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# Analysis of Spatial and Temporal Variations in Area, Production and Productivity of Tobacco in Prakasam District of Andhra Pradesh

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**ABSTRACT**

This paper attempted to identify the spatial and temporal variations in tobacco area, production and productivity of Prakasam district of Andhra Pradesh on the basis of 28 years of secondary data covering the years from 1987 to 2014 by using the graphical approach. The growth rates were also calculated by using the Compound Growth Rate (CGR) function. The influence of area and productivity on production was studied separately by fitting a simple Linear regression Equation. Forecasting of tobacco production was done by using spline regression and conventional models. The results of the study showed that there were a positive shifts in area, production and productivity for the crops during the two periods.

Key words: *Compound Growth Rates, Karl Pearson's correlation coefficient, Multiple Linear regression, Spline Regression, $R^2$.*

Tobacco also called "Golden Leaf" is one of the important commercial crops of India and it is vital to the Indian economy. India is the world's second largest producer of tobacco after China, endowed with rich agro-climatic attributes such as fertile soils, rainfall and ample sunshine which lead to produce various types of tobacco. Around 0.25% of India's cultivated land is being used for tobacco production. Tobacco is cultivated in an area of 0.4 million ha producing annually around 700 million kg of cured leaf out of which 260 million kg is Flue-Cured Virginia tobacco (cigarette type). The other types are *Bidi,* Hookah and Chewing, Cigar filler, Cigar Wrapper, *Cheroot*, Burley, Oriental, HDBRG, *Lanka* etc. The major tobacco producing states in India are Andhra Pradesh (AP), Gujarat, and Karnataka. Andhra Pradesh, Gujarat, Karnataka and UP together account for over 90% of the total tobacