (2000) studied effect of climate change on rice production in Kasargod, Pattambi, Ollukara, Kottayam and Kayamkulam of Kerala from 1954 to 1992. The result of the analysis predicted that during the monsoon season, mean surface temperature raises of the order about 1.5°C over the decade 2040 to 2049 and rainfall also increases of the order of 2 mm per day.

Kumar *et al.* (2007) reported that weather parameters play an important role in determining the coconut palm growth, development and yield. Historical data on weather variables and coconut yield from different agro-climatic zones *viz.*, Western coastal area - hot sub-humid-per-humid (Kasaragod - Kerala;

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Ratnagiri - Maharashtra), hot semi-arid (Arisikere - Karnataka) and Eastern coastal plains - hot subhumid (Veppankulam - Tamil Nadu; Ambajipeta - Andhra Pradesh) of India were used for developing models for prediction of coconut yield. The prediction models with three and four year lag had high R^2. Interestingly, the parameters used in models for western coastal area - hot sub-humid-per-humid are temperature and relative humidity, as indicated even in the classification of these areas. Models were verified for 2 years and prediction of yield during 1998–99 and 1999–2000 within 10% confidence level validated these models.

Guruswamy *et al.* (2008) were studied the mean annual and seasonal rainfall behavior and the effects of weather parameters on coconut productivity in Thanjavur district, Tamil Nadu, India, during 1996-2005 and stated that southwest monsoon and winter rainfall had a negative correlation with coconut productivity, whereas summer and NEM rainfall had a positive relation with coconut productivity. The percentage of barren nut production in coconut had a positive correlation with summer rainfall and negative correlation with winter, southwest and northeast monsoons. The maximum temperature, minimum temperature, relative humidity, pan evaporation and rainfall had a positive correlation with coconut productivity.

Gupta (2011) studied the critical assessment of climate change impacts on rice and wheat in India during 2010. The study concluded that, productivity could decline in case of rice and wheat considerably due to change in climate. Farmers may lose net revenue between 9 and 25 per cent due to 2 to 3.5 °C rise in temperature accompanied by 7 to 25 per cent decrease in precipitation.

Sunil *et al.* (2011) conducted a research in Regional Agricultural Research Station (RAS) Ambalavayal, Wayanad to study the relationship between the yield of Areca nut and weather parameters *viz.* temperature, relative humidity and rainfall. Results of the analysis revealed that during flowering stage *i.e.*, January to March, an increase in minimum temperature, relative humidity and rainfall had significant and positive influence on nut yield. In contrast, rainfall during the nut development (June to July) would have adverse effect on crop yield. Arecanut needs high relative humidity during the morning period throughout the growth period. Multiple regression equations were developed for predicting the areca nut yield based on rainfall and minimum temperature.

Kumar and Aggarwal (2013) studied the impact of climate change on coconut production in several states of India from 2000 to 2013. The study concluded that high performance areas such as Andhra Pradesh, Orissa, Southern and Central parts of West Bengal, Gujarat, Karnataka and Tamil Nadu are expected to decline productivity. But this study reported that all India level productivity was expected to increase at 4.3 per cent.

Birthal *et al.* (2014) examined how Indian agriculture is complex for climate change using district level panel data from 1969 to 2005 for 200 districts. In this model, area and production were taken as dependent variables. Meteorological parameters, such as temperature and rainfall were taken as independent variables. It was found that increase in temperature would reduce the yield. The results of this study concluded that productivity of Indian agriculture will reduce upto 25 per cent at the end of this century.

Iqbal and Siddique (2015) calculated the impact of climate change on agricultural productivity in Bangladesh using panel data of 23 regions from 1975 to 2008. Rice productivity was taken as dependent variable and climatic variables such as temperature, rainfall and humidity as independent variables. On execution of panel data analysis (fixed effects and random effects models), results indicated that, increase in the average minimum temperature during dry season by one unit, will result in increased per acre rice output by 3.7 to 11.6 per cent.

Tokunaga *et al.* (2015) studied the influence of climate change on agriculture in Japan using panel data for eight regions from 1995 to 2016. The function comprised of production as dependent variable and temperature, precipitation and solar radiation as independent variables. Upon execution of panel data analysis, results showed that, 1°C increase in temperature bring about in reduction of rice production by 5.8 per cent in short term and by 3.9 per cent in long term. Similarly vegetables and potatoes production also reduced to 5 per cent in short term and 8.6 per cent in long term for every 1 °C increase in temperature.

Kumar *et al.* (2016) calculated the impact of climate change on land productivity of 15 Indian crops across 13 states using panel data from 1989 to 2009. In the model, productivity of the crop was taken as the dependent variable. Climatic parameters such as, minimum temperature, maximum temperature and rainfall were taken as independent variables. By execution of the panel data analysis, it was revealed that, land productivity might go down by 3.29 per cent because of 1 per cent increase in annual temperature. Modified Wald test was used to check for heteroscedasticity. Wooldridge test was used for testing serial correlation.

Materials and Methods

3. MATERIALS AND METHODS

The aim of this chapter briefly describes the materials that provide the database required for this study, as well as selection of crops, location and statistical tools used in the analysis. The methodology is presented under the following heads.

3.1 Description of the study area.

3.2 Data source

3.3 Statistical tools and models applied

3.1 STUDY AREA

3.1.1 Paddy

Rice is the most important staple food of more than half of the world's population and more than 3.5 billion people depend on rice for more than 20 per cent of their daily calories. Asia accounts for 90 per cent of global rice consumption and total rice demand there continues to rise. In India, rice is grown in 42.95 million ha, the production level is 112.91 million tones and the productivity is about 2585 kg ha-1 (GOI, 2018). Karnataka, Tamil Nadu and Kerala accounted for nearly 8.13 per cent production and 6.66 per cent area to all India. Karnataka has contributed over 8.74 Lakh hectare of land for rice cultivation with an average production of 2699 kg ha-1. The state Tamil Nadu also covers 18.45 lakh hectares of land for rice cultivation with an average production of 3467 kg per hectare. Kerala accounts 1.4 million ha of paddy area and 4.2 million tonnes of production with the productivity of 2965 kg per ha.

3.1.2 Coconut

Coconut (*Cocos nucifera L.*) is the most useful palm tree in the world. Every part of the tree is useful for human life many purpose. Therefore, the coconut palm is affectionately called 'kalpavriksha' which means the tree of

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paradise. The copra obtained from the drying of coconut is the richest source of vegetable oil containing from 65 to 70 per cent of oil.

Coconut provides nutritious food and a refreshing drink, oil is used for edible and inedible uses, commercially valuable fibre, fuel peel and industrial uses, coconut thatch, an alcoholic beverage and wood of different products for use as domestic fuel.

Coconut provides nutritious food and a refreshing drink, oil for edible and non-edible uses, fibre of commercial value, shell for fuel and industrial uses, thatch, an alcoholic beverage, timber and a variety of miscellaneous products for use as domestic fuel.

In coconut production, India currently ranks third in the world next to the Philippines and Indonesia. In India, Kerala is the main coconut growing state with an area of 7.7 lakh hectares and production of 7448 million nuts, followed by Karnataka (5.1 lakh hectares and 6773 million nuts), Tamil Nadu (4.6 lakh hectares and 6571 million nuts). These three southern states together contribute around 84 per cent of total area and 87 per cent of the total production to the country (GOI, 2018).

3.2 DATA SOURCE

The present study is based on secondary data. The secondary data related to area, production and productivity of paddy and coconut in the region of Karnataka, Kerala and Tamil Nadu were collected from Directorate of Economics and Statistics (GOK), Department of Economics and Statistics (GOTN and GOK) for the period of past 25 years. Secondary data of weather parameters regarding rainfall data were collected for all three states from Indian Meteorological Department (IMD).

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3.2.1 Paddy

Area ('000 ha), production ('000 Tonnes) and productivity (kg ha^{-1}) was collected yearly and also for two seasons namely kharif and rabi. This season wise and yearly data were used to estimate the comparative performance of growth rate in across Karnataka, Kerala and Tamil Nadu. Co-integration analysis using monthly average wholesale price (Rs q^{-1}) of paddy medium grain type was collected from Raichur (Karnataka) and Thanjavur (Tamil Nadu) markets for a period from January 1993 to December 2018.

3.2.2 Coconut

In the case of coconut, Area ('000 ha), production (million nuts) and productivity (nuts ha^{-1}) was collected for Karnataka, Kerala and Tamil Nadu. This data were used to estimate the comparative performance of growth rate across Karnataka, Kerala and Tamil Nadu. Co-integration analysis using monthly average wholesale price (Rs q^{-1}) of copra was collected from Tumkur (Karnataka), Kochi (Kerala) and Kangayam(Tamil Nadu) markets for a period from January 2000 to December 2018. Price data (monthly wholesale price) related to coconut (in the form of Copra) and paddy were collected from Coconut Development Board, Directorate of Economics and Statistics (Kerala and Karnataka), Department of Economics and Statistics (Tamil Nadu) and also from the website: www.indiastat.com and agmarknet.gov.in

3.3 STATISTICAL TOOLS AND MODELS APPLIED

The data collected from the above-mentioned sources was analysed by using the following analytical techniques:

1. Statistical models on trend in area, production and productivity of paddy and coconut across Kerala, Karnataka and Tamil Nadu

2. Statistical models for analysing the price movement

3. Analysis on factors of production

3.3.1 Methodology for fitting the trend equations

The trend equations were fitted by using different growth models. Growth models are nothing but the models that describe the behaviour of a variable over time. The growth models taken under consideration here are as follows.

3.3.1.1 Semi log function

A linear model is one in which all the parameters appear linearly.

The mathematical equation is given by

$$\ln Y_t = b_0 + b_1 t + \varepsilon_t$$

Where,

Y_t is the dependent variable viz., area, production and productivity

t is the independent variable, time in years

b_0 and b_1 are the constants

ε_t is the error term

The constants 'b_0' and 'b_1' are estimated by applying the Ordinary Least Square approach.

3.3.1.2 Double logarithmic function

This model shows very rapid growth, followed by slower growth.

The mathematical equation is given by

$$\ln Y_t = b_0 + b_1 \ln(t) + \varepsilon_t$$

Where,

Y_t is the dependent variable viz., area, production and productivity t is the time in years, independent variable

'b_0' and 'b_1' are constants or parameters

ε_t is the error term

The constants 'b_0' and 'b_1' are estimated by applying the Ordinary Least Squares approach.

3.3.1.3 Inverse function

Inverse curve shows a decreasing growth.

Inverse fit is given by the equation

$$\ln Y_t = b_0 + \frac{b_1}{t} + \varepsilon_t$$

Where,

Y_t is the dependent variable viz., area, production and productivity

t is the independent variable, time

'b_0' and 'b_1' are parameters

ε_t is the error term

The parameters can be estimated by the method of Ordinary Least Squares (OLS).

3.3.1.4 Quadratic function

This function is useful when there is a peak or a trough in the data of past periods.

Quadratic fit is given by the equation

$$\ln Y_t = b_0 + b_1(t) + b_2 t^2 + \varepsilon_t$$

Where,

Y_t is the dependent variable viz., area, production and productivity

t is the independent variable, time in years

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b_0, b_1 and b_2 are constants

ε_t is the error term

The constants can be calculated by applying the method of ordinary least squares approach.

3.3.1.5 Cubic function

This function is useful when there is or has been, two peaks or two troughs in the data of past periods.

Cubic fit or third degree curve is given by the equation:

$$\ln Y_t = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon_t$$

Where,

Y_t is the dependent variable viz., area, production and productivity

t is the independent variable, time in years

b_0, b_1, b_2 and b_3 are parameters

ε_t is the error term

The parameters are calculated by ordinary least squares method.

3.3.1.6 Compound function

This function is useful when it is known that there is or has been, increasing growth or decline in past periods

Compound fit is given by

$$Y_t = b_0 b_1^{\,t} \varepsilon_t$$

$$\ln(Y_t) = \ln(b_0) + t\ln(b_1) + \varepsilon_t$$

Where,

Y_t is the dependent variable viz., area, production and productivity

t is the independent variable, time in years

b_0 and b_1 are parameters or constants

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ε_t is the error term

The parameters are calculated by ordinary least squares method.

3.3.1.7 Power function

The function is given by the equation

$$Y_t = b_0 t^{b_1} \varepsilon_t$$

$$\ln(Y) = \ln(b_0) + b_1 \ln(t) + \varepsilon_t$$

Where,

Y_t is the dependent variable viz., area, production and productivity

t is the independent variable, time in years

b_0 and b_1 are parameters or constants

ε_t is the error term

The parameters are calculated by ordinary least squares method.

The fit is alike to exponential fit, but creates a forecast curve that increases or decreases at different rate.

3.3.1.8 Exponential function

When the values of t are organized in an arithmetic series, the parallel values of y form a geometric series, the relation is of the exponential type.

The function of this type can be given by

$$Y_t = b_0 e^{(b_1 t)} \varepsilon_t$$

Or $$\ln(Y_t) = \ln(b_0) + b_1 t + \varepsilon_t$$

Where,

Y_t is dependent variable viz., area, production and productivity

t is independent variable, time in years

b_0 and b_1 are constants

ε_t is the error term

The parameters are calculated by ordinary least squares method.

3.3.1.9 Methodology for the best fitted model

The choice of the trend equation amongst the available alternatives is very crucial. So coefficient of multiple determination, R^2 or adjusted R^2 as the criterion of model selection and also use Root Mean Square Error (RMSE).

3.3.1.9.1 Coefficient of determination

The coefficient of determination is a key part of regression analysis and one of the measures of goodness of fit of a regression model. It is interpreted as the proportion of the variance in the dependent variable explained by the independent variables. The value of R^2 lies between 0 and 1. The closure it is to 1, the better is the fit. If R^2 is zero that means dependent variable cannot be predicted from the independent variables. If R^2 is one that means dependent variable can be predicted from the independent variables without any error. The R^2 lies between 0 and 1 indicate the extent to which the dependent variable is predictable.

How well the estimated model fits the data can be measured by the value of R^2. In general, R^2 measures the percentage of variation explained by the independent variables in the total variability, which is given by

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}, \qquad 0 \leq R^2 \leq 1$$

By using F test, significance of R^2 have been tested

$$F = \frac{R^2}{(1-R^2)} \cdot \frac{n-k-1}{k} \qquad \sim F \text{ distribution with k, (n-k-1) degrees of}$$

freedom.

Where k is the number of parameters in the model, n is the number of observations.

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The main problem of R^2 is that, R^2 cannot fall when more variables are added to the model. Therefore, there is a chance of maximizing the R^2 by simply adding more variables to the model.

3.3.1.9.2 Adjusted R^2 ($\overline{R}^2$)

Henry Theil developed the adjusted R^2 to avoid increasing the R^2 value when adding more variables to the model; it is denoted by $\overline{R}^2$.

$$Adj\ R^2 = 1 - (1 - R^2)\frac{(n-1)}{(n-k-1)}$$

Where 'k' is the number of parameters in the model, n is the total number of observations. From above formula it is clear that $\overline{R}^2$ can be negative and always less than or equal to R^2. For comparative purpose, $\overline{R}^2$ is a better measure than R^2. The $\overline{R}^2$ increases only if the added new variable improves the model more than that is expected by chance.

3.3.1.9.3 Root Mean Square Error (RMSE)

RMSE is defined as the square root of the average of squared errors. It is generally utilized to measure the adequacy of the fitted model and it can be computed as follows:

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - \widehat{Y}_i)^2}{n}}$$

The lower the value of this statistic was better for the fitted model.

3.3.1.10 Assumption of error term

An important assumption of regression models is that the error term 'ε_t' should follow normal distribution and random process.

3.3.1.10.1 Test for normality: Shapiro-Wilk test

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There are many tests available to test the normality. Some of the popular tests for normality are Shapiro – Wilk test, Cramer Von Misses test, Kolmogorov-Smirnov test etc.

The Shapiro-Wilk test is the common and better, if the sample size is less than 2000.

Shapiro-Wilk test statistic 'W' is given as

$$W = \frac{\left[\sum_{i=1}^{n} a_i X_{(i)}\right]^2}{\sum_{i=1}^{n}(X_i - \overline{X})^2}$$

Where, $X_{(i)}$ = ordered sample values, $\overline{X}$ is the overall mean.

i=1, 2,..., n

a_i = constants generated from mean, variance and covariance of the order statistics of a sample size 'n' from a normal distribution.

In this test, H_0: Residuals are normal. If the p-value is greater than critical value, usually 0.05, H_0 is accepted and we conclude that residuals are normal. Shapiro-Wilk test statistic W, ranges in between 0 and 1 and highly skewed to the right.

3.3.1.10.2 Test for randomness: Runs test

Randomness of residuals can be tested by using non-parametric test called runs test. A run is defined as an uninterrupted sequence of identical symbols in which the individual scores or observations originally were obtained. Consider an example where series of binary events occurred in this order

+ + - - - + + - - - - + + - - +

If the number of runs are very few, a time trend or positive autocorrelation is present. If the numbers of runs are many, systematic short-period cyclical fluctuations seem to be influencing the scores. In the above example there are seven runs.

In a sequence, if $n=n_1+n_2$ binary events, let n_1 be the number of elements of positive values and n_2 be the number of elements of negative values. If both n_1 and n_2 are less than 20, then the number of runs present in the sequence is defined as r, lies between the confidence interval then do not reject the null hypothesis i.e. events are random.

For large samples, if either n_1 or n_2 is larger than 20, a good approximation to the sampling distribution of 'R' is the normal distribution with,

$$Mean = \mu_r = \frac{2n_1n_2}{n_1n_2} + 1$$

$$Standard\ deviation = \sigma_r = \sqrt{\frac{2n_1n_2(2n_1n_2 - n_1 - n_2)}{(n_1+n_2)^2(n_1+n_2-1)}}$$

Then H_0 may be tested by $z = \frac{r-\mu_r}{\sigma_r} \sim SND(0,1)$

The significance of any observed value of z computed by using the equation may be determined from a normal distribution table. The run test rejects the null hypothesis, if $|z| > z_{1-\frac{\alpha}{2}}$

3.3.2 Compound Annual Growth Rate (CAGR)

To analyse the comparative change in area, production and productivity of paddy and coconut over the years in Karnataka, Kerala and Tamil Nadu compound annual growth rates were estimated. Compound annual growth rates of area, production and productivity of coconut and paddy were estimated by using exponential model and its mathematical equitation is given as

$$Y_t = b_0 e^{(b_1 t)} \varepsilon_t$$

$$ln\, Y_t = ln(b_0) + b_1 t + \varepsilon_t$$

Y_t- dependent variable (area, production and productivity)

t - time in years, independent variable

b_0 and b_1 are constants or parameters

ε_t - error term

The constants in the above equation are estimated by using the ordinary least squares method of estimation.

The compound annual growth rate (CAGR %) was calculated by using the formula

$$\text{CAGR (\%)} = (\text{Antilog } b_1\text{-}1) \times 100$$

The significance of compound annual growth rates can be tested by using student's t test

$$t = \frac{r}{SE(r)}$$ with (n-2) degrees of freedom (df).

Where,

'r' is the growth rate

'n' is the total number of years considered under study

SE(r) is the standard error of growth rate

3.3.3 Co-integration analysis

Co-integration is an econometric concept which mimics the existence of a long-run equilibrium among economic time series. If two or more series are themselves nonstationary, but a linear combination of them is stationary, then they are said to be co-integrated.

Applying this concept to any two given markets, co-integration between their price series implies long run dependence between them. Since, the very essence of market integration is the price dependence across markets, it follows that co-integration between prices in two given markets implies integration of the markets. Co-integration analysis also used to establish the co-movement of two or

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more time series. Market integration is the price dependence across markets, it follows that co-integration between prices in two given markets implies integration of the markets.

3.3.3.1 Test for stationarity

If the series is stationary, this means that the series has constant mean and variance which does not change over the period. Roughly speaking, a time series is stationary if its behavior does not change over time.

Generally the concept of stationarity can be summarized by the following conditions. A time series $\{Y_t\}$ is said to be stationary if:

$$E(Y_t) = E(Y_{t-s}) = \mu,$$

$$E(Y_t - \mu)^2 = E(Y_{t-s} - \mu)^2 = \sigma_y^2$$

$$E(Y_t - \mu)(Y_{t-s} - \mu) = E(Y_{t-j} - \mu)(Y_{t-j-s} - \mu) = \gamma(s), \; s \geq 1$$

Where μ, σ_y^2 and $\gamma(s)$ are all time invariant.

Consider the equation,

$$Y_t = Y + \varepsilon_t$$

Where, Y_t is the observed value of the series at time 't', Y is the mean value of the series and ε_t is a random disturbance term. The series Y_t is said to be stationary as expressed as I (0). But often the series tend to display an increase or decrease, which violates the above condition. In such case successive differencing reduced the series to stationary, thus,

$$Y_t - Y_{t-1} = \varepsilon_t \;\text{ or }\; Y_t = Y_{t-1} + \varepsilon_t$$

A series which becomes stationary after differencing once is said to be integrated of order 1 and it is expressed as I (1). In general, a series which must be differenced "d" time to become stationary is expressed as I (d). A major difference between I(0) and I (d) , d>0 series is that the I(0) series has a finite mean and variance, while in I (d) series this magnitudes do not exist.

3.3.3.2 Augmented Dickey-Fuller (ADF) Test

The ADF test is comparable with the simple DF test, but is augmented by adding lagged values of the first difference of the dependent variable as additional regressors which are required to account for possible occurrence of autocorrelation. Consider the AR (1) model:

$$y_t = \beta_1 + \alpha Y_{t-1} + \varepsilon_t$$

We can write the above equation as:

$$\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t$$

Where, Y_t denotes the variable being tested, $\varepsilon_t \sim$ IID $N(0, \sigma^2)$, $\beta = 1 - \rho$ and $\Delta Y_t = Y_t - Y_{t-1}$, $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$, etc. α, β and δ_i are parameters to be estimated.

The null and alternative hypotheses tested is

H_0: $\beta = 0$ or Y_t is not I(0), against

H_1: $\beta < 0$ or Y_t is I(0)

The test statistic is the conventional t-ratio

$$t = \frac{\hat{\beta}}{SE(\hat{\beta})}$$

Where, $\hat{\beta}$ is the ordinary least square (OLS) estimate of β and $SE(\hat{\beta})$ is the coefficient standard error. But, Dickey and Fuller (1979) showed that under the null hypothesis of a unit root, this statistic does not follow the conventional Student's *t* distribution and it follows the τ (*tau*) statistic. They also computed the critical values of the *tau* statistic on the basis of Monte Carlo simulations for various sample sizes. More recently, MacKinnon (1991, 1996) had developed more extensive than those tabulated by Dickey and Fuller. In addition, MacKinnon estimates response surfaces for the simulation results, permitting the calculation of Dickey-Fuller critical values and p-values for arbitrary sample sizes.

In general, if the estimate of β is negative and significantly different from zero then reject the null hypothesis, H_0 which indicates that series is stationary.

3.3.3.3 Johansen's co-integration test

Johansen (1988) has developed a multivariate approach, which allows for simultaneous adjustment of two or even more than two variables. Johansen's approach is also widely used in many bivariate studies as it has some advantages to the single equation approach. First, it allows estimating the co-integration vector with smaller variance. The second advantage of the multivariate approach is that in the simultaneous estimation, it is not necessary to presuppose exogeneity of either of the variables.

Johansen's co-integration test relies on maximum likelihood method. This procedure is based on the relationship between the rank of a matrix and its characteristic roots. Johansen derived the maximum likelihood estimation using sequential tests for determining the number of co-integrating vectors. Johansen suggested two test statistics to test the null hypothesis that there are at most 'r' co-integrating vectors. This can equivalently be stated as the rank of the coefficient matrix (Π), is at most 'r' for r=0, 1, 2, 3…n-1. The two test statistics are based on the trace and maximum Eigen values, respectively.

$$\Delta Y_t = \alpha + \beta_t + (p - 1)\ Y_{t-1} + \theta_1 \Delta Y_{t-1} + \ldots + \theta_{k-1}\ \Delta Y_{t-k+1} + W_t$$

$$\lambda_{max} = -T \sum_{t=r+1}^{n} \text{In}\ (1 - \lambda t)$$

$$\lambda_{trace} = T\ \text{In}\ (1 - \lambda_{r-1})$$

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In testing for co-integration for different markets (which is the necessary condition for market integration) the null hypothesis should be tested for r=0 and r=1. If r=0 cannot be rejected, it can be concluded that there is no co-integration. On the other hand, if r=0 is rejected and r=1 cannot be rejected then it can be concluded that there is a co-integrating relationship. Co-integration implies that there exist a co-integrating vector β.

3.3.3.4 Granger causality test

Granger causality test is used to find out the direction of causation between the markets. When co-integration relationship is present for two variables, a Granger causality test can be used to analyse the direction of this co-movement relationship. Granger causality tests come in pairs, testing weather variable X_t Granger-causes variable Y_t and vice versa. All permutations are possible viz., univariate Granger causality from X_t to Y_t or from Y_t to X_t, bivariate causality or absence of causality. An autoregressive distributed lag (ADL) model for the Granger-causality test was specified as below:

$$X_t = \sum_{i=1}^{n} \alpha_i Y_{t-i} + \sum_{j=1}^{n} \beta_j X_{t-j} + u_{1t}$$

$$Y_t = \sum_{i=1}^{n} \gamma_i Y_{t-i} + \sum_{j=1}^{n} \delta_j X_{t-j} + u_{2t}$$

Where, t is the time period, u_{1t} and u_{2t} are the error terms, X and Y are the prices series of different markets.

3.3.4 Analysing the influencing factors of production

Production of coconut and paddy is influenced by so many independent factors viz., weather parameters.

3.3.4.1 Panel data regression analysis

For empirical analysis, types of data that are generally available are time series, cross section and panel data. In time series data, the values of one or more variables are observed over a period of time. In cross section data, values are collected for one or more variables for several sample units at the point of time. In case of panel data consists of both place as well as time dimensions. Regression models based on such panel data are called panel data regression models (Gujarati, 2004)

In this study, production of coconut data collected for the 1987-2016 from Karnataka, Kerala and Tamil Nadu was taken as dependent variables. Rainfall was considered as independent variable which was divided into four quarters namely Q_1(January-March), Q_2(April-June), Q_3(July-September) and Q_4(October-December) data from 1986-2015. Panel data consists of 90 observations for Karnataka, Kerala and Tamil Nadu for 30 years. Thus, data set is a balance data set.

Model specification:

The model for coconut production under this study is specified as

$$\text{Production } (Y_{it}) = f\,(Q1it\text{-}1,\ Q2it\text{-}1,\ Q3it\text{-}1,\ Q4it\text{-}1)$$

$$\log Y_{it} = \beta_0 + \beta_i logQ_{1it-1} + \beta_{2i} logQ_{2it-1} + \beta_{3i} logQ_{3it-1} + \beta_{4i} logQ_{4it-1}$$

Production (Y_{it}) = Coconut production of i^{th} region during t^{th} period

Q_{1it-1} = Rainfall during January to March of i^{th} region during t-1^{th} period

Q_{2it-1} = Rainfall during April to June of i^{th} region during t-1^{th} period

Q_{3it-1} = Rainfall during July to September of i^{th} region during t-1^{th} period

Q_{4it-1} = Rainfall during October to December of i^{th} region during t-1^{th} period

Production of paddy data was collected from 1987-2016 from Karnataka and Tamil Nadu was taken as dependent variables. Rainfall was considered as independent variable which was collected in quarterly data from 1987-2016. Panel data consists of 60 observations for Karnataka and Tamil Nadu for 30 years. Thus, data set is a balance data set.

Model specification:

The model for paddy production under this study is specified as

$$\text{Production } (Y_{it}) = f\,(Q_{1it}, Q_{2it}, Q_{3it}, Q_{4it})$$

$$\log Y_{it} = \beta_0 + \beta_i logQ_{1it} + \beta_{2i} logQ_{2it} + \beta_{3i} logQ_{3it} + \beta_{4i} logQ_{4it}$$

Production (Y_{it})= Paddy production of i^{th} region during t^{th} period

Q_{1it-1} = Rainfall during January to March of i^{th} region during t^{th} period

Q_{2it-1} = Rainfall during April to June of i^{th} region during t^{th} period

Q_{3it-1} = Rainfall during July to September of i^{th} region during t^{th} period

Q_{4it-1} = Rainfall during October to December of i^{th} region during t^{th} period

In regression data analysis, natural logarithm was taken for both dependent and independent variables to avoid too much fluctuation in the results. Later results are expressed in terms of percentage by removing the log of regression coefficient.

Statistical package STATA was used to analyse the panel data regression. To decide between random effects and fixed effects model Hausman test was used.

Choosing between Fixed Effects (FE) and Random Effects (RE)

1. With large time series data and small cross section data there is likely to be little difference, so FE is preferable as it is easier to compute

2. With large cross section data and small time series data, estimates can differ significantly. If the cross-sectional groups are a random sample of the population RE is preferable. If not the FE is preferable.

Variance inflation factor (VIF) was calculated to check the multicollinearity in the function. It was calculated using the formula:

$$VIF = 1/1-R^2$$

Where,

VIF = Variance Inflation Factor

R^2 = Coefficient of determination

If the VIF value is equal to 10 or more than 10, then the particular independent variable is considered to have high multicollinearity with one or more independent variables.

Durbin – Watson test was conducted to check the autocorrelation. It was calculated using the formula:

$$D= 2 (1-\rho)$$

Where,

D = Durbin – Watson value

ρ = Correlation coefficient of error term

If d value is lies between 1.696 and 4 then, the model is said to have no autocorrelation.

Results and Discussion

4. RESULTS AND DISCUSSION

In accordance with the objectives formulated for the present study in the introduction chapter, this chapter deals with presentation and interpretation of the results obtained along with relevant discussions. For convenience and better focus, this chapter is divided into three sections:

4.1. Trend models for area, production and productivity

4.2. Comparison of growth rates across states

4.3. Price co-movement using co-integration technique

4.4. Influencing factors on production

4.1 LINEAR AND NON-LINEAR TREND MODELS

In the present study, eight growth models *viz.,* semi log, double logarithmic, inverse, quadratic, cubic, compound, power and exponential have been fitted to the data on area (in '000 ha), production and productivity of the paddy and coconut in South Indian states viz., Karnataka, Kerala and Tamil Nadu. To measure the goodness of fit of the model, adjusted R^2, criteria of randomness, normality of time series and Root Mean Square Error (RMSE) were used. The growth models were fitted by using the IBM.SPSS 16.0 package.

4.1.1 Paddy

Different growth models were fitted to study the trends in area (in '000 ha), production (in '000 tonnes) and productivity (in kg ha^{-1}) of paddy in South Indian states Karnataka, Kerala and Tamil Nadu. The results are presented in the following section.

4.1.1.1 Trends in area, production and productivity of paddy in Karnataka

Area under paddy in Karnataka showed a positive growth rate during the study period 1987-88 to 2016-17. The results obtained by fitting all the eight growth models of area under paddy in Karnataka are presented in Table 1 along with adjusted R^2, Shapiro-Wilks test statistic to test normality of error terms, Runs test for independence of error terms and Root Mean Square Error (RMSE). Adjusted R^2 value for all the models were ranging from -0.5 per cent for semi log function to 32.6 per cent for cubic function. Among the eight fitted models, cubic function showed maximum adj. R^2 (32.6 %), but none of the estimated regression coefficients was not significant. Next highest adjusted R^2 (31.8 %) was found in quadratic model. According to Runs test and Shapiro-Wilk test, the residual of quadratic model was random and normally distributed. Moreover, quadratic model has minimum RMSE (0.09). Thus the best model was selected and its trend values are shown in Fig. 1. The estimated equation was

$$Y_t = 6.989 + 0.031t - 9.42\times10^{-4}t^2 \quad (\text{Adj. } R^2 = 0.318)$$

Production of paddy in Karnataka showed a positive and significant growth rate during the study period. The results obtained by fitting all the eight growth models of paddy production in Karnataka are presented in Table 2 along with adjusted R^2, Shapiro-Wilks test statistic to test normality of error terms, Runs test for independence of error terms and RMSE. Adjusted R^2 ranges from 26.9 per cent for semi-log/compound/exponential model to 51.1 per cent for quadratic model. Among eight models quadratic model explained 51.1 per cent of total variation and the estimated coefficient were found to be significant (Table.2). According to Shapiro-Wilk test and Runs test, the residuals of quadratic model were normal and random and also the model has lowest RMSE value (0.16). The trend values of quadratic function are shown in Fig. 2. The estimated equation was

$$Y_t = 7.615 + 0.064t - 0.002t^2 \quad (\text{Adj. } R^2 = 0.511)$$

The results obtained by fitting all the eight growth models of paddy productivity in Karnataka are presented in Table 3. Among the fitted linear and nonlinear growth models for productivity of paddy in Karnataka, the maximum adjusted.R^2 of 72 per cent was observed in power model and minimum adjusted

R^2 was observed in inverse model (57.3 %). According to Shapiro-Wilk test and Runs test the residuals of power model were found to be normal and random. And also power function having least RMSE value of 0.09. Hence, among the fitted models power function was considered as the best fitted model for productivity of paddy in Karnataka. Estimated power function was

$$Y_t = 7.515t^{0.117} \quad (\text{Adj. } R^2 = 0.720)$$

The actual and fitted trends for productivity of paddy in Karnataka using power function were depicted in Fig.3.

Table 1. Fitted linear and non-linear models for area under paddy in Karnataka for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	7.144** (0.042)	.002^{NS} (0.002)			-.005	.920* [0.027]	-3.148** [.002]	0.11
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.062** (.060)	.046^{NS} (.023)			.096	.898^{NS} [0.078]	-2.287* [0.022]	0.10
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	7.212** (.022)	-.256* (.097)			.170	.909* [0.014]	-2.738** [.006]	0.10
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	6.989** (.054)	.031** (.008)	-9.42×10^{-4}** (2.49×10^{-4})		.318	.900^{NS} [0.059]	-.665^{NS} [.625]	0.09
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	7.050** (.076)	.009^{NS} (.021)	.001^{NS} (.002)	-3.8×10^{-5} ^{NS} (3.3×10^{-5})	.326	.862^{NS} [0.061]	-.575^{NS} [.565)]	0.08
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	7.144** (.042)	1.000** (3.28×10^{-4})			-.006	.921* [0.028]	-3.148** [.002]	0.11
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	7.062** (.060)	.006^{NS} (.003)			.095	.898** [0.008]	-2.287* [.022]	0.10
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	7.144** (.042)	2.97×10^{-4} ^{NS} (3.28×10^{-4})			-.006	.921* [0.028]	-3.148** [.002]	0.10

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 2. Fitted linear and non-linear models for production of paddy in Karnataka for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	7.899** (.075)	.011* (.004)			.269	$.931^{NS}$ [.053]	-3.838** [.000]	0.19
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.688** (.103)	.151** (.039)			.468	.911* [.016]	-2.287* [.022]	0.17
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	8.155** (.039)	-.686** (.169)			.476	$.931^{NS}$ [.053]	-2.044* [.041]	0.17
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	7.615** (.096)	.064** (.014)	-.002** (4.48×10^{-4})		.511	$.908^{NS}$ [.063]	$-.908^{NS}$ [.364]	0.16
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	7.648** (.139)	$.052^{NS}$ (.038)	-7.77×10^{-4NS} (.003)	-2.03×10^{-4NS} (6.02E-5)	.492	.908* [.013]	-.900** [.000]	0.16
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	7.897** (.073)	1.001** (.001)			.269	$.931^{NS}$ [.052]	-3.838** [.000]	0.19
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	7.690** (.097)	.019** (.005)			.472	.912* [.016]	-2.287* [.022]	0.18
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	7.897** (.073)	.001* (.001)			.269	$.931^{NS}$ [.052]	-3.838** [.000]	0.19

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

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Table 3. Fitted linear and non-linear models for productivity of paddy in Karnataka for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	7.648** (.039)	.010** (.002)			.577	.800* [.023]	-2.415* [.016]	0.10
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.513** (.054)	.117** (.021)			.717	.717* [.045]	$-.186^{NS}$ [.853]	0.09
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	7.865** (.023)	-.460** (.101)			.573	.812** [.000]	-1.981* [.048]	0.10
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	7.542** (.057)	.030** (.008)	-6.4×10^{-4}** (2.65×10^{-4})		.663	$.769^{NS}$ [.062]	$-.908^{NS}$ [.364]	0.09
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	7.516** (.082)	.039** (.023)	$-.001^{NS}$ (.002)	1.6×10^{-5NS} (3.5×10^{-5})	.676	$.744^{NS}$ [.326]	$-.908^{NS}$ [.364]	0.09
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	7.647** (.038)	1.001** (2.81×10^{-4})			.575	$.801^{NS}$ [.124]	-2.415* [.016]	0.10
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	7.515** (.051)	.117** (.003)			.720	$.718^{NS}$ [.068]	$-.186^{NS}$ [.853]	0.09
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	7.647** (.038)	.001** (2.8×10^{-4})			.575	.801* [.023]	-2.415* [.016]	0.10

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

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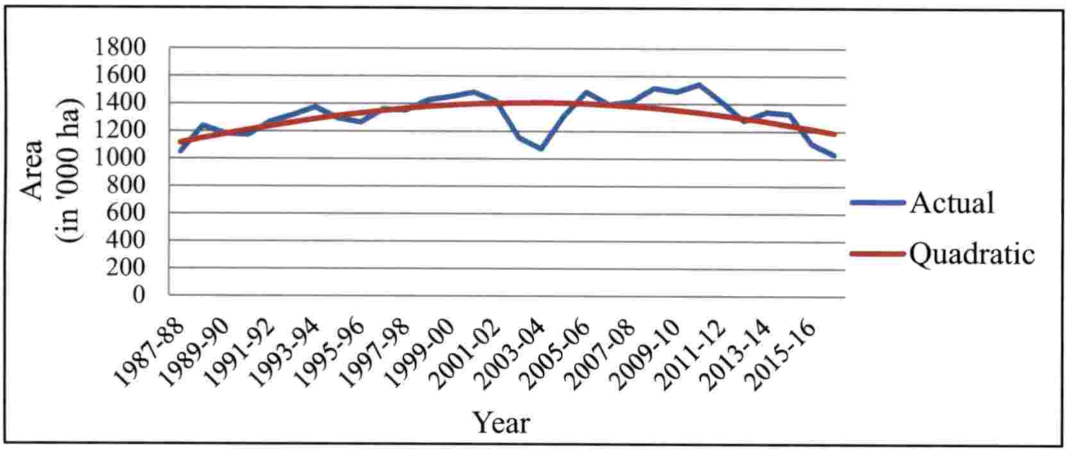

Figure 1. Actual and estimated trends in area under paddy in Karnataka

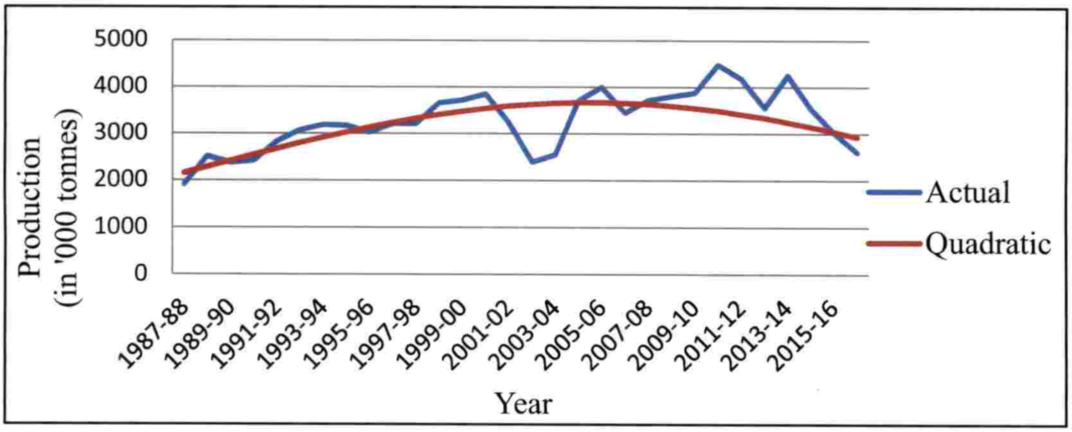

Figure 2. Actual and estimated trends in production of paddy in Karnataka

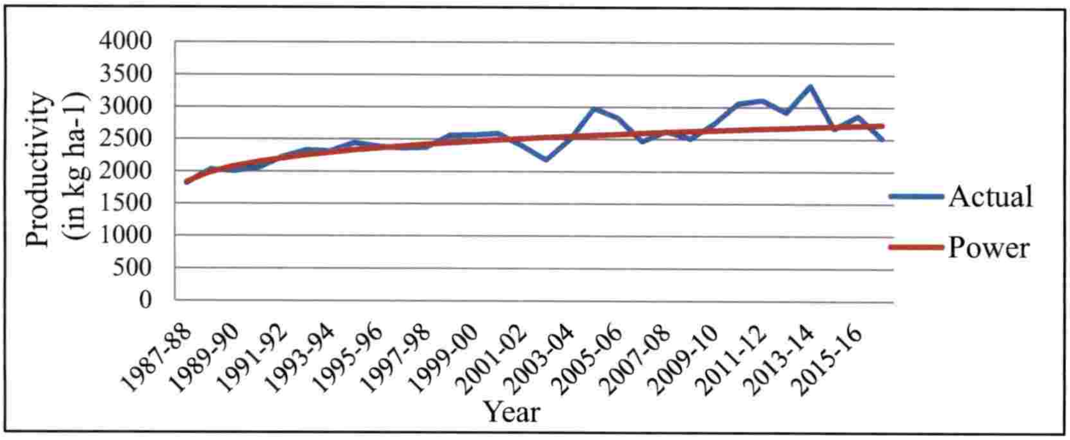

Figure 3. Actual and estimated trends in productivity of paddy in Karnataka

4.1.1.2 Trends in area, production and productivity of paddy in Kerala

Area under paddy in Kerala showed a declining trend pattern during the study period 1987-88 to 2016-17. All the estimated models had high adjusted R^2 ranges from 80.5 per cent to 98.6 per cent. Cubic model had highest adjusted R^2 of 98.6 per cent with significant estimated coefficients and a minimum adjusted R^2 of 36.8 per cent was observed in inverse model. Moreover residuals of the cubic model were independent and normally distributed based on Shapiro-Wilk test and Runs test. Because of maximum adjusted R^2 of 98.6 per cent and minimum RMSE value 0.04, cubic model was the best model among the eight linear and non-linear models. At the same time semi-log, quadratic, compound and exponential models also having high adjusted R^2 values. According to Shapiro-Wilk test and Runs test the residuals of cubic model were normal and random. Fig.4 represents the actual and fitted trends for area under paddy in Kerala using cubic function. So the best estimated cubic model was

$$Y_t = 6.441 - 0.021t - 0.002t^2 + 4.96\times10^{-5}t^3 \quad (\text{Adj. } R^2 = 0.986)$$

The estimated equations along with adjusted R^2, Shapiro-Wilk test, Runs test and RMSE of production of paddy in Kerala are presented in Table.5. All the models except inverse model had high adjusted R^2 ranging from 76.4 per cent to 93.1 per cent. Table.5 indicates that cubic model had highest adjusted R^2 of 93.1 per cent with non-significant coefficients. Quadratic model had next highest adjusted R^2 of 92.3 per cent with significant estimated regression coefficients and it satisfying all the criteria for the best model. So, quadratic model was the best fitted model among eight linear and non-linear models. Fig.5 represents the actual and fitted values for production of paddy in Kerala using quadratic function. The fitted quadratic model was

$$Y_t = 7.102 - 0.04t + 3.2\times10^{-4}t^2 \quad (\text{Adj. } R^2 = 0.923)$$

Productivity of paddy in Kerala showed an increasing trend during the study period which may be on account of introduction of high yielding varieties of paddy for cultivation. It is evident from Table.6 that among eight linear and non-linear models highest adjusted R^2 of 91.8 per cent was found in semi-log, compound and exponential models but residuals of none of these models were not normal. Therefore quadratic model was the best fitted model because it had adjusted R^2 value of 91.5 per cent with minimum RMSE value of 0.14. According to Shapiro-Wilk test and Runs test the residuals of quadratic model were normal and random. Fig.6 represents the actual and fitted values for productivity of paddy in Kerala using quadratic function. The estimated quadratic model was

$$Y_t=7.519+0.002t+4.1\times10^{-5}t^2 \quad (\text{Adj. } R^2=0.915)$$

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Table 4. Fitted linear and non-linear models for area under paddy in Kerala for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	6.495** (0.020)	-.045** (0.001)			0.983	0.972 ^{NS} [0.584]	-2.870** [0.004]	0.05
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	6.863** (0.098)	-.430** (0.037)			0.751	.959 ^{NS} [0.285]	-4.642** [0.000]	0.16
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	5.619** (0.071)	1.302** (0.308)			0.330	.935 ^{NS} [0.065]	-4.642** [0.000]	0.31
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	6.522** (0.031)	-.050** (0.005)	-8.7×10^{-5} ^{NS} (3.23×10^{-4})		0.918	.977 ^{NS} [0.734]	-2.870 ^{NS} [0.094]	0.05
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	6.441** (0.039)	-.021* (0.011)	-.002* (0.001)	4.9×10^{-5} * (4.28×10^{-5})	0.917	.965 ^{NS} [0.420]	-2.287 ^{NS} [0.364]	0.04
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	6.524** (0.022)	.992** (4.1×10^{-4})			0.923	.974 ^{NS} [0.657]	-2.717 ^{NS} [0.094]	0.05
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	6.941** (0.122)	-.074** (0.007)			0.739	.943 ^{NS} [0.111]	-4.642** [0.000]	0.18
8	Exponential $Y = b_0 e^{(b_1 t)}$	6.524** (0.022)	-.008** (4.1×10^{-4})			0.923	.974 ^{NS} [0.657]	-2.717 [0.094]	0.05

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

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Table 5. Fitted linear and non-linear models for production of paddy in Kerala for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	7.049** (0.030)	-.030** (0.002)			.920	.981 ^{NS} [0.848]	-0.929 ^{NS} [0.353]	0.08
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.298** (0.077)	-.290** (0.029)			0.820	.957 ^{NS} [0.262]	-2.402* [0.016]	0.13
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	6.464** (0.051)	.850** (0.221)			0.330	.959 ^{NS} [0.291]	-4.645** [0.000]	0.22
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	7.102** (0.046)	-.040** (0.007)	3.20E-4* (2.12E-4)		0.982	.966 ^{NS} [0.433]	-0.186 ^{NS} [0.853]	0.07
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	7.014** (0.061)	-.009 ^{NS} (0.017)	-.002 ^{NS} (0.001)	5.4×10^{-5} ^{NS} (2.65×10^{-5})	0.986	.937 ^{NS} [0.075]	-0.088 ^{NS} [0.930]	0.07
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	7.060** (0.032)	.995** (2.15E-5)			0.983	.979 ^{NS} [0.793]	-0.162 ^{NS} [0.871]	0.08
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	7.328** (0.086)	-.044** (0.004)			0.805	.952 ^{NS} [0.188]	-2.402* [0.016]	0.13
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	7.060** (0.032)	-.005** (2.52E-4)			0.983	.979 ^{NS} [0.793]	0.162 ^{NS} [0.871]	0.08

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 6. Fitted linear and non-linear models for productivity of paddy in Kerala for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	7.467** (0.015)	.015** (0.001)			0.918	.398* [.016]	-0.592 ^{NS} [0.554]	0.14
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.341** (0.037)	.144** (0.014)			0.783	.544** [.006]	-2.287* [0.022]	0.15
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	7.762** (0.024)	-.466* (0.102)			0.406	.747 ^{NS} [.0126]	-4.642** [0.000]	0.17
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	7.519** (0.024)	.002** (0.004)	4.5×10^{-5} ^{NS} (3.96×10^{-4})		0.915	.451 ^{NS} [.068]	-1.552 ^{NS} [0.121]	0.14
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	7.476** (0.034)	.013 ^{NS} (0.009)	8.9×10^{-5} ^{NS} (0.001)	-9.4×10^{-7} ^{NS} (5.3×10^{-5})	0.912	.462* [.012]	-0.592 ^{NS} [0.554]	0.14
6	**Compound** $Y = b_0 b_1{}^t \varepsilon$	7.469** (0.014)	1.002** (4.1×10^{-4})			0.918	.399* [.016]	-0.592 ^{NS} [0.554]	0.14
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	7.352** (0.090)	.017** (0.005)			0.789	.542** [.000]	-2.287* [0.022]	0.15
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	7.469** (0.014)	0.002** (4.1×10^{-5})			0.918	.399* [.016]	-0.592 ^{NS} [0.554]	0.14

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

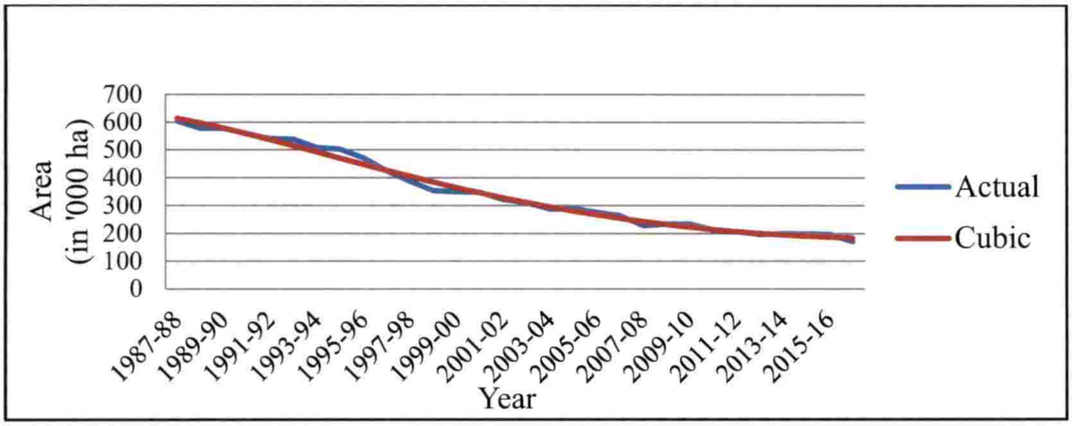

Figure 4. Actual and estimated trends in area under paddy in Kerala

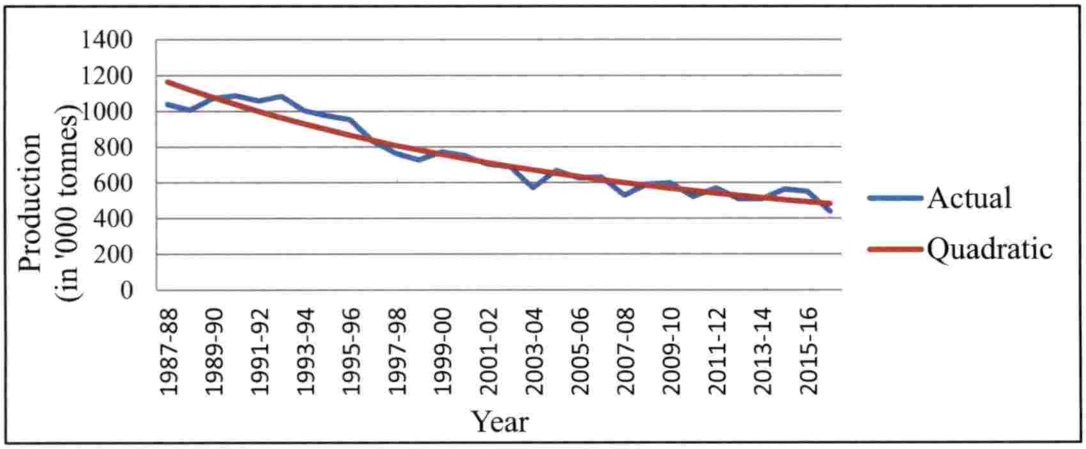

Figure 5. Actual and estimated trends in production of paddy in Kerala

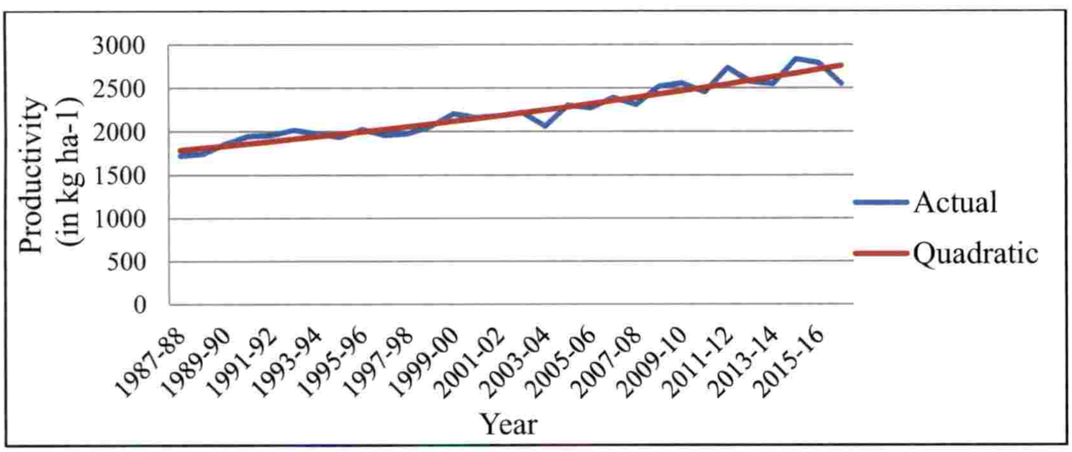

Figure 6. Actual and estimated trends in productivity of paddy in Kerala

4.1.1.3 Trends in area, production and productivity of paddy in Tamil Nadu

Area under paddy in Tamil Nadu showed a declining trend pattern during the study period 1987-88 to 2016-17. All the fitted models for area under paddy in Tamil Nadu are presented in Table.7. Among eight fitted linear and nonlinear models cubic model has highest adjusted R^2 but estimated regression coefficients are non-significant and residuals are not normally distributed. Quadratic model has next highest adjusted R^2 of 33.2 per cent of total variation and it has minimum RMSE values of 0.10. According to Shapiro-Wilk test and Runs test the residuals of quadratic model were normal and random. Fig.7 represents the actual and fitted values for area under paddy in Tamil Nadu using quadratic function. The estimated quadratic model was

$$Y_t = 7.574+0.016t-7.3\times10^{-4}t^2 \quad (\text{Adj. } R^2=0.332)$$

Production of paddy in Tamil Nadu showed a decreasing trend pattern during the study period. All the fitted models for production of paddy in Tamil Nadu are presented in Table.8. Among eight models, compound model showed highest adjusted R^2 and it explains only 8 per cent of total variation with RMSE of 0.25. All eight models had very low adjusted R^2 and it may lead more errors during prediction. According to Runs test and Shapiro-Wilk test the residuals of compound model were random and normal. The actual and fitted values for production of paddy in Tamil Nadu using compound model have been shown in Fig.8. The estimated compound model was

$$Y_t=8.808(0.990)^t \quad (\text{Adj. } R^2=0.080)$$

Productivity of paddy in Tamil Nadu showed a positive trend during the study period. The result obtained from eight fitted linear and nonlinear trend models of productivity in Tamil Nadu is shown in Table.9. The value of adjusted R^2 of the estimated models ranges from 29.5 per cent for inverse model to 62.5 per cent for cubic model. Further cubic model had least RMSE (0.17). According to Shapiro-Wilk test and Runs test the residuals of cubic model were normal and random. Thus the best model selected was cubic and trend values are presented in Fig.9. The estimated cubic model was

$$Y_t = 8.032 - 0.009t - 0.001t^2 - 2.367\times10^{-5}t^3 \quad (\text{Adj. } R^2=0.625)$$

Similar results were found by Ramesh et al., (2016), who reported that models were rejected when the residuals are not normally or independently distributed in a study on statistical modelling of potato in West Bengal. In another study (Gundu, 2013), the fitted models for rice production in Rayalaseema region of Andhra Pradesh explained very small variation.

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Table 7. Fitted linear and non-linear models for area under paddy in Tamil Nadu for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	7.695** (.044)	-.007 ^{NS} (.002)			.207	.954 ^{NS} [.215]	-.088 ^{NS} [.930]	0.11
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.699** (.074)	-.047 ^{NS} (.028)			.059	.964 ^{NS} [.392]	-.088 ^{NS} [.930]	0.12
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	7.573** (.030)	.068 ^{NS} (.129)			-.025	.958 ^{NS} [.278]	-1.603 ^{NS} [.109]	0.13
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	7.574** (.063)	.016* (.009)	-7.3×10^{-5} * (2.95×10^{-4})		.332	.935 ^{NS} [.065]	-1.003 ^{NS} [.105]	0.10
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	7.516** (.090)	.036 ^{NS} (.025)	-.002 ^{NS} (.002)	3.5×10^{-5} ^{NS} (3.9×10^{-5})	.337	.918* [.023]	-1.600 ^{NS} [.100]	0.10
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	7.696** (.045)	.999** (3.28×10^{-4})			.209	.954 ^{NS} [.213]	-.088 ^{NS} [.930]	0.11
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	7.701** (.075)	-.006 ^{NS} (.004)			.060	.964 ^{NS} [.399]	-.088 ^{NS} [.930]	0.12
8	Exponential $Y = b_0 e^{(b_1 t)}$	7.696** (.045)	-9.6×10^{-5} * (3.28×10^{-5})			.209	.954 ^{NS} [.213]	-.088 ^{NS} [.930]	0.11

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 8. Fitted linear and non-linear models for production of paddy in Tamil Nadu for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	8.805** (.098)	-.003 ^{NS} (.006)			.078	.934 ^{NS} [.073]	-1.655 ^{NS} [.098]	0.25
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	8.827** (.155)	-.073 ^{NS} (.059)			.018	.913* [.017]	-1.655 ^{NS} [.098]	0.26
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	8.633** (.062)	.104 ^{NS} (.266)			-.030	.878** [.003]	-1.512 ^{NS} [.131]	0.27
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	8.699** (.154)	.010 ^{NS} (.023)	-6.4×10^{-4} ^{NS} (.023)		.071	.920* [.026]	-1.655 ^{NS} [.098]	0.25
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	8.655** (.222)	.026 ^{NS} (.061)	-.002 ^{NS} (.005)	2.7×10^{-5} ^{NS} (9.63×10^{-5})	.038	.911* [.016]	-1.655 ^{NS} [.098]	0.25
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	8.808** (.102)	.990** (.001)			.080	.937 ^{NS} [.073]	-1.655 ^{NS} [.098]	0.25
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	8.833** (.162)	-.009 ^{NS} (.007)			.019	.915* [.019]	-1.655 ^{NS} [.098]	0.26
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	8.808** (.102)	-.001 ^{NS} (.001)			.080	.937 ^{NS} [.073]	-1.655 ^{NS} [.098]	0.25

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 9. Fitted linear and non-linear models for productivity of paddy in Tamil Nadu for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	8.032** (.065)	.002 NS (.004)			0.483	.938 NS [.079]	-.846 NS [.398]	0.17
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	8.031** (.100)	.016 NS (.038)			0.553	.922* [.030]	-.846 NS [.398]	0.17
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	7.993** (.039)	.006 NS (.168)			0.295	.906* [.012]	-.737 NS [.461]	0.17
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	7.993** (.103)	.005 NS (.015)	-2.3E-4 NS (4.79×10^{-4})		0.618	.945 NS [.127]	-.846 NS [.398]	0.17
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	8.032** (.148)	.009** (.041)	.001* (.003)	-2.4×10^{-5} NS (6.42×10^{-5})	0.625	.955 NS [.227]	-.846 NS [.398]	0.17
6	**Compound** $Y = b_0 b_1^{t} \varepsilon$	8.033** (.066)	1.000** (4.63×10^{-5})			0.483	.940 NS [.089]	-.846 NS [.398]	0.17
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	8.033** (.102)	.002 NS (.005)			0.559	.924* [.034]	-.846 NS [.398]	0.17
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	8.033** (.066)	-3.4×10^{-5} NS (4.63×10^{-4})			0.483	.940 NS [.089]	-.846 NS [.398]	0.17

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

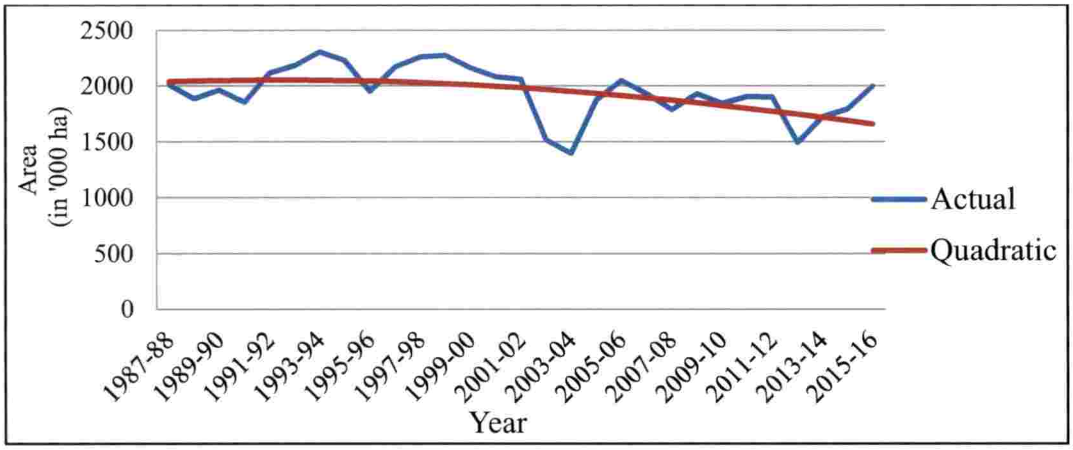

Figure 7. Actual and estimated trends in area under paddy in Tamil Nadu

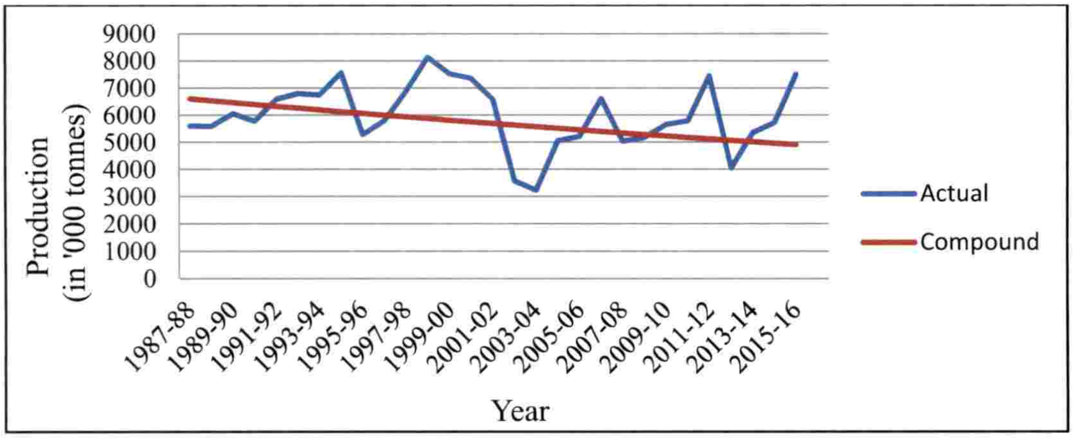

Figure 8. Actual and estimated trends in production of paddy in Tamil Nadu

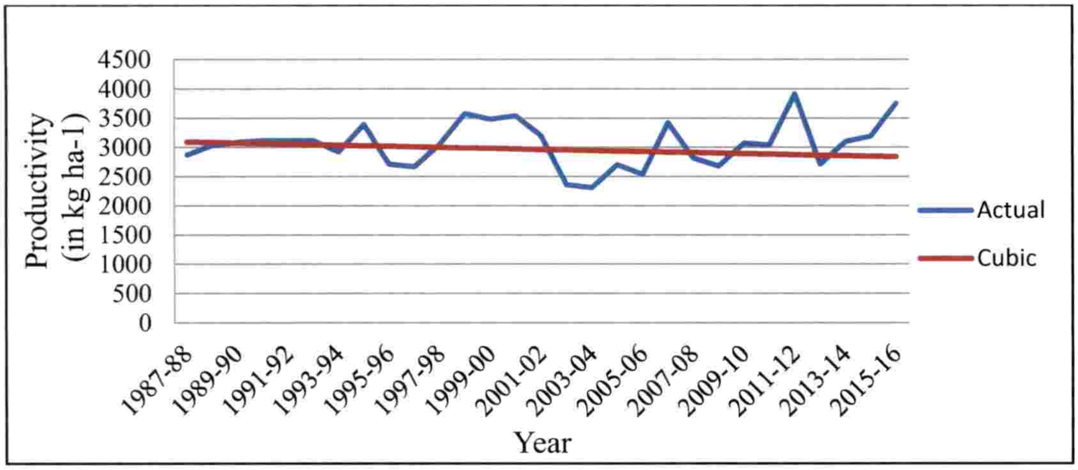

Figure 9. Actual and estimated trends in productivity of paddy in Tamil Nadu

4.1.2 Coconut

Different growth models were fitted to study the trends in area (in '000 ha), production (in million nuts) and productivity (in nuts ha^{-1}) of coconut in South Indian states viz., Karnataka, Kerala and Tamil Nadu. The results are given below:

4.1.2.1 Trends in area, production and productivity of coconut in Karnataka

Area under coconut in Karnataka showed an increasing trend during the study period. All the fitted models for area under coconut in Karnataka are presented in Table.10 along with adjusted R^2, Shapiro-Wilk test, Runs test and RMSE. Adjusted R^2 values for the entire models ranges from 39.9 per cent for inverse model to 98.1 per cent for quadratic model with RMSE value of 0.04. According to Shapiro-Wilk test and Runs test the residuals of quadratic model were normal and random. There are other additional models like log-linear, cubic, compound and exponential which had high adjusted R^2 value. The actual and fitted value of area under coconut in Karnataka using quadratic function was presented in Fig.10. The estimated quadratic model was

$$Y_t = 5.302 + .038t - 1.63\times10^{-4}t^2 \text{ (Adj. } R^2 = 0.981)$$

Production of coconut in Karnataka showed an increasing trend during the study period. All the fitted models for area under coconut in Karnataka are presented in Table.11 along with adjusted R^2, Shapiro-Wilk test, Runs test and RMSE. Adjusted R^2 values for the entire models ranges from 14.6 per cent for inverse model to 87.6 per cent for cubic model. Cubic model has the highest adjusted R^2 value of 87.6 per cent but none of the regression coefficients are significant. Quadratic model was the best fitted model among eight linear and non-linear models because quadratic model has maximum adjusted R^2 value of 84.3 per cent with comparatively least RMSE value of 0.21 and significant estimated regression coefficients. According to Shapiro-Wilk test and Runs test the residuals of quadratic model were normal and random. The actual and fitted value of production of coconut in Karnataka using quadratic function was presented in Fig.11.The estimated quadratic model was

$$Y_t=7.253-0.046t-0.003t^2 \quad (\text{Adj. } R^2=0.843)$$

Productivity of coconut in Karnataka showed an increasing trend during the study period. All the fitted models for productivity of coconut in Karnataka are presented in Table.12. Adjusted R^2 values for the entire models ranges from 7 per cent for inverse model to 72.7 per cent for cubic model. The estimated regression coefficients are not significant for cubic model. Quadratic model explains 64.3 per cent of total variation with comparatively least RMSE value of 0.21. According to Shapiro-Wilk test and Runs test the residuals of quadratic model were normal and random. The actual and fitted value of production of coconut in Karnataka using quadratic function was presented in Fig.12.The estimated quadratic model was

$$Y_t=8.863-0.085t+0.003t^2 \quad (\text{Adj. } R^2=0.643)$$

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Table 10. Fitted linear and non-linear models for area under coconut in Karnataka for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test(z)	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	5.329** (0.016)	.033** (0.001)			0.980	.955 ^{NS} [0.234]	-2.287 ^{NS} [0.072]	0.04
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	5.052** (0.067)	.317** (0.026)			0.840	.925* [0.037]	-2.982** [0.003]	0.11
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	5.971** (0.051)	-.983** (0.219)			0.399	.914* [0.019]	-3.895** [0.000]	0.22
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	5.302** (0.024)	.038** (0.004)	-1.6×10^{-4} ^{NS} (0.000)		0.981	.970 ^{NS} [0.547]	-2.787 ^{NS} [0.065]	0.04
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	5.321** (0.034)	.031* (0.009)	3.7×10^{-5} ^{NS} (0.001)	-1.2×10^{-5} ^{NS} (0.000)	0.980	.970 ^{NS} [0.529]	-2.775** [0.006]	0.04
6	**Compound** $Y = b_0 b_1^t \varepsilon$	5.343** (0.015)	1.006** (0.000)			0.979	.957 ^{NS} [0.257]	-2.360 ^{NS} [0.078]	0.04
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	5.089** (0.056)	.055** (0.004)			0.852	.932 ^{NS} [0.057]	-3.063** [0.002]	0.11
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	5.343** (0.015)	.006** (0.000)			0.979	.957 ^{NS} [0.257]	-2.360 ^{NS} [0.078]	0.04

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 11. Fitted linear and non-linear models for production under coconut in Karnataka for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	6.719** (0.118)	.054* (0.007)			0.695	.931 ^{NS} [0.053]	-3.838* [0.009]	0.30
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	6.437** (0.245)	.451** (0.093)			0.436	.911* [0.016]	-2.287* [0.022]	0.41
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	7.724** (0.117)	-1.234* (0.505)			0.146	.931 ^{NS} [0.053]	-2.044* [0.041]	0.51
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	7.253** (0.132)	-.046** (0.020)	.003** (0.001)		0.843	.908 ^{NS} [0.113]	-0.908 ^{NS} [0.364]	0.21
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	6.914** (0.166)	.076 ^{NS} (0.046)	-0.006 ^{NS} (0.003)	2.1×10^{-5} * (7.2×10^{-5})	0.876	.908 ^{NS} [0.134]	-0.812 ^{NS} [.080]	0.19
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	6.769** (0.099)	1.007** (0.001)			0.707	.931 ^{NS} [0.052]	-3.838** [0.006]	0.30
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	6.519** (0.200)	.058** (0.012)			0.453	.912* [0.016]	-2.287* [0.022]	0.41
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	6.769** (0.099)	.007* (0.001)			0.707	.931 ^{NS} [0.052]	-3.838** [0.006]	0.30

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 12. Fitted linear and non-linear models for productivity under coconut in Karnataka for 1987-2017

	Models	Regression coefficients				Goodness of fit			RMSE
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	8.290** (0.122)	.022* (0.007)			0.244	.964 ^{NS} [0.393]	-4.613** [0.006]	0.31
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	8.283** (0.207)	.140 ^{NS} (0.079)			0.070	.954 ^{NS} [0.215]	-4.613** [0.000]	0.35
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	8.667** (0.084)	-.263 ^{NS} (0.362)			0.017	.870** [0.002]	-4.431* [0.020]	0.36
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	8.863** (0.131)	-.085** (0.001)	.003** (0.019)		0.643	.984 ^{NS} [0.921]	-3.530 ^{NS} [0.113]	0.21
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	8.511** (0.162)	.041 ^{NS} (0.045)	-.007 ^{NS} (0.003)	2.16×10^{-4} * (0.000)	0.727	.904 ^{NS} [0.910]	-2.775 ^{NS} [0.066]	0.18
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	8.303** (0.116)	1.002** (0.001)			0.232	.967 ^{NS} [0.461]	-4.631** [0.006]	0.31
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	8.300** (0.196)	.015 ^{NS} (0.009)			0.063	.949 ^{NS} [0.158]	-4.613** [0.000]	0.35
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	8.303** (0.116)	.002* (0.001)			0.232	.967 ^{NS} [0.461]	-4.631** [0.006]	0.31

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

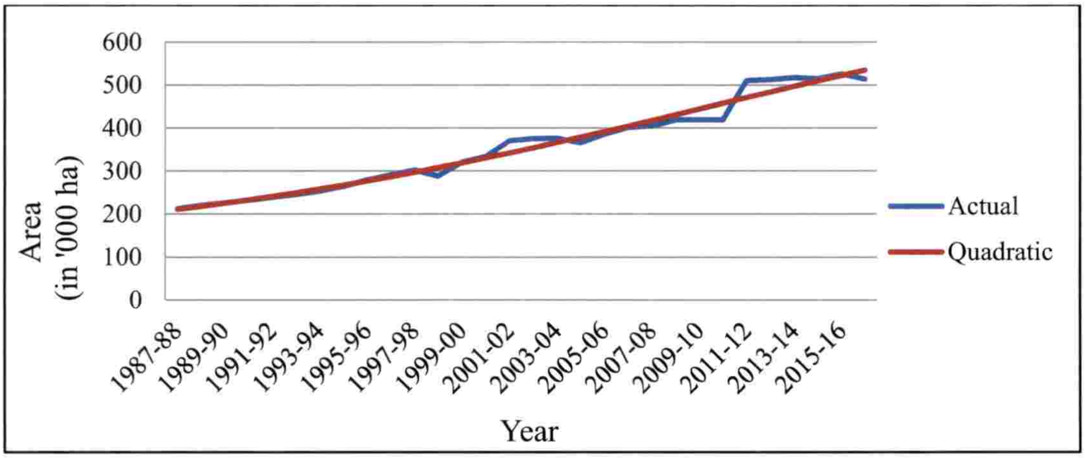

Figure 10. Actual and estimated trends in area under coconut in Karnataka

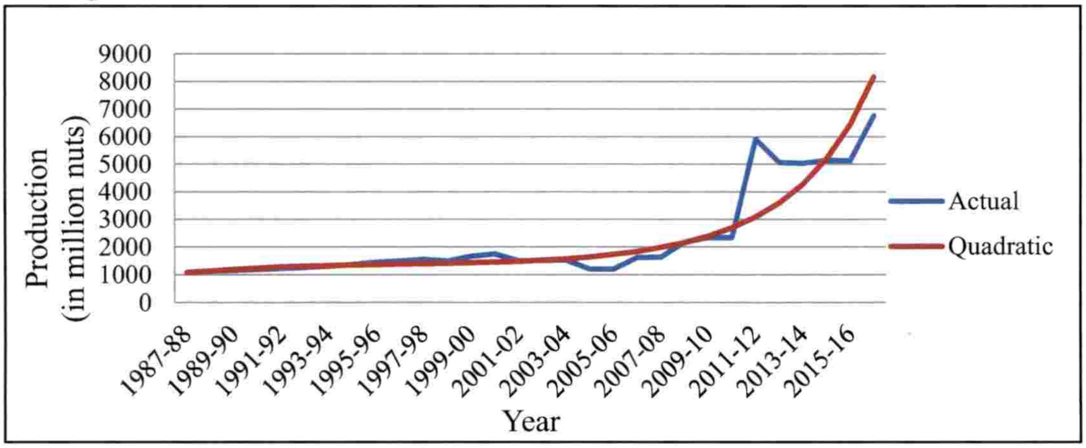

Figure 11. Actual and estimated trends in production of coconut in Karnataka

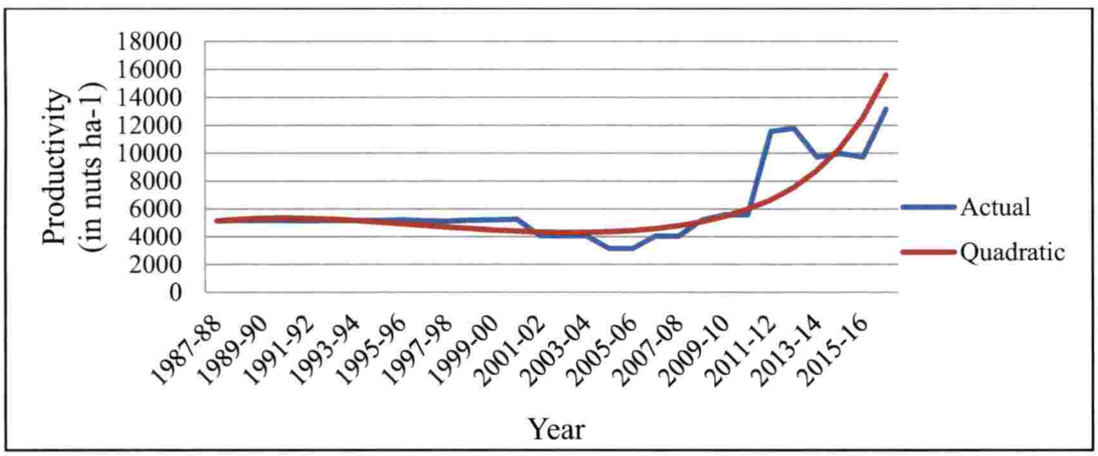

Figure 12. Actual and estimated trends in productivity of coconut in Karnataka

4.1.2.2 Trends in area, production and productivity of coconut in Kerala

Area under coconut in Kerala showed a declining trend pattern during the study period. All the fitted models for area under coconut in Kerala are presented in table.13. Adjusted R^2 values for the all the models ranges from 0.2 per cent for power model to 76.5 per cent for cubic model with minimum RMSE of 0.05 and estimated regression coefficients were significant. According to Shapiro-Wilk test and Runs test the residuals of cubic model were found to be normal and random. The best model selected was cubic model and its trend values are presented in Fig.13. The estimated cubic model was

$$Y_t = 6.561+.066t-.004t^2+6.855\times10^{-5}t^3 \quad (\text{Adj. } R^2=0.765)$$

Production of coconut in Kerala showed an increasing pattern during the study period. All the fitted models for production of coconut in Kerala are presented in Table.14. Adjusted R^2 values for the entire models ranges from 52.8 per cent for compound/exponential model to 75.6 per cent for cubic model with minimum RMSE of 0.08 and the estimated regression coefficients of cubic model were significant. According to Shapiro-Wilk test and Runs test the residuals of cubic model were normal and random. The best model selected was cubic model and its trend values are presented in Fig.14. The estimated cubic model was

$$Y_t = 8.058+0.110t-.006t^2+1.18\times10^{-4}t^3 \quad (\text{Adj. } R^2=0.756)$$

Productivity of coconut in Kerala showed a positive trend pattern during the study period. All the fitted models for productivity of coconut in Kerala are presented in Table.15. Adjusted R^2 values for the all the models range from 41.7 per cent for inverse model to 89.1 per cent for cubic model with minimum RMSE of 0.06 and estimated regression coefficients of cubic model were significant. According to Shapiro-Wilk test and Runs test the residuals of cubic model were normal and random. The best model selected was cubic model and its trend values are presented in Fig.15. The estimated cubic model was

$$Y_t = 8.404+0.044t-.002t^2+5.043\times10^{-5}t^3 \quad (\text{Adj. } R^2=0.891)$$

Table 13. Fitted linear and non-linear models for area under coconut in Kerala for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test(z)	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	6.843** (0.035)	-.006* (0.002)			.205	.983^{NS} [0.890]	-4.631** [.000]	0.09
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	6.809** (0.060)	-.022^{NS} (0.023)			.003	.976^{NS} [.712]	-4.645** [(.000]	0.10
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	6.763** (.024)	-.062^{NS} (.102)			.022	.969^{NS} [.517]	-3.895** [.000]	0.10
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	6.674** (.036)	.026** (.005)	-.001** (.000)		.651	.947^{NS} [.139]	-.976^{NS} [.329]	0.06
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	6.561** (.042)	.066** (.012)	-.004** (.001)	6.9×10^{-5}** (.000)	.765	.960^{NS} [.307]	-.908^{NS} [.364]	0.05
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	6.843** (.035)	.999** (.000)			.207	.982^{NS} [.887]	-4.631** [.000]	0.09
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	6.809** (.061)	-.003^{NS} (.003)			.002	.976^{NS} [.717]	-4.645** [.000]	0.10
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	6.843** (.035)	.006* (.000)			.207	.983^{NS} [.890]	-4.631** [.000]	0.09

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 14. Fitted linear and non-linear models for production under coconut in Kerala for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test(z)	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	8.391** (.044)	.014** (.002)			.530	$.951^{NS}$ [.174]	-1.981* [.048]	0.11
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	8.186** (.053)	.172** (.020)			.714	$.960^{NS}$ [.304]	-1.282^{NS} [.200]	0.09
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	8.710** (.024)	-.712** (.102)			.623	$.961^{NS}$ [.325]	-1.603^{NS} [.109]	0.10
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	8.253** (.062)	.040** (.009)	-8.3×10^{-4} * (.000)		.629	$.972^{NS}$ [.604]	-2.675** [.007]	0.10
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	8.058** (.071)	.110** (.019)	-.006** (.001)	$1.\times10^{-4}$** (.000)	.756	$.926^{NS}$ [.139]	-1.301^{NS} [.193]	0.08
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	8.390** (.044)	1.002** (.000)			.528	$.950^{NS}$ [.171]	-1.981* [.048]	0.11
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	8.190** (.050)	.020** (.002)			.719	$.959^{NS}$ [.291]	-1.282^{NS} [.200]	0.09
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	8.390** (.044)	.002** (.000)			.528	$.950^{NS}$ [.171]	-1.981* [.048]	0.11

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 15. Fitted linear and non-linear models for productivity under coconut in Kerala for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test(z)	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	8.455** (.025)	.020** (.001)			.874	.966^{NS} [.429]	-1.301^{NS} [.193]	0.07
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	8.285** (.054)	.194** (.021)			.750	.923* [.032]	-2.287* [.022]	0.09
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	8.855** (.032)	-.650** (.139)			.417	.925* [.035]	-4.642** [.000]	0.14
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	8.487** (.039)	.014* (.006)	1.9×10^{-4} ^{NS} (.000)		.874	.975^{NS} [.689]	-1.301^{NS} [.193]	0.06
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	8.404** (.052)	.044** (.014)	-.002^{NS} (.001)	5.0×10^{-5} * (.000)	.891	.946^{NS} [.131]	-1.301^{NS} [.193]	0.06
6	**Compound** $Y = b_0 b_1^{t} \varepsilon$	8.459** (.024)	1.002** (.000)			.876	.970^{NS} [.536]	-1.301^{NS} [.193]	0.07
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	8.294** (.050)	.022** (.002)			.760	.922* [.030]	-2.287* [.022]	0.09
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	8.459** (.024)	.002** (.000)			.876	.970^{NS} [.536]	-1.301^{NS} [.193]	0.07

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

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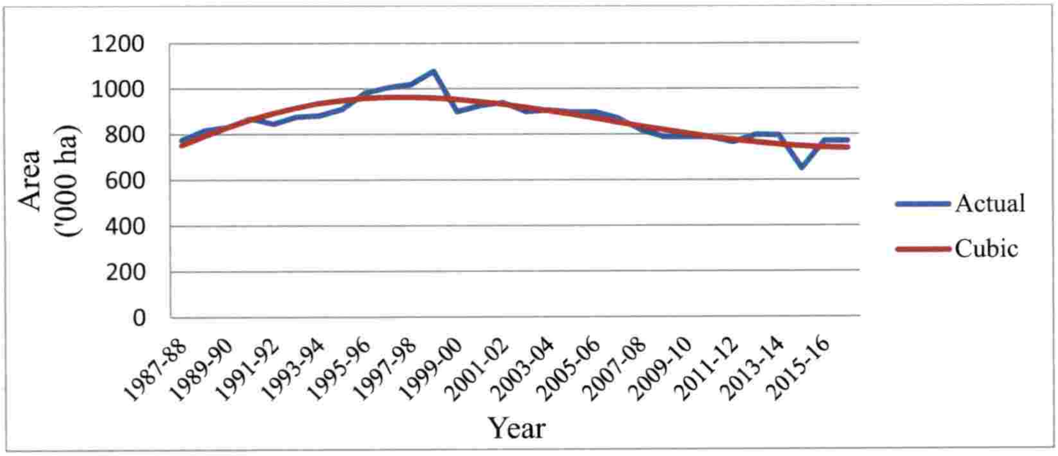

Figure 13. Actual and estimated trends in area under coconut in Kerala

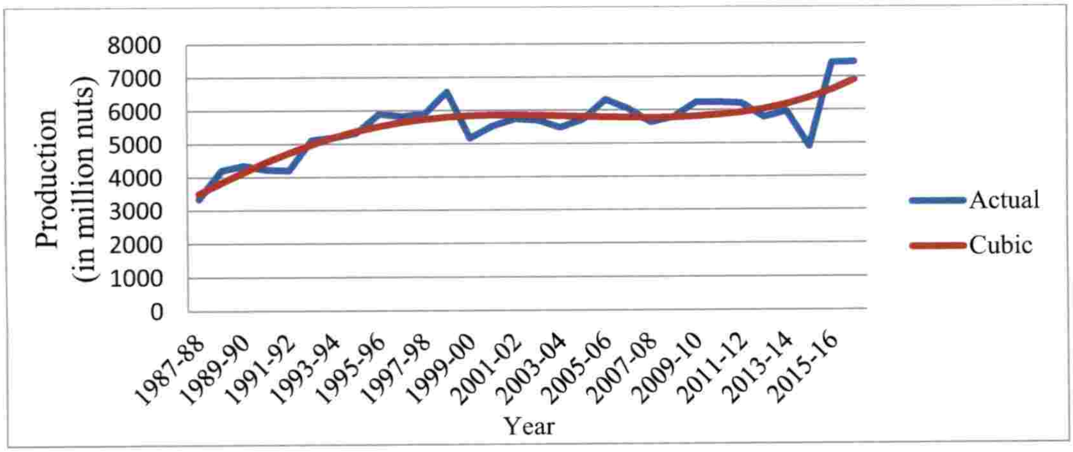

Figure 14. Actual and estimated trends in production of coconut in Kerala

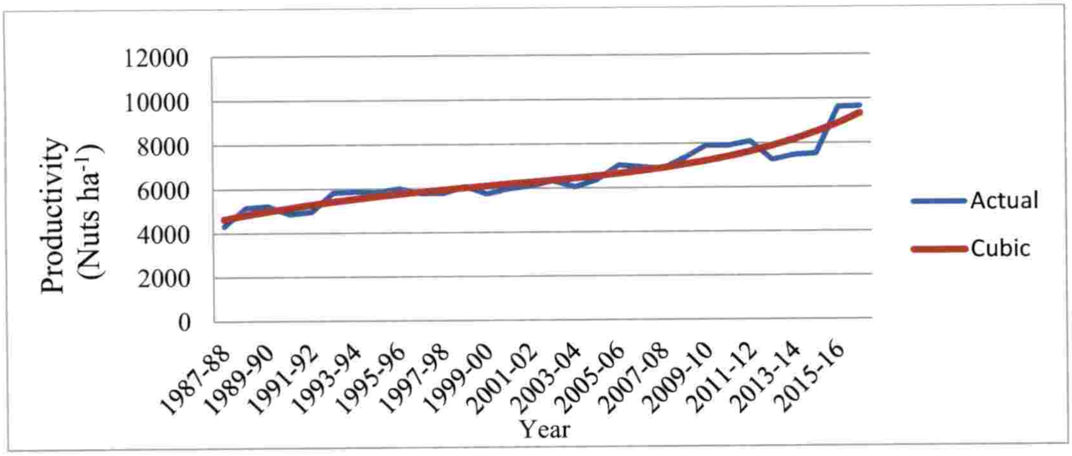

Figure 15. Actual and estimated trends in productivity of coconut in Kerala

4.1.2.3 Trends in area, production and productivity of coconut in Tamil Nadu

Area under coconut in Tamil Nadu shows positive growth pattern during the study period. All the fitted models for area under coconut in Tamil Nadu are presented in table.16. Adjusted R^2 values for the entire models ranges from 45.1 per cent for inverse model to 89.9 per cent for quadratic model with minimum RMSE of 0.08 and estimated regression coefficients were significant. According to Shapiro-Wilk test and Runs test the residuals of cubic model were found to be normal and random. The best model selected was quadratic model and its trend values are presented in Fig.16. The estimated quadratic model was

$$Y_t = 5.224+0.047t-5.29\times10^{-5}t^2 \quad (\text{Adj. } R^2=0.899)$$

Production of coconut in Tamil Nadu showed a positive growth pattern during the study period. All the fitted models for production of coconut in Tamil Nadu are presented in Table.17. Adjusted R^2 values for the entire models ranges from 44.5 per cent for inverse model to 79.4 per cent for cubic model with minimum RMSE of 0.18 and significant estimated regression coefficients. According to Shapiro-Wilk test and Runs test the residuals of cubic model were normal and random. The best model selected was cubic model and its trend values are presented in Fig.17. The estimated cubic model was

$$Y_t= 7.495+0.085t-.004t^2+8.07\times10^{-5}t^3 \quad (\text{Adj. } R^2=0.794)$$

Productivity of coconut in Tamil Nadu showed a positive growth pattern during the study period. All the fitted models for productivity of coconut in Tamil Nadu are presented in table.18. Adjusted R^2 values for the entire models ranges from 14.8 per cent for inverse model to 24.8 per cent for quadratic model with minimum RMSE of 0.18 and all the estimated regression coefficients of quadratic were significant. According to Shapiro-Wilk test and Runs test the residuals of cubic model were normal and random. The best model selected was quadratic model and its trend values are presented in Fig.18. The estimated equation was

$$Y_t=9.310-0.009t-0.001t^2 \quad (\text{Adj. } R^2=0.248)$$

Table 16. Fitted linear and non-linear models for area under coconut in Tamil Nadu for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test(z)	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	5.312** (0.036)	.030** (0.002)			0.886	.937 ^{NS} [0.075]	-1.603 ^{NS} [0.109]	0.09
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	5.024** (0.066)	.304** (0.025)			0.834	.928* [0.045]	-3.148** [0.002]	0.11
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	5.913** (0.047)	-1.001** (0.201)			0.451	.954 ^{NS} [0.221]	-4.645** [0.000]	0.20
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	5.224** (0.052)	.047** (0.008)	-5.3×10^{-4} ^{NS} (0.000)		0.899	.939 ^{NS} [0.085]	-1.655 ^{NS} [0.098]	0.08
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	5.182** (0.075)	.062* (0.021)	-.002 ^{NS} (0.000)	2.6×10^{-5} ^{NS} (0.000)	0.898	.925* [0.036]	-1.224 ^{NS} [0.221]	0.08
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	5.320** (0.035)	1.005** (0.000)			0.875	.949 ^{NS} [0.161]	-1.603 ^{NS} [0.109]	0.09
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	5.054** (0.058)	.053** (0.004)			0.835	.914* [0.019]	-3.159** [0.002]	0.11
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	5.320** (0.035)	.005** (0.000)			0.875	.949 ^{NS} [0.161]	-1.603 ^{NS} [0.109]	0.09

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 17. Fitted linear and non-linear models for production under coconut in Tamil Nadu for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	**b_1**	**b_2**	**b_3**	**Adj. R^2**	**Shapiro-wilk test**	**Runs test(z)**	**RMSE**
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	7.599** (0.070)	.043** (0.004)			0.793	.965 ^{NS} [0.407]	-3.117 ^{NS} [0.072]	0.18
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.211** (0.125)	.421** (0.048)			0.726	.923* [0.032]	-2.180* [0.029]	0.21
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	8.455** (0.069)	-1.474** (0.299)			0.445	.896** [0.007]	-3.895* [0.015]	0.30
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	7.627** (0.112)	.037* (0.017)	1.7×10^{-4} ^{NS} (0.001)		0.791	.969 ^{NS} [0.502]	-3.838 ^{NS} [0.123]	0.18
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	7.495** (0.158)	.085* (0.043)	-.004* (0.003)	8.1×10^{-5} ^{NS} (0.000)	0.794	.978 ^{NS} [0.771]	-3.838 ^{NS} [0.118]	0.18
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	7.614** (0.066)	1.005** (0.000)			0.793	.967 ^{NS} [0.467]	-3.838 ^{NS} [0.072]	0.18
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	7.253** (0.108)	.052** (0.006)			0.739	.923* [0.032]	-2.180* [0.029]	0.21
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	7.614** (0.066)	.005** (0.000)			0.739	.967 ^{NS} [0.467]	-3.838 ^{NS} [0.072]	0.18

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

Table 18. Fitted linear and non-linear models for productivity under coconut in Tamil Nadu for 1987-2017

	Models	Regression coefficients				Goodness of fit			
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Runs test(z)	RMSE
1	**Log-Linear/ semi-log** $\ln Y = b_0 + b_1(t) + \varepsilon$	9.196** (0.071)	.012** (0.004			0.226	.942 ^{NS} [0.106]	-3.063** [0.002]	0.18
2	**Double logarithmic** $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	9.095** (0.112)	.118** (0.043)			0.185	.928* [0.042]	-4.226** [0.000]	0.19
3	**Inverse** $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	9.451** (0.045)	-.474** (0.192)			0.148	.917* [0.022]	-3.117** [0.002]	0.19
4	**Quadratic** $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	9.310** (0.110)	-.009** (0.016)	.001* (0.001)		0.248	.963 ^{NS} [0.370]	-3.063 ^{NS} [0.072]	0.18
5	**Cubic** $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	9.223** (0.158)	.022* (0.043)	-.002 ^{NS} (0.003)	5.4×10^{-5} ^{NS} (0.000)	0.237	.964 ^{NS} [0.382]	-3.117 ^{NS} [0.102]	0.18
6	**Compound** $Y = b_0 b_1^{\,t} \varepsilon$	9.196** (0.071)	1.001** (0.000)			0.222	.943 ^{NS} [0.107]	-3.063** [0.002]	0.18
7	**Power** $Y = b_0 t^{b_1} \varepsilon$	9.096** (0.110)	.013** (0.005)			0.183	.928* [0.043]	-4.226** [0.000]	0.19
8	**Exponential** $Y = b_0 e^{(b_1 t)}$	9.196** (0.071)	.001** (0.000)			0.222	.943 ^{NS} [0.107]	-3.063** [0.002]	0.18

[ ] indicates p-values, ( ) indicates standard error, ** significant at 1% level, * significant at 5% level, NS indicates non-significant

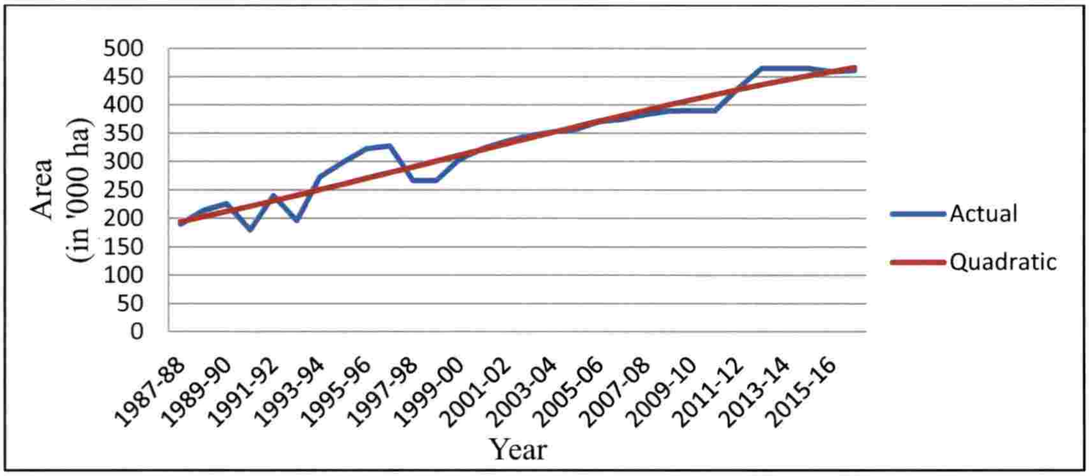

Figure 16. Actual and estimated trends in area under coconut in Tamil Nadu

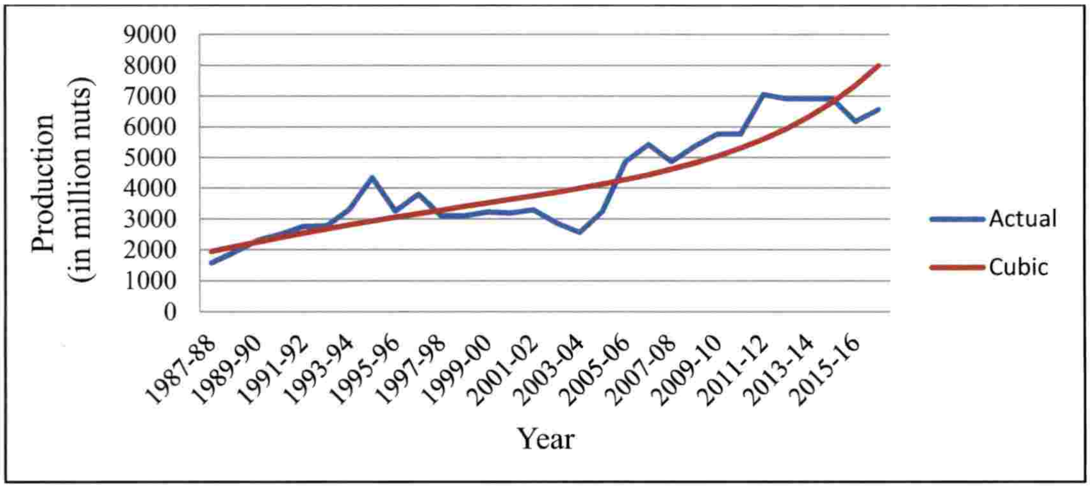

Figure 17. Actual and estimated trends in production of coconut in Tamil Nadu

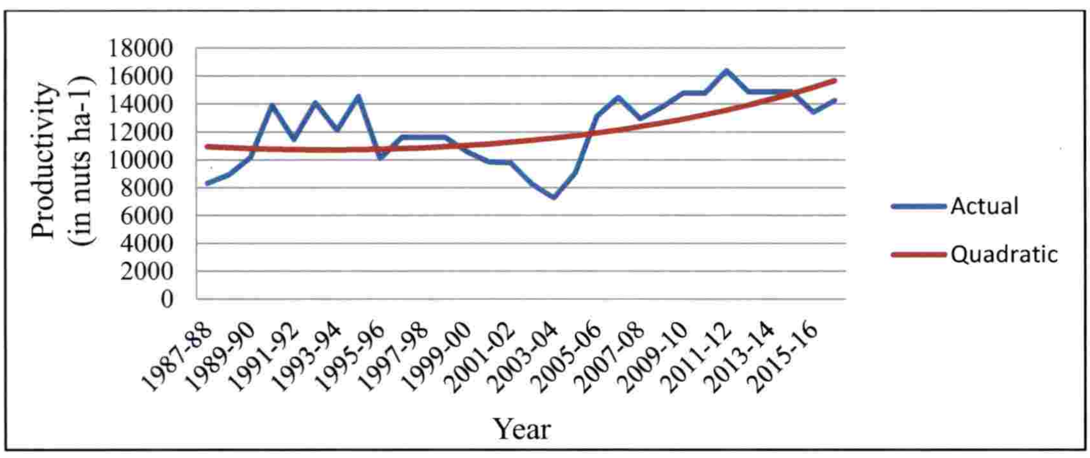

Figure 18. Actual and estimated trends in productivity of coconut in Tamil Nadu

4.2. GROWTH RATES IN AREA, PRODUCTION AND PRODUCTIVITY OF PADDY AND COCONUT CROP IN SOUTH INDIA

In this section, the compound growth rates of area, production and productivity of paddy and coconut crop in South India (Karnataka, Kerala and Tamil Nadu) were presented with relevant discussions.

4.2.1 Compound Annual Growth Rate of Paddy

In order to analyse the growth in area, production and productivity of paddy in Karnataka, Kerala, Tamil Nadu and India compound annual growth rates were estimated during the period of 1987 to 2017 (30 years). The growth rates of paddy were also estimated based on season wise (Kharif and Rabi) for area, production and productivity. The results are presented below with discussions.

4.2.1.1 Karnataka

It is evident from Table 19, the area under paddy in Karnataka was 1051 thousand ha in 1987-88 and it was 1034 thousand ha in 2016-17. The estimated CAGR (%) of area under paddy in kharif (0.1%), rabi (0.3%) and total area (0.2%) in Karnataka was positive but not significant. However, the production has increased from 1909 thousand tonnes in 1987-88 to 2604 thousand tonnes in 2016-17 with a positive and significant growth rate of 1.1 per cent. Similarly production of paddy in kharif showed a significant positive growth rate. The growth rate in rabi production was positive but not significant. The productivity of paddy in Karnataka during 1987-88 was 1816 Kg ha^{-1} and 2519 Kg ha^{-1} in 2016-17. The estimated CAGR were 1.1 per cent, 0.9 per cent and 1.0 per cent respectively for kharif, rabi and total productivity in Karnataka. This positive and significant growth rate in productivity indicates that improvement in adoption of high yielding varieties, introduction of machineries in paddy cultivation and better management practices by the farmers. According to Kannan (2011) cost structure of paddy in Karnataka showed a negative growth with the introduction of new technologies, machinery and good management practices.

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Table 19. Area, production and productivity of paddy in Karnataka along with CAGR(%) (1987-2017)

Year	**Kharif**			**Rabi**			**Total**		
	Area ('000 ha)	**Production ('000 Tons)**	**Productivity (Kg ha^{-1})**	**Area ('000 ha)**	**Production ('000 Tons)**	**Productivity (Kg ha^{-1})**	**Area ('000 ha)**	**Production ('000 Tons)**	**Productivity (Kg ha^{-1})**
1987-88	949	1643	1731	102	144	1412	1051	1909	1816
1990-91	977	1906	1951	197	509	2584	1173	2415	2059
1995-96	1009	2318	2297	257	706	2747	1265	3024	2390
2000-01	1121	2793	2492	363	1054	2904	1483	3847	2593
2005-06	1076	3935	3657	409	1809	4423	1485	5744	3868
2010-11	1130	3057	2705	410	1131	2759	1540	4188	2719
2015-16	977	2642	2704	133	379	2850	1110	3021	2722
2016-17	942	2343	2487	92	262	2848	1034	2604	2519
CAGR (%)	0.1^{NS}	1.2**	1.1**	0.3^{NS}	1.4^{NS}	0.9*	0.2^{NS}	1.1*	1.0**

**- significant at 1% level of significance *- significant at 5% level of significance NS- not significant

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4.2.1.2 Kerala

From Table.20, area and production of paddy in Kerala exposed a negative trend and it was found significant at 1per cent level of significance. The area under paddy during 1987-88 was 604 thousand hectares and 171 thousand hectares during 2016-17 periods. The estimated CAGR (%) were -5.1 per cent, -1.9 per cent and -4.5 per cent respectively for kharif, rabi and total area under paddy in Kerala. The production of paddy during 1987-88 was 1039 thousand tonnes and 437 thousand tonnes during 2016-17 periods. Similarly, the production of paddy in Kerala has also showing the negative and significant CAGR (%) whereas productivity of paddy showing a positive and significant CAGR (%). Productivity of paddy in Kerala was increased over the period of time may be due to the introduction of high yielding variety (HYV) and improved cultivation practices. The estimated CAGR were 1.8 per cent. 1.1 per cent and 1.5 per cent respectively for kharif, rabi and total productivity of paddy in Kerala.

In Kerala, area and production under paddy was decreased over the period 1987 to 2017 period due to shortage in agricultural labour, expense involved in purchasing of agricultural inputs (fertilizers, seeds, etc.,), low level of profitability as compared to plantation crops (Rubber and Coconut), competition from other crops (rubber, coconut, banana) and agricultural land become a speculative asset. Similar kind of results was given by Kannan (2011), Krishnadas (2009) and Thomas (2011). According (NSSO, 2006) data from the National Sample Survey, 35.5 per cent of Kerala workers were engaged with agriculture, fisheries and forestry while the Indian average was 56.5 per cent during 2004-05.

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Table 20. Area, production and productivity of paddy in Kerala along with CAGR(%) (1987-2017)

Year	**Kharif**			**Rabi**			**Total**		
	Area ('000 ha)	**Production ('000 Tons)**	**Productivity (Kg ha^{-1})**	**Area ('000 ha)**	**Production ('000 Tons)**	**Productivity (Kg ha^{-1})**	**Area ('000 ha)**	**Production ('000 Tons)**	**Productivity (Kg ha^{-1})**
1987-88	534	895	1676	70	155	2184	604	1039	1720
1990-91	495	944	1907	65	143	2200	559	1087	1945
1995-96	411	802	1952	60	151	2517	471	953	2023
2000-01	292	597	2042	55	155	2796	348	751	2162
2005-06	254	570	2246	22	60	2726	276	627	2273
2010-11	162	385	2377	51	137	2691	213	522	2452
2015-16	151	407	4698	46	143	3094	197	549	2790
2016-17	132	324	2451	39	114	2883	171	437	2550
CAGR (%)	-5.1**	-3.7**	1.8**	-1.9**	-0.9^{NS}	1.1**	-4.5**	-3.0**	1.5**

**- significant at 1% level of significance *- significant at 5% level of significance NS- not significant

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4.2.1.3 Tamil Nadu

From Table.21 area and production of paddy in Tamil Nadu showing the negative trend but productivity showing positive trend during 1987-17. The area under paddy during 1987-88 was 2012 thousand hectares and 1443 thousand hectares during 2016-17 periods. Area and production during rabi season over the period showing a negative CAGR (%) of -3.4 per cent and -2.7 per cent respectively which was significant at 1 per cent level of significance. Total area under paddy in Tamil Nadu showed a negative and significant CAGR (%) of -0.7 per cent at 5 per cent level of significance. In kharif season, area and production showing a negative and non-significant growth rate during the study period. Northeast monsoon was worst in Tamil Nadu, where rainfall for the season was 62 per cent short of normal rainfall during 2016-17. Due to shortage of rainfall area under rice was dropped to 33 per cent in 2016-17.

From Fig. 19, 20 and 21, area and production of paddy in Karnataka have shown an increasing growth rate in kharif, rabi seasons as well as overall whereas, Kerala and Tamil Nadu have shown a negative growth in area production during the study period (1987-2017). In case of productivity, all the three states showed a positive compound annual growth rate during the study period. Among all three states growth in productivity of paddy was more in Kerala in both season as compared to Karnataka and Tamil Nadu.

Table 21. Area, production and productivity of paddy in Tamil Nadu along with CAGR (%) (1987-2017)

Year	Kharif			Rabi			Total		
	Area ('000 ha)	Production ('000 Tons)	Productivity (Kg ha^{-1})	Area ('000 ha)	Production ('000 Tons)	Productivity (Kg ha^{-1})	Area ('000 ha)	Production ('000 Tons)	Productivity (Kg ha^{-1})
1987-88	1394	3825	2744	617	1779	2883	2012	5604	2785
1990-91	1520	4700	3092	336	1082	3220	1856	5782	3115
1995-96	1766	4722	2674	185	568	3070	1951	5290	2712
2000-01	1885	6680	3545	195	686	3518	2084	7366	3535
2005-06	1875	4657	2483	175	563	3216	2050	5220	2546
2010-11	1743	5168	2965	163	625	3838	1906	5792	3040
2015-16	1829	6707	3666	171	810	4745	2000	7517	3758
2016-17	1313	2114	1610	130	255	1967	1443	2375	1642
CAGR (%)	-0.4^{NS}	-0.1^{NS}	1.3^{NS}	-3.4**	-2.7**	0.7*	-0.7*	-0.3^{NS}	0.2^{NS}

**- significant at 1% level of significance *- significant at 5% level of significance NS- not significant

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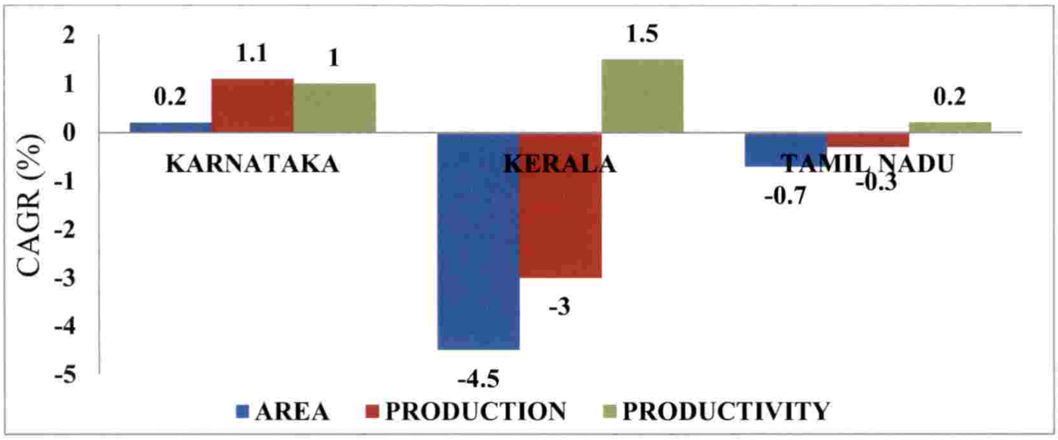

Figure 19. CAGR of Area, Production and Productivity of paddy in Karnataka, Kerala and Tamil Nadu (1987-2017)

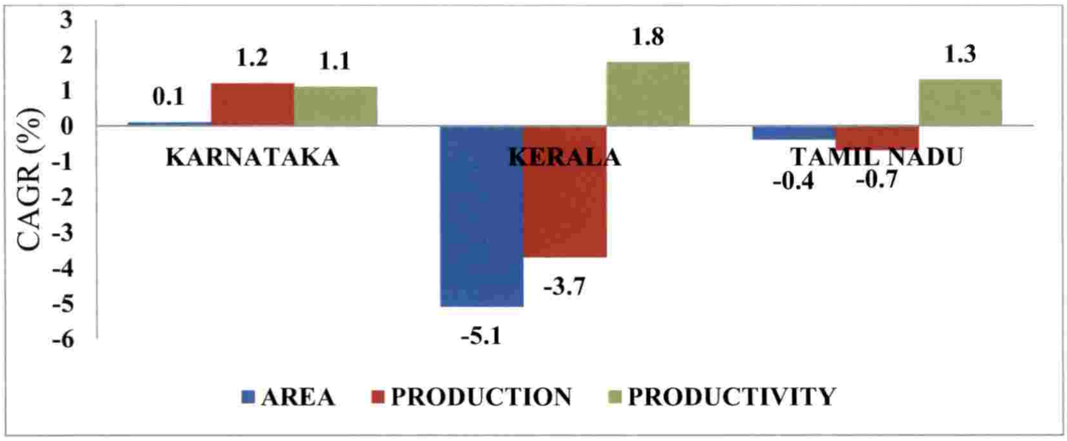

Figure 20. CAGR of area, production and productivity of paddy during kharif season in Karnataka, Kerala and Tamil Nadu (1987-2017)

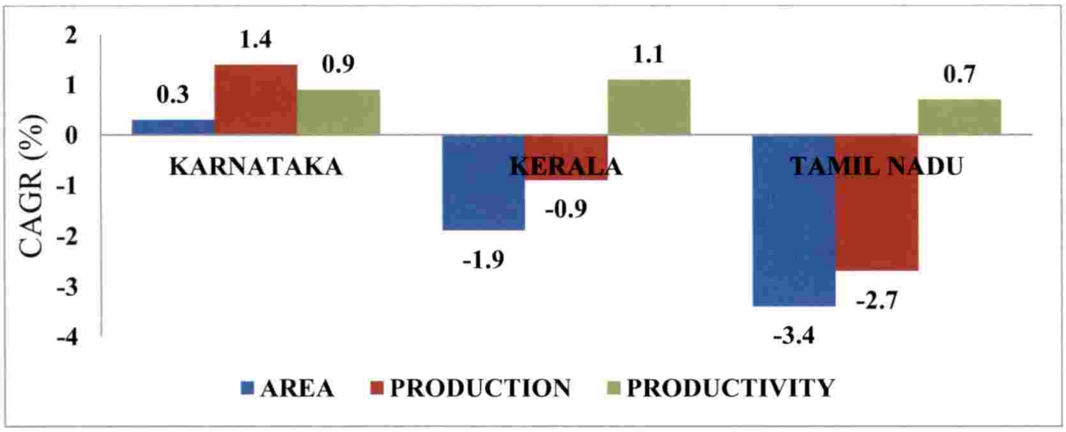

Figure 21. CAGR of area, production and productivity of paddy during rabi season in Karnataka, Kerala and Tamil Nadu (1987-2017)

4.2.2 Compound Annual Growth Rate of Coconut

In order to compare the changes in area, production and productivity of coconut in Karnataka, Kerala and Tamil Nadu during the period 1987-88 to 2016-17 compound annual growth rates were estimated and presented below with discussions.

4.2.2.1 Karnataka

From Table.22 area under coconut during 1987-88 was 213 thousand hectares and 171 thousand hectares during 2016-17. Area under coconut in Karnataka has shown a positive and significant CAGR (%) of 3.3 per cent at 1 per cent level of significance during the study period 1987-2017.

Table 22. Area, production and productivity of coconut in Karnataka along with CAGR(%) (1987-2017)

Year	Area (in '000 ha)	Production (in million nuts)	Productivity (in nuts ha^{-1})
1987-88	213	1097	5145
1990-91	232	1199	5160
1995-96	279	1451	5204
2000-01	334	1754	5255
2005-06	385	1210	3139
2010-11	419	2340	5584
2015-16	526	5129	9744
2016-17	514	6773	13181
CAGR (%)	3.3**	5.4**	2.2*

*- significance at 5%　　　**- significance at 1%

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Similarly, the production (5.4%) and productivity (2.2%) of coconut also showed a positive growth rate. According to Acharya et al., (2012) growth rate of coconut area and production (1.95 per cent per year) in Karnataka was increased positively during 1982-2008.

4.2.2.2 Kerala

From Table.23 the area under of coconut in Kerala during 1987-88 was 213 thousand hectares and 171 thousand hectares during 2016-17 periods. The production and productivity of coconut in Kerala showing positive and significant CAGR(%) of 1.4 per cent and 2.0 per cent at 1 per cent level of significance during the study period of 1987-2017. However, area under coconut in Kerala has shown a negative and significant growth rate of -0.6 per cent during the study period.

Table 23. Area, production and productivity of coconut in Kerala along with CAGR(%) (1987-2017)

Year	**Area (in '000 ha)**	**Production (in million nuts)**	**Productivity (in nuts ha^{-1})**
1987-88	775	3346	4315
1990-91	870	4231	4863
1995-96	982	5908	6016
2000-01	925.8	5536	5980
2005-06	897.8	6326	7046
2010-11	788	6239.5	7918
2015-16	770.62	7429.39	9641
2016-17	770.79	7448.65	9664
CAGR (%)	-0.6*	1.4**	2.0**

*- significance at 5%   **- significance at 1%

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According to Preethi *et al.* (2018) growth rate in area under coconut was decreased during 1996-2015 in Kerala. Similarly, Thamban *et al.* (2016) who reported that lower growth in area during the period from 2000-01 to 2013-14, with a compound growth rate of -0.96 per cent and revealed that productivity effect had greater role in coconut production compared to area in Kerala.

4.2.2.3 Tamil Nadu

From Table.24 area, production and productivity of coconut in Tamil Nadu showing a positive trend during 1987-2017. The production of coconut in Tamil Nadu during 1987-88 was 1578 million nuts and 6571 million nuts during 2016-17 periods. The area, production and productivity of coconut in Tamil Nadu showing a positive and significant CAGR (%) of 3.0 per cent, 4.3 per cent and 1.2 per cent at 1 per cent level of significance respectively during the study period of 1987-2017.

Table 24. Area, production and productivity of coconut in Tamil Nadu along with CAGR(%) (1987-2017)

Year	Area (in '000 ha)	Production (in million nuts)	Productivity (in nuts ha^{-1})
1987-88	190	1578	8329
1990-91	180	2499	13921
1995-96	323	3258	10101
2000-01	324	3192	9867
2005-06	371	4867	13133
2010-11	390	5771	14796
2015-16	460	6171	13423
2016-17	461	6571	14251
CAGR (%)	3.0**	4.3**	1.2*

*- significance at 5% **- significance at 1%

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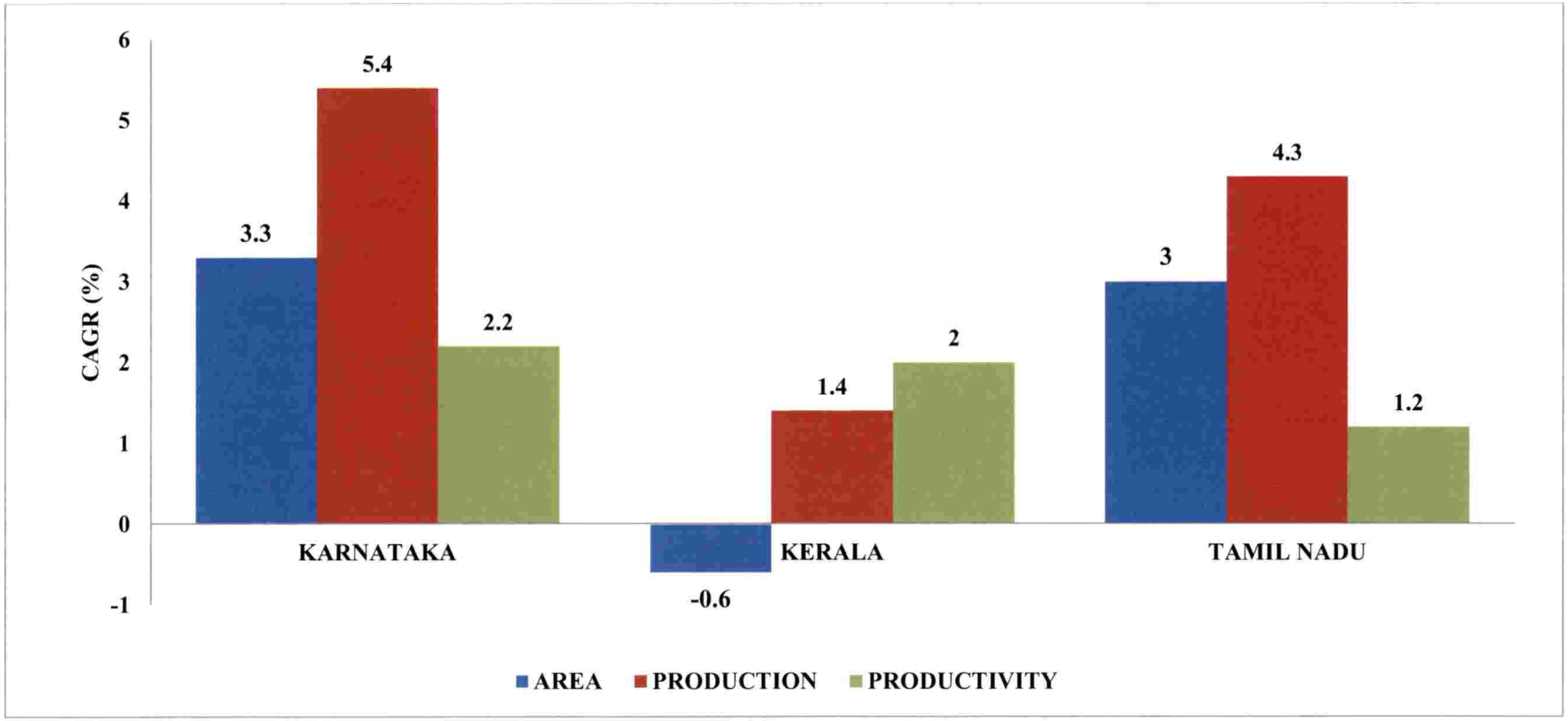

Figure 22. CAGR of area, production and productivity of coconut in Karnataka, Kerala and Tamil Nadu (1987-2017)

From Fig.22, it is evident that CAGR in area, production and productivity of coconut was positive in Karnataka and Tamil Nadu. Kerala showed a positive growth rate in production and productivity but area under coconut showed a negative growth rate during 1987-2017. During the study period area, production and productivity of coconut in Karnataka has increased more as compared to Kerala and Tamil Nadu.

4.3 PRICE MOVEMENT IN DIFFERENT MARKETS OF SOUTH INDIA

4.3.1 Price movement of paddy in Raichur and Thanjavur markets

Monthly wholesale prices of paddy markets in Raichur and Thanjavur for the period of January, 1993 to December, 2018 are presented in Table 25. A perusal of Table 29 reveals that average price during 1993 was varied from Rs.312 per quintal in Thanjavur to Rs. 353 per quintal in Raichur market. In 2018 average price varied from Rs.1570 Rs per quintal in Raichur market to Rs. 1798 per quintal in Thanjavur market. The average prices were found to be Rs.877 (Rs q^{-1}) in Raichur and Rs.828 (Rs q^{-1}) in Thanjavur. The standard deviation in price was found to be maximum (453.39) in Thanjavur market and minimum (417.87) in Raichur market from January, 1993 to December, 2018.

Table 25. Summary statistics of monthly wholesale price of paddy in Raichur and Thanjavur

MARKET	Average wholesale price (Rs per q)			Standard Deviation	CV (%)
	In 1993	In 2018	Mean		
THANJAVUR	312	1798	828	453.39	55
RAICHUR	353	1570	877	417.87	48

4.3.1.1 ADF test

The Augmented Dickey fuller test was done to check whether the price series of paddy in two markets were stationary or not. For testing stationarity of price series, the null hypothesis (H_0) of unit root against alternative hypothesis (H_1) of stationarity was framed. From Table.26, null hypothesis of non-stationarity was not rejected based on unit root test conducted for original price. It reveals that series were non stationary or presence of unit root in price of Raichur and Thanjavur markets. The null hypothesis of ADF test for all the price series after taking first difference was rejected at 5 per cent level of significance indicating that price series were free from impact of unit root. The result of ADF test for paddy revealed that original price were non stationary but their first difference were stationary which concluded that the price series were integrated of order 1 *i.e.,* I(1). This is appropriate to proceed with co-movement of market price using Johansen's co-integration test.

According to Myint (2010) and Ojo *et al.,* (2013) price of rice in different markets are not stationary at level but market price are stationary at order 1 *i.e.* I (1).

Table 26. Unit root test for monthly wholesale price of paddy markets

Market	At Level/First Difference	T-cal	Probability	Remark
THANJAVUR	Thanjavur (Yt)	-0.08	0.9643	Non-stationary
	Thanjavur (Δyt)	-9.10**	2.33e-16	Stationary
RAICHUR	RAICHUR (Yt)	-1.17	0.6909	Non-stationary
	RAICHUR (ΔYt)	-13.01**	5.57e-29	Stationary

** indicates significance of values at $p = 0.05$

4.3.1.2 Johansen co-integration test

In Johansen' co-integration test, finding the optimal lag length is very essential to check out the Gaussian distribution error terms. The optimal lag length of two (lag 2) was chosen using Akaike Information Criteria (AIC). The result of Johansen's co-integration relationship between selected paddy markets in

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Karnataka and Tamil Nadu are presented in Table 27. Johansen co-integration test provides two test statistic values: one based on trace and second one based on eigen values. The estimated trace test statistic value of 45.25 was greater than the critical value of 15.41 at 5 per cent level of significance. Similarly, the observed maximum eigen value test statistic (44.48) was also greater than estimated value (15.44) indicating that the null hypothesis (r=0) was rejected. This implies that there will be at least one co-integrating regression between the price in two markets viz., Thanjavur and Raichur market. It is evident from Table.27, both trace statistic and maximum eigen-value test statistic, the null hypothesis H_0: r =1 is accepted. Therefore, the results of Johansen's test suggested that there exist one cointegrating relationship between price in these two markets. This indicated that wholesale market price had long run equilibrium or co-movement in price among Raichur and Thanjavur markets during the study period.

Similar results were reported by Kumar and Sharma (2003) regarding price movement of rice in different markets in Haryana and Hossain and Verbeke (2010) on market integration of rice in Bangladesh using Johansen's method.

Table.27: Johansen co-integration test results for paddy markets

H_0	**H_1**	**Statistics**	**Critical value**	**Probability**
		Trace Statistics		
r=0	$r \geq 1$	45.25**	15.41	0.0159
$r \leq 1$	r = 2	0.77	3.76	0.9008
		Maximum Eigen-value test		
r= 0	$r \geq 1$	44.48 **	15.44	0.0088
$r \leq 1$	r = 2	0.77	3.76	0.9000

** indicates significance of values at p = 0.05

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4.3.1.3 Granger Causality test

Granger causality test was used to identify the direction of causation in price between the paddy markets. The result of pairwise Granger causality test statistic was given in Table.28. It revealed that there was a bidirectional influence on paddy price in Raichur and Thanjavur markets (Fig.28). So both market price are interdependent in the sense of price change in one market will affect the other market price. Similar type of results was obtained from Hossain and Verbeke (2010) while studying causality of rice markets in Bangladesh.

Table.28 Pairwise granger causality tests for paddy markets

Null hypothesis	**$\chi 2$ statistics**	**Prob.**	**Granger cause**	**Direction**
Raichur does not Granger cause Thanjavur	8.99*	0.011	Yes	Bidirectional
Thanjavur does not Granger cause Raichur	32.54**	0.000	Yes	

** → 1 % level of significance * → 5 % level of significance

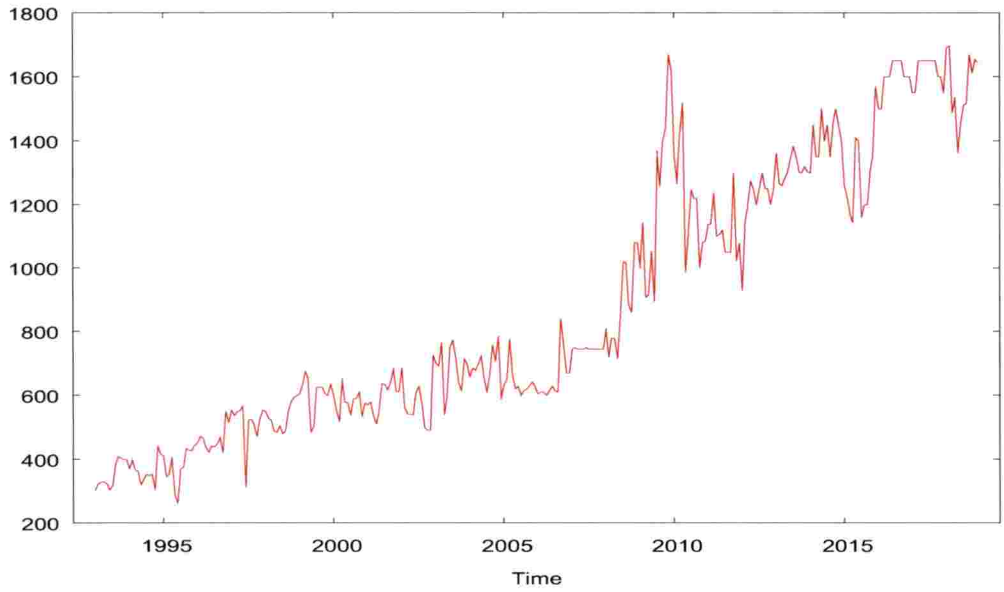

Figure 23. Trends in price of paddy in Raichur market

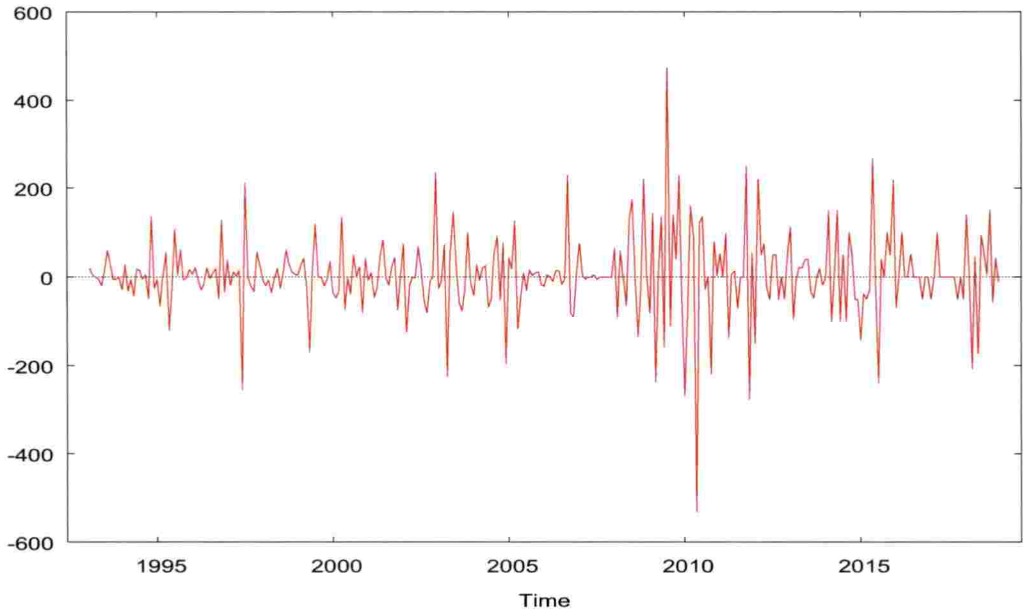

Figure 24. Trends in change in price of paddy in Raichur market (differenced series)

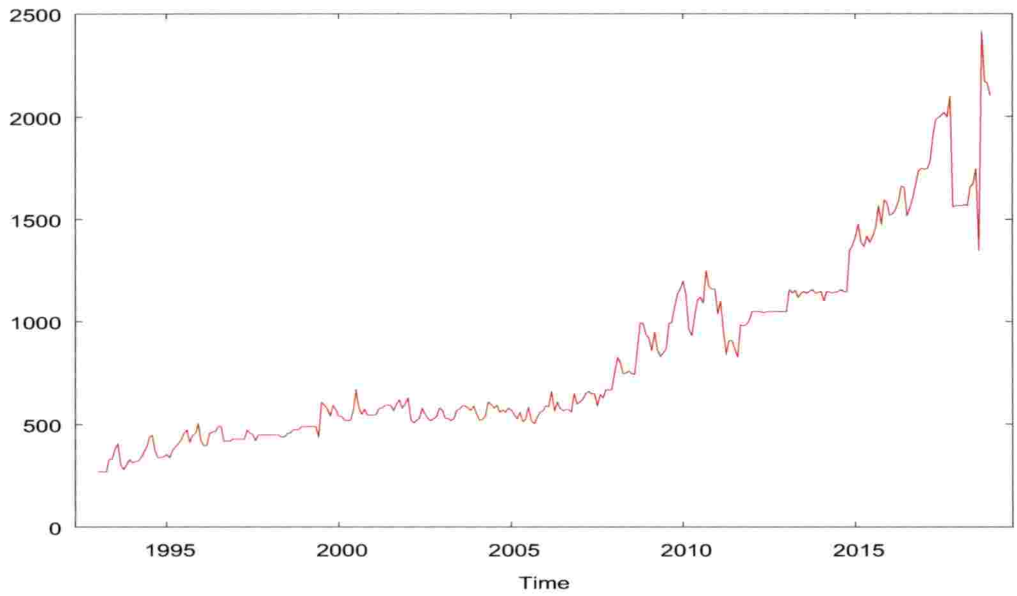

Figure 25. Trends in price of paddy in Thanjavur market

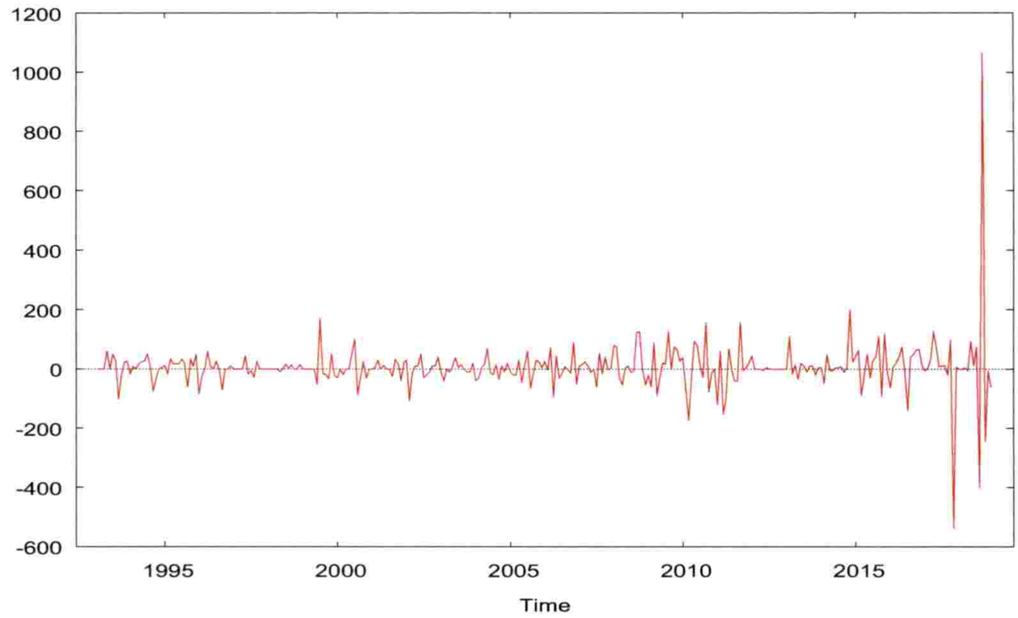

Figure 26. Trends in change in price of paddy in Thanjavur market (differenced series)

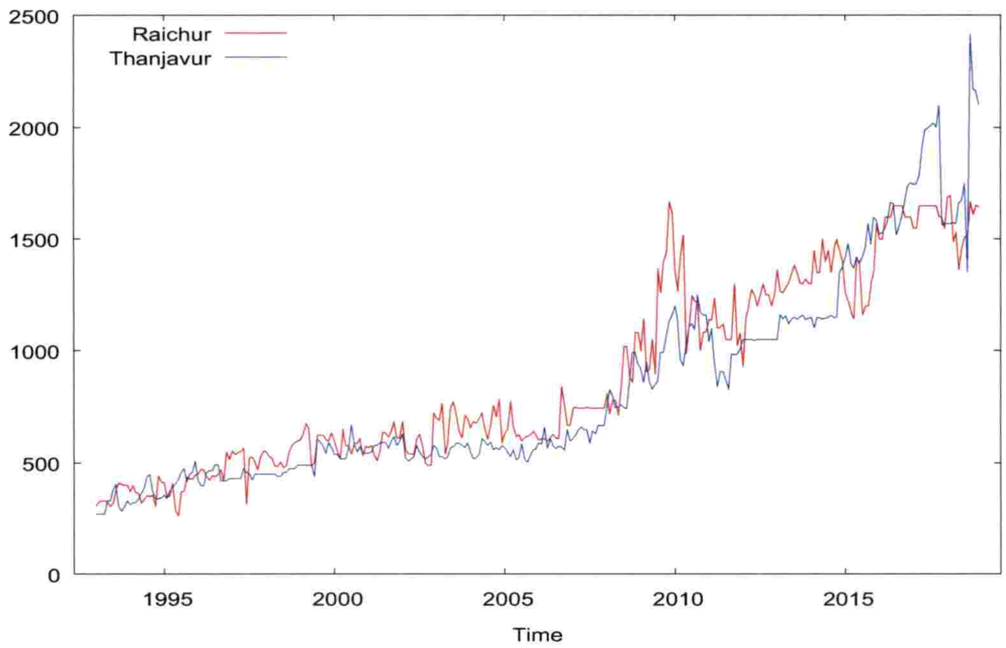

Figure 27. Trends in price of paddy in Raichur and Thanjavur markets

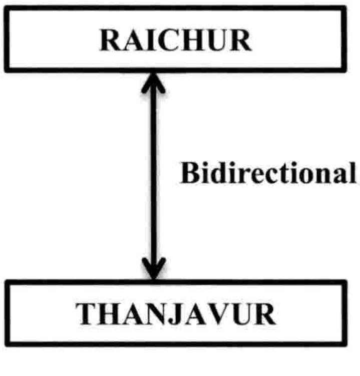

Figure 28. Granger causality direction between paddy markets in Raichur and Thanjavur

4.3.2 Price movement in coconut markets

To analyse the price movement of coconut in Kerala, Karnataka and Tamil Nadu the price of copra from Kochi market in Kerala, Tumkur market in Karnataka and Kangayam market in Tamil Nadu were used. Summary statistic regarding price in three markets are given in Table.29 and trends in price among the three markets were presented in Fig.25. A perusal of Table.29 reveals that the average price in 2000 varied from Rs. 2,324 per quintal in Kochi market to Rs. 2552 per quintal in Tumkur market, while average price in 2018 varied from Rs.10926 per quintal in Kangayam market to Rs.15750 per quintal in Tumkur market. The average price over the time was found to be Rs.4971 per quintal in Kangayam, Rs. 5220 per quintal in Kochi, Rs.7737 per quintal in Tumkur. The standard deviation in price was found to be maximum in the Tumkur wholesale market (4953) and minimum in Kangayam wholesale market (2622.4) from January, 2000 to December, 2018.

Table. 29. Summary statistics of monthly wholesale price of copra markets

Market	**Average wholesale price** (Rs per q)			**Standard Deviation**	**CV (%)**
	In 2000	**In 2018**	**Mean**		
KOCHI	2324	11810	5220	2868	55
KANGAYAM	2608	10926	4971	2622	53
TUMKUR	2552	15750	7737	4953	62

4.3.2.1 ADF test

The Augmented Dickey fuller test was done to check whether the price of copra in three markets were stationary or not. For testing stationarity of price series, the null hypothesis of non-stationarity against alternative hypothesis of stationarity was framed. From Table.30, null hypothesis of non-stationarity was not rejected for the unit root test conducted at level series of price. It reveals that the price series were non stationary or presence of unit root for price in all the markets. The null hypothesis of ADF test for all the price series after taking first difference was rejected at 5 per cent level of significance indicating that price series were free from the effect of unit root. The result of ADF test for copra revealed that price data in level were non stationary but their first difference were stationary which concluded that the price series were integrated of order 1 *i.e.,* I(1). This is appropriate to proceed with co-movement of market price using Johansen's co-integration test.

Similar result was obtained from Patil *et al.,* (2013) when studying about the market integration of arecanut. Reddy (2011) reported that, whole sale price of ground nut in India was stationary after differencing once and integrated of order 1 or I (1).

Table 30. Unit root test for monthly wholesale price of copra in Kochi, Kangayam and Tumkur markets

At level		
Market	**ADF**	**p-value**
Kochi	-1.58	0.49
Kangayam	-1.07	0.73
Tumkur	-1.73	0.42
After first difference		
Market	**ADF**	**p-value**
Kochi	-6.82**	0.00
Kangayam	-10.74**	0.00
Tumkur	-5.75**	0.00

** indicates significance of values at $p = 0.05$

4.3.2.2 Johansen co-integration test

In Johansen' co-integration test, identifying the optimal lag length is very essential to find out the Gaussian error terms. The optimal lag length of two (lag 2) was chosen using Akaike Information Criteria (AIC). The result of Johansen's co-integration relationship between selected copra markets in South India were presented in Table 31. Johansen co-integration test provides two test statistic values: one based on trace and second one based on eigen values. The observed trace value of 69.45 was greater that critical value of 29.68 at 5 per cent level of significance. Hence, we obtained at least one co-integrating equation. However, the null hypothesis $r \leq 1$ was accepted at 5 per cent level of significance identifying that there was at least one co-integration relationship between these three markets. Similarly in maximum eigen value test statistic, 57.42 was greater than critical value of 20.97. Hence, we obtained at least one co-integrating equations. This indicated that the wholesale market price had a long run equilibrium or co-movement among Kochi, Kangayam and Tumkur markets during the study period.

Table.31: Johansen co-integration test results for copra markets

H_0	H_1	Statistic	Critical Value	Prob.
Trace				
r=0	**r ≥1**	69.45**	29.68	0.00
r ≤ 1	**r ≥ 2**	12.03	15.41	0.16
r ≤ 2	**r = 3**	0.58	3.76	0.45
Maximum Eigen-value				
r=0	**r ≥1**	57.42**	20.97	0.00
r ≤ 1	**r ≥ 2**	11.45	14.07	0.13
r ≤ 2	**r =3**	0.58	3.76	0.45

** indicates significance of values at p = 0.05

Similar results were reported by Wani *et al., (2015)* in the study of market integration of apple in India and Patil *et al.,* (2013) while studying the market

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integration of different types of arecanut (White chali and Red boiled type) in Karnataka.

4.3.2.3 Granger causality test

Granger causality test was used to know the direction of price movement between the markets. The results of pairwise Granger causality explained in Table.32 revealed that there was a bidirectional influence of copra prices of Kochi and Kangayam markets. While, there was a unidirectional influence of price in Kochi and Tumkur markets and it was from Kochi to Tumkur markets (Fig.32).

Similar results were obtained from Makhare and Tarpara (2015) in a study on co-integration of cotton markets in Gujarat and *Singh et al.,* (2018) while studying the co-integration and causality of pigeon pea markets in Uttar Pradesh and Madhya Pradesh.

Table.32 Pairwise Granger causality tests for copra markets

Null hypothesis	**$\chi 2$ statistic**	**Prob.**	**Granger cause**	**Direction**
Kangayam does not Granger cause Kochi	15.10**	0.001	Yes	Bidirectional
Kochi does not Granger cause Kangayam	82.37**	0.000	Yes	
Tumkur does not Granger cause Kochi	2.32	0.314	No	Unidirectional
Kochi does not Granger cause Tumkur	9.45**	0.009	Yes	
Tumkur does not Granger cause Kangayam	4.36	0.113	No	None
Kangayam does not Granger cause Tumkur	2.50	0.287	No	

** indicates significance of values at p = 0.05

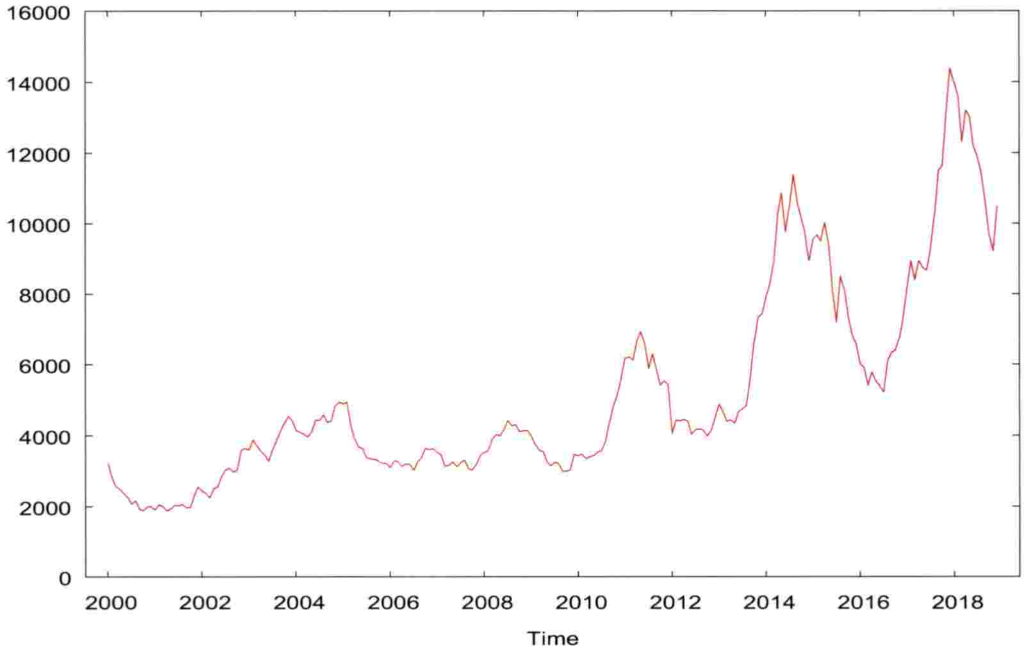

Figure 29. Trends in price of copra in Kochi market

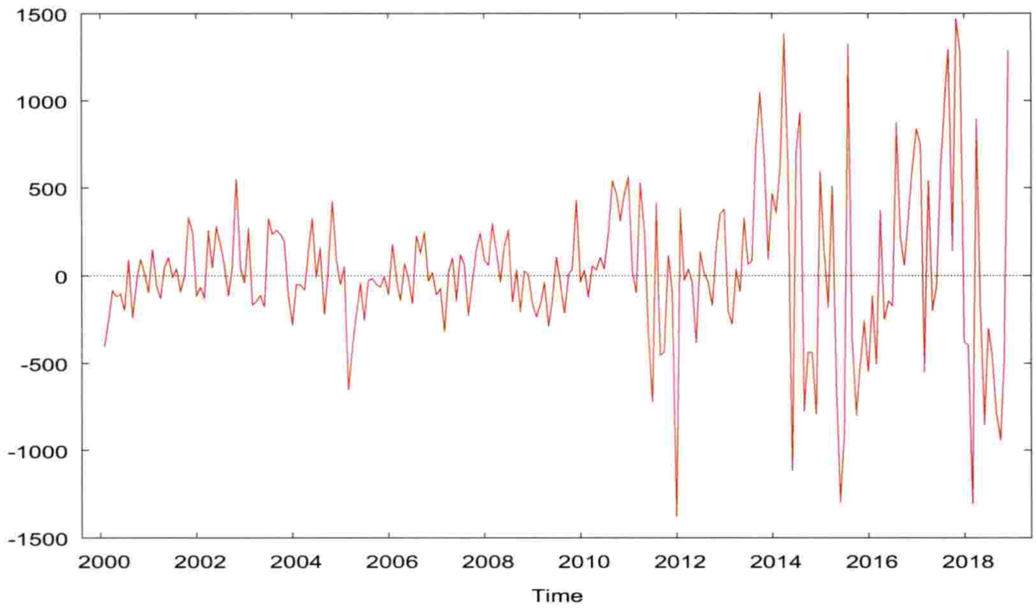

Figure 30. Trends in change in price of copra in Kochi market (differenced series)

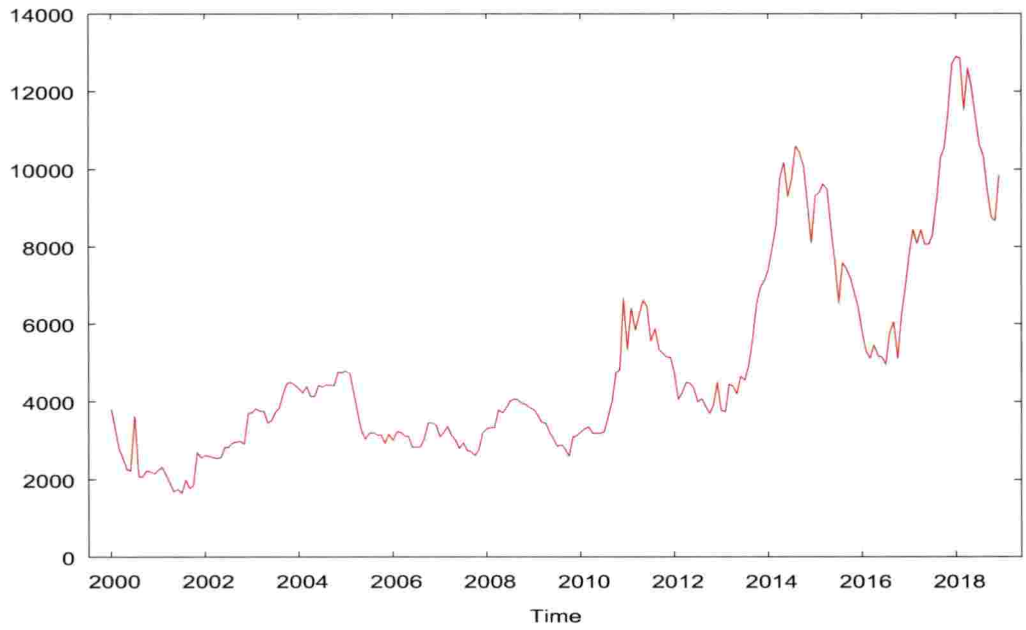

Figure 31. Trends in price of copra in Kangayam market

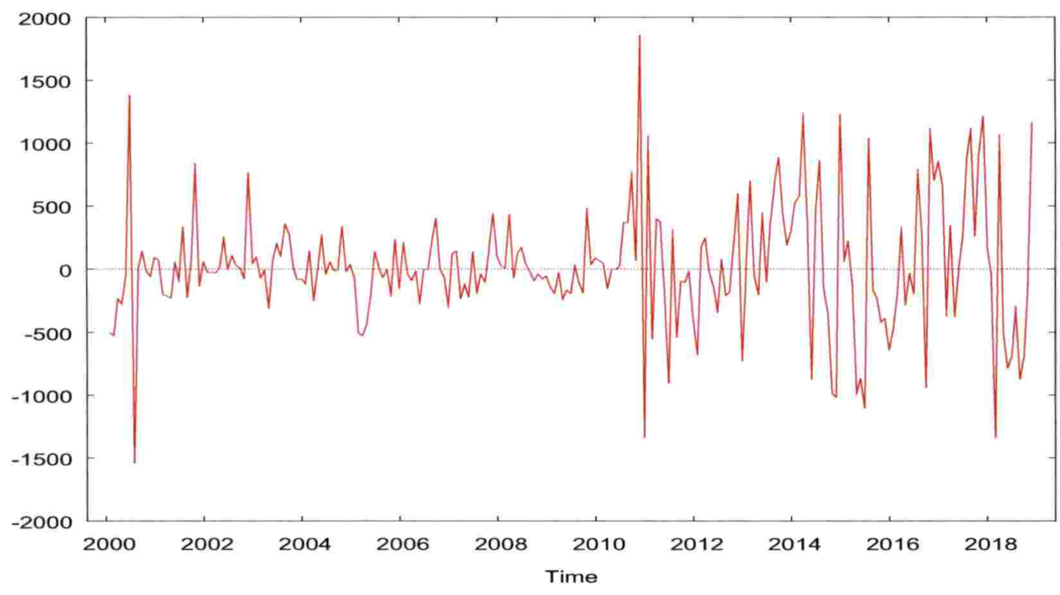

Figure 32. Trends in change in price of copra in Kangayam market (differenced series)

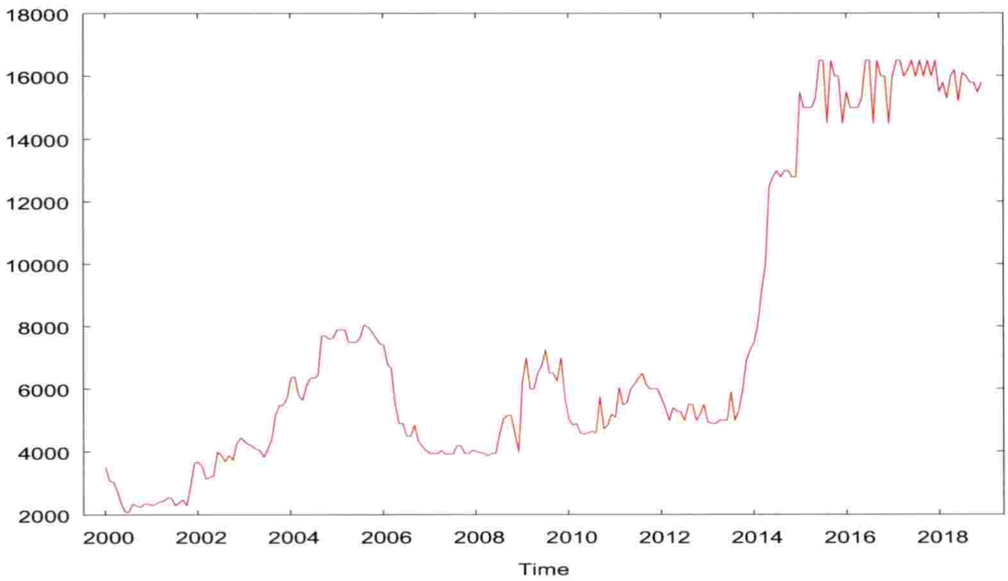

Figure 33. Trends in price of copra in Tumkur market

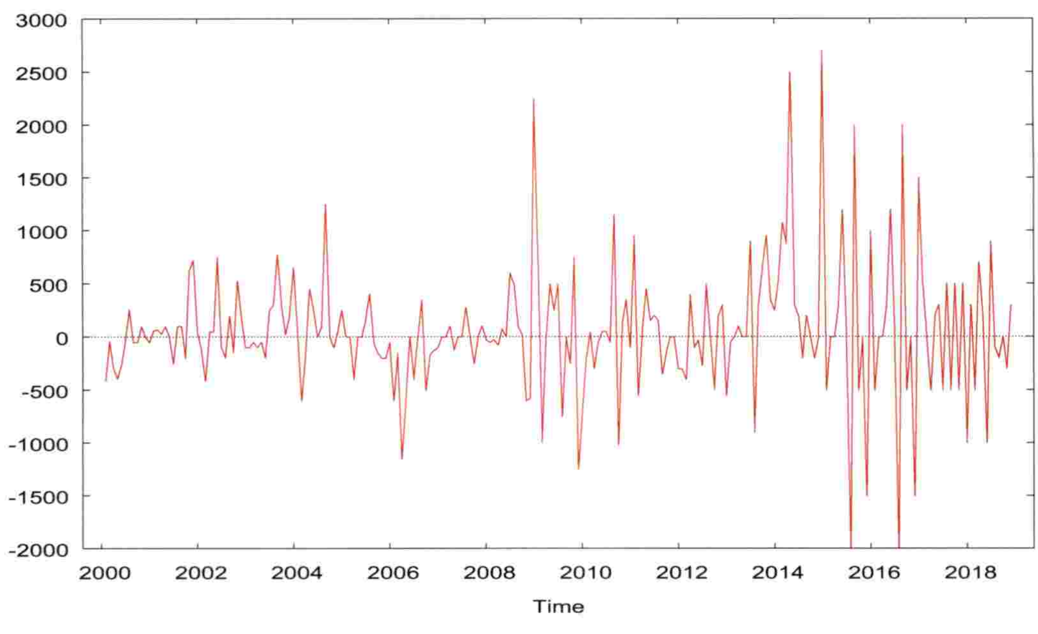

Figure 34. Trends in change in price of copra in Tumkur market (differenced series)

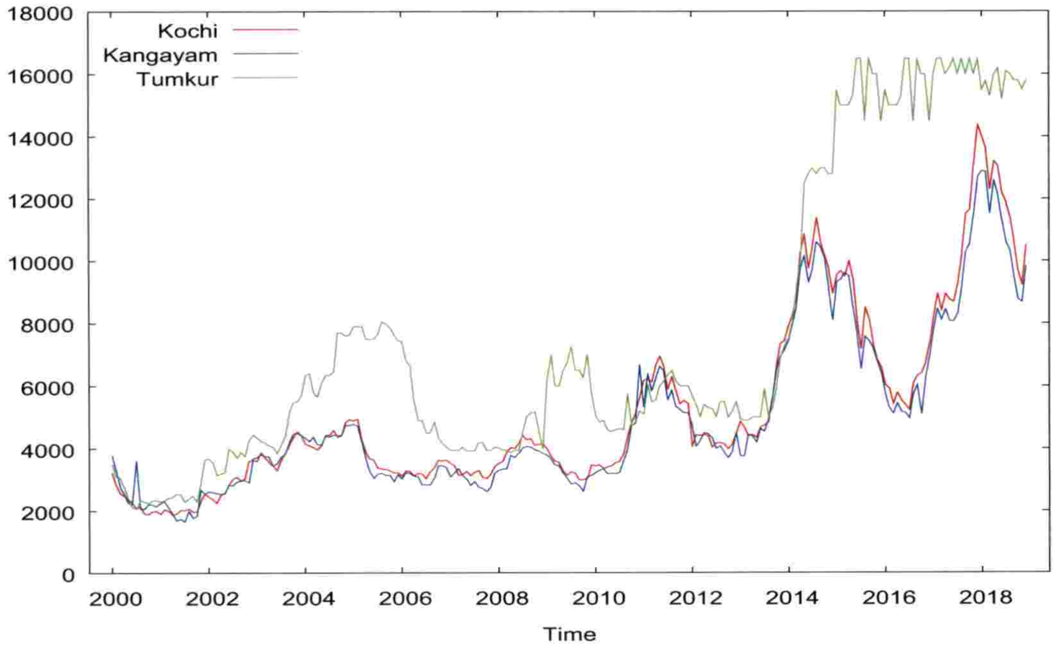

Figure 35. Trend in price of copra in Kochi, Kangayam and Tumkur markets

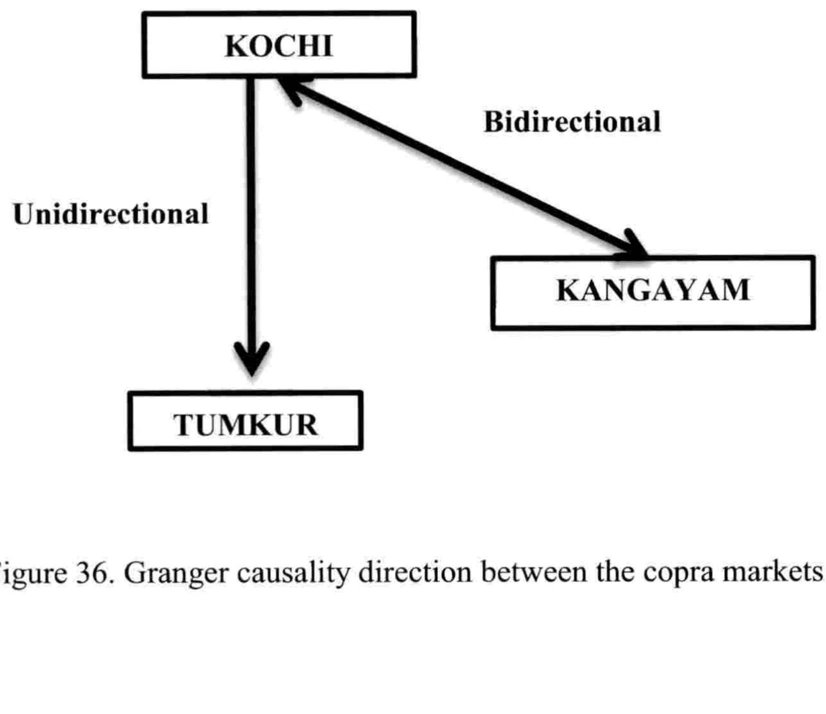

Figure 36. Granger causality direction between the copra markets

4.4 INFLUENCING FACTORS ON PRODUCTION OF PADDY AND COCONUT

4.4.1 Influencing factors on production of paddy

Production of a crop may be influenced by endogenous and exogenous factors. The endogenous factors are those which directly influencing the production of a crop but exogenous factors are outside to the production system viz., price, change in weather parameter etc. In this section, an attempt has been made to analyse the influencing of exogenous factors on production of paddy in Karnataka and Tamil Nadu using time series data on rainfall for the period 1987 to 2015. Annual rainfall data was divided into four sub-periods: representing Q_1 (January-March), Q_2 (April – June), Q_3 (July-September) and Q_4 (October-December). The summary statistics of quarterly rainfall is presented in Table.33.

The factors influencing on production of paddy was measured by panel data regression analysis by considering production of paddy in Karnataka and Tamil Nadu states together. Log value of the quarterly data on climatic variable such as rainfall for the period from 1987 to 2015 was taken as independent variable. Log value of production of paddy from 1987 to 2015 was taken as the dependent variable. Model specified as, production is a function of same year climatic condition. The present analysis is based on the data from Karnataka and Tamil Nadu, because there was a similarity in paddy cultivation in terms of varieties.

Panel data regression provides two models for estimating the parameters named as fixed effects and random effects model. Hausman t test was used to identify the appropriate model. If Hausman t test gave probability value of Chi square which was below 5 per cent indicate that we reject the null hypothesis suggesting of fixed effects model fits well to explain the influence of climatic factors on paddy production. A number of models were tried by incorporating climatic (rainfall) variables and the best model was presented here. The results of influencing factors of production on paddy and coconut are presented in Table 34 and 35.

Table 33. Summary statistics of rainfall in Karnataka, Kerala and Tamil Nadu

	Rainfall(mm)	Mean	Maximum	Minimum	SD	CV (%)
Kerala	Q_1	21.24	69.50	1.40	17.95	84.51
	Q_2	360.78	762.00	169.70	142.26	39.43
	Q_3	1917.30	2688.50	1347.20	379.62	19.80
	Q_4	489.30	823.30	166.60	138.63	28.33
Karnataka	Q_1	5.54	18.83	0.003	5.60	101.10
	Q_2	124.94	248.10	55.20	53.78	42.36
	Q_3	1420.0	1758.80	997.63	192.41	13.60
	Q_4	201.05	104.7	64.07	67.39	33.59
Tamil Nadu	Q_1	24.24	104.7	2.70	27.78	114.61
	Q_2	127.26	250.0	45.70	50.96	40.04
	Q_3	318.21	434.30	94.20	84.64	26.60
	Q_4	433.95	782.30	149.30	463.73	37.73

To check the multicollinearity of independent variables, VIF test was conducted and the values are represented in Table 34. VIF value ranges from 1.98 to 3.19 for fixed effect model. Hence, multicollinearity was not a serious problem among the independent variables included in this model. Test for autocorrelation was done with the help of Durbin – Watson test. Durbin-Watson value was 2.33 and hence it can be concluded that there is no autocorrelation in the function. R^2 value was 0.43 for the fixed effect model, indicating that 43 per cent of variation in the dependent variable was explained by the independent variables included in the panel regression function. Probability value for F test was 0.0001 indicating that model was significant.

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From Table 34 it was clear that only Q_3 (July to September) and Q_4 (October to December) rainfall had positive sign for the estimated paddy production and significant at 5 per cent level of significance. This indicates that increase in rainfall during this period resulted in increased production of paddy in Karnataka and Tamil Nadu. Q_3 and Q_4 are the two important paddy growing season in Karnataka (Q_3- Kharif season and Q_4- Rabi season) and Tamil Nadu (Q_3- Kuruvai/ Samba season and Q_4- Thaladi season).

Table 34. Results of Fixed effects model for 1986-2015

Sl. No.	Particulars	Coefficient	Standard error	p value	VIF
1	Intercept	5.92	0.49	0.000	-
2	Q_1 Rainfall (Jan-Mar)	0.02	0.02	0.332	1.98
3	Q_2 Rainfall (Apr-June)	0.12	0.07	0.111	3.19
4	Q_3 Rainfall (July-Sept)	0.15*	0.06	0.026	1.99
5	Q_4 Rainfall (Oct-Dec)	0.16*	0.06	0.019	1.99
6	Calculated F	18.99			
7	R^2	0.431			
8	Prob>F	0.0001			
9	No. of observations	60			
10	No. of groups	2			
11	Observations per group	30			

* Significant at 5 per cent level Note: The coefficients are obtained with log values

Similar findings were found by Kiran (2016), reported that kharif rice production was positively correlated with July, August and September rainfall and rabi production was influenced by October, November and December rainfall. December rainfall was positively correlated with production of paddy in rabi.

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Kumar et al. (2004) reported that all India rice production and monsoon rainfall had a strong positive correlation. This study also reported that production had significant positive correlation with individual month rainfall from June to October.

4.4.2 Factors influencing production of coconut

The influencing factors on production of coconut were measured by panel data regression analysis for Karnataka, Kerala and Tamil Nadu states together. Log value of the quarterly data on climatic variable such as rainfall for the period from 1986 to 2015 was taken as independent variables. Log value of production of coconut from 1987 to 2016 was taken as the dependent variable. Model was specified as production is a function of previous year climatic condition. Results are represented in Table 35.

As similar to paddy production, rainfall was categorised into four viz., Q_1 (January-March), Q_2 (April – June), Q_3 (July-September) and Q_4 (October-December) and they are defined as independent variables. Logarithmic values of dependent and independent variables are used to estimate the coefficients.

To check the multicollinearity among independent variables, VIF test was conducted and the values are represented in Table 35. VIF value ranges from 1.16 to 6.94 for fixed effects model. Hence, multicollinearity was not a serious problem among the independent variables included in this model. Test for autocorrelation was done with the help of Durbin – Watson test. Durbin-Watson value was 2.36 and hence it can be concluded that autocorrelation is not a serious problem. R^2 value was 0.48 for the fixed effects model, indicating that 48 per cent of variation in the dependent variable was explained by independent variables included in the panel regression function. Probability value for F test was 0.0036 indicating that model was significant.

From Table 35, it was clear that only previous year rainfall during January to March (Q_1) and October to December (Q_4) rainfall were positive and significant at 5 per cent level of significance. This indicates that increase in rainfall during this period resulted in increased production of coconut in Karnataka, Kerala and Tamil Nadu states.

Table 35. Results of Fixed effects model for 1987-2016

Sl. No.	**Particulars**	**Coefficient**	**Standard error**	**p value**	**VIF**
1	Intercept	5.873	1.261	0.000	-
2	Q_1 Rainfall (Jan-Mar)	0.107*	0.042	0.013	1.16
3	Q_2 Rainfall (Apr-June)	-0.188	0.206	0.364	6.93
4	Q_3 Rainfall (July-Sept)	0.178	0.182	0.331	6.94
5	Q_4 Rainfall (Oct-Dec)	0.328*	0.127	0.012	1.30
6	Calculated F	5.98			
7	R^2	0.483			
8	Prob>F	0.0038			
9	No. of observations	90			
10	No. of groups	3			
11	Observations per group	30			

* Significant at 5 per cent level Note: The coefficients are obtained with log values

According to Peiris and Peris (1993), rainfall during 1969-1989 had a positive and significant influence on coconut productivity and Krishnakumar (2018), coconut productivity in Kerala will increase when heavy rain takes place.

Summary

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5. SUMMARY

Rice *(Oryza sativa L.)* is the second largest cereal produced in the world. Asia is the biggest rice producer and consumer, accounted for 90 per cent of world's production. Rice has shaped the culture, diets and economy of billions of people. India ranked first in area under rice cultivation in the world. Karnataka, Kerala and Tamil Nadu states contributed 7 per cent to total area and 8 per cent to total production in India (GOI,2017).

Coconut *(Cocos nucifera L.)* is the most useful palm tree in the world because every part of the tree is useful for human life in many purposes. Therefore, the coconut palm is affectionately called 'KALPAVRIKSHA' which means the tree of paradise. India ranked third in world coconut map next to the Philippines and Indonesia. India contributes about 17.54 per cent in area and 33.02 per cent in terms of production of coconut to the world. South Indian states *viz.*, Karnataka, Kerala and Tamil Nadu together accounted for 84 per cent of total area and 87 per cent of total production in India.

The research entitled "Time series modelling for comparative performance and influencing factors of production on paddy and coconut in South India" was conducted with the objective to develop statistical models on trend in area, production and productivity of paddy and coconut across Kerala, Karnataka and Tamil Nadu. The present study also focus to develop different statistical models for analysing the price movement of these crops across the states overtime and to develop models for analysing the influencing factors of production.

This research work is based on secondary data. The data pertaining to area, production, and productivity were collected from various publications of Directorate of Economics and Statistics (Govt. of Karnataka), Department of Economics and Statistics (Govt. of Tamil Nadu and Kerala) and Coconut Development Board (GOI) for the period 1987 to 2017. Meteorological data on rainfall for three states was collected from Indian Meteorological Department (GOI). The secondary data on price of paddy (1993-2018) from Thanjavur and Raichur markets and price of copra (2000-2018) from Kochi, Kangayam and Tumkur markets were also collected from indiastat.com and agmarknet.

Different linear and nonlinear models were estimated to understand the trends in area, production and productivity of paddy and coconut. Among the estimated models, best model was selected based on highest adjusted R^2, least RMSE, criteria of randomness and normality.

- In paddy, quadratic model was found to be the best fitted model for area and production in Karnataka, production and productivity in Kerala and area in Tamil Nadu.
- Cubic model was found to be the best model for area in Kerala, productivity in Tamil Nadu and power model for productivity in Karnataka and compound model for production in Tamil Nadu.
- In case of coconut, quadratic model was found to be the best fitted model for area, production and productivity in Karnataka and area and productivity in Tamil Nadu.
- Cubic model was found to be the best model for area, production and productivity of coconut in Kerala and production in Tamil Nadu.

The comparative performance in area, production and productivity of paddy and coconut in Kerala, Karnataka and Tamil Nadu for the period of 1987-2017 was done based on the compound annual growth rates.

- In Karnataka, CAGR for production of paddy in kharif (1.2 %) and total production (1.1%) had positive significant growth rate. Productivity of paddy in kharif (1.1%), rabi (0.9%) and total productivity (1.0%) had significant and positive growth rate suggests that productivity of paddy shows an increasing trend during the study period. Area under paddy in kharif (0.1%) and rabi (1.4%) had positive growth rate but it was not significant.

- CAGR of area under paddy in Kerala during kharif (-5.1%), rabi (-1.9%) season was negative and significant and the rate of decline in area was more in kharif as compared to rabi season. However, the productivity of paddy in kharif (1.8%) and rabi (1.1%) have shown positive and significant CAGR. Even if the productivity has shown an increasing trend, CAGR of production of paddy in kharif (-3.7%) and rabi was negative and it was significant.
- In Tamil Nadu, CAGR of area under paddy in kharif (-0.4%) and rabi (-3.4%) was negative and decline was more in rabi season. Production of paddy in rabi (-2.7%) showed a negative and significant growth rate. The growth rate of productivity of paddy in Kharif (1.3%) was more and significant as compared to rabi (0.7%) season.
- Area and production of paddy in Karnataka have shown an increasing growth rate in kharif and rabi season as well as overall. Whereas, Kerala and Tamil Nadu have shown a negative growth rate during the study period (1987-2017). In case of productivity, all three states showed a positive compound annual growth rate during the study period. Among all three states growth in paddy productivity was more in Kerala in both season as compared to Karnataka and Tamil Nadu.
- The estimated CAGR of area (3.3%), production (5.4%) and productivity (2.2%) of coconut in Karnataka have shown a positive and significant growth rate. Productivity of coconut in Karnataka increased from 5160 nuts per ha in 1990-91 to 13181 nuts per ha in 2016-17.
- However, the estimated CAGR of area (-0.6%) under coconut in Kerala was negative and significant at 5 per cent level of significance. Moreover, production (1.4%) and productivity (2.0%) have shown a positive and significant CAGR. In Kerala, productivity of coconut was increased 4863 in 1990-91 to 9664 nuts per ha in 2016-17.

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- The estimated CAGR of area (3.0%), production (4.3%) and productivity (1.2%) of coconut in Tamil Nadu have shown a positive and significant growth. In Tamil Nadu, productivity of coconut was increased from 13921 in 1990-91 to 14251 nut per ha in 2016-17. Even if the compound annual growth rate in Tamil Nadu (1.2%) was less as compared Kerala and Karnataka, average productivity (nuts per ha) was very high in Tamil Nadu.

Johansen's co-integration technique was used to understand the price movement of paddy and copra markets across the states. The co-integration of price paddy in Thanjavur (TN) and Raichur (Karnataka) markets was tested using monthly wholesale price. In case of copra, co-integration was done based on the price of copra in Kochi (Kerala), Tumkur (Karnataka) and Kangayam (TN). Granger Causality test was also applied to find the direction of causality from one market to another.

- Stationarity of all the price series of paddy in Thanjavur (TN) and Raichur (Karnataka) markets and price of copra in Kochi (Kerala), Kangayam (TN) and Tumkur (Karnataka) markets were tested using Augmented Dickey-Fuller(ADF) test and the results of the analysis suggested that all the price series were integrated of order one I(1).
- The result of Johansen's co-integration test revealed that monthly wholesale price of paddy in Thanjavur and Raichur markets were co-integrated. The result of Granger causality test revealed that there was a bidirectional influence of price in Thanjavur and Raichur markets of paddy.
- Similarly price of copra in Kochi (Kerala), Kangayam (TN) and Tumkur (Karnataka) markets was also co-integrated which means that price in different markets are moving together. The results of Granger causality test revealed that there was a bidirectional influence between Kochi and Kangayam market price and unidirectional influence on prices of Kochi to Tumkur markets.

Panel data regression analysis was done to identify the climatic factors that have influence on the production of paddy and coconut. In panel data, the production of paddy or coconut was taken as dependent variable and quarterly rainfall as independent variable.

- The effect of climatic factors on production of paddy was analysed using panel data regression with fixed effect model and result suggests that average rainfall during Q_3 (July – September) and Q_4 (October – December) had a positive and significant effect on production.
- In case of coconut, one year lagged average rainfall during Q_{1t-1} (January - March) and Q_{4t-1} (October – December) had a positive and significant influence on production.

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TIME SERIES MODELLING FOR COMPARATIVE PERFORMANCE AND INFLUENCING FACTORS OF PRODUCTION ON PADDY AND COCONUT IN SOUTH INDIA

By

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ABSTRACT

The research entitled "Time Series modelling for comparative performance and influencing factors of production on paddy and coconut in South India" was conducted with the objective of developing statistical models on trend in area, production and productivity of paddy and coconut across Kerala, Karnataka and Tamil Nadu and to develop different statistical models for analysing the price movement of these crops across the states overtime and to develop models for analysing the influencing factors of production. Secondary data regarding area, production, productivity and rainfall were collected for a period of past 25 years from Directorate of Economics and Statistics (Govt. of Karnataka), Department of Economics and Statistics (Govt. of Kerala and Tamil Nadu) and Coconut Development Board. Secondary data on price was collected for major markets of paddy (Thanjavur and Raichur) and copra (Kochi, Kangayam and Tumkur) from indiastat and Agmarknet.

Trend analysis was used to understand the trends in area, production and productivity using different linear and nonlinear growth models. Compound Annual Growth Rate (CAGR) was estimated using exponential model to compare the performance in area, production and productivity of paddy and coconut in South India. Johansen's co-integration technique was used to understand the price movement in the markets across the states for price of paddy and copra. Panel data regression analysis was done to identify the climatic variables that influence the production of paddy and coconut.

From trend analysis, the best model was selected based on adj. R^2, criteria of randomness, normality and Root Mean Square Error (RMSE). In paddy, quadratic model was found to be the best fitted model for area and production in Karnataka, production and productivity in Kerala and area in Tamil Nadu. Cubic model was found to be the best model for area in Kerala, productivity in Tamil Nadu and power model for productivity in Karnataka and compound model for production in Tamil Nadu. In case of coconut, quadratic model was found to be

the best fitted model for area, production and productivity in Karnataka and area and productivity in Tamil Nadu. Cubic model was found to be the best model for area, production and productivity in Kerala and production in Tamil Nadu.

Comparative performance of paddy and coconut in Southern states was compared based on CAGR for a period from 1987-2017. CAGR revealed that production (1.1%) and productivity (1.0%) of paddy in Karnataka and productivity (1.5%) in Kerala was found to be positive and significant. Area (-4.5%) and production (-3.0%) of paddy in Kerala and area (-0.7%) in Tamil Nadu was found to be negative and significant. In case of coconut, positive and significant CAGR was noticed for area, production and productivity in Karnataka and Tamil Nadu and production (1.4%) and productivity (2.0%) in Kerala where as a declining trend in area (-0.6%) was noticed in Kerala.

Stationarity is the prime requirement for co-integration analysis of price of paddy and coconut in various markets and it was tested using Augmented Dickey Fuller test (ADF). The results of ADF test indicated that price of paddy in Thanjavur (TN) and Raichur (Karnataka) markets and price of copra in Kochi (Kerala), Kangayam (TN) and Tumkur (Karnataka) markets were stationary after taking the first difference which suggested that all the price series were integrated of order one I(1). The result of Johansen's co-integration test revealed that monthly wholesale price of paddy in Thanjavur and Raichur markets were co-integrated. Similarly price of copra in Kochi (Kerala), Kangayam (TN) and Tumkur (Karnataka) markets was also co-integrated which means that price in different markets are moving together. Granger Causality test was applied to find the direction of causality from one market to another and it revealed that there was a bidirectional influence in Thanjavur and Raichur market price of paddy. In case of copra, there was a bidirectional influence between Kochi and Kangayam market price and unidirectional influence on prices of Kochi and Tumkur.

The effect of climatic factors on production was analysed using panel data regression with fixed effect model suggests that average rainfall during Q_3 (July -

September) and Q_4 (October - December) had a positive and significant effect on production of paddy. In case of coconut, previous year average rainfall during Q_{1t-1} (January - March) and Q_{4t-1} (October - December) had a positive and significant influence on production of coconut.

Trend in area, production and productivity was well explained by cubic and quadratic model for paddy and coconut with high adj R^2 and least RMSE. CAGR of productivity of paddy in three South Indian states has shown a positive trend but there was a declining trend in area under paddy in Kerala and Tamil Nadu. There was a significant positive growth rate in area, production and productivity of coconut in Karnataka and Tamil Nadu and production and productivity in Kerala. However, the productivity in Tamil Nadu (14251 nuts ha^{-1}) and Karnataka (13181 nuts ha^{-1}) was far ahead as compared to that of Kerala (9664 nuts ha^{-1}). The monthly wholesale price of paddy in Thanjavur and Raichur markets and price of copra in Kochi, Kangayam and Tumkur markets were co-integrated which indicates that any price change in one market influence the price in other markets. Production of paddy was influenced by Q_3 (July - September) and Q_4 (October - December) rainfall, in case of coconut, production was influenced by previous year average rainfall during Q_{1t-1} (January - March) and Q_{4t-1} (October - December).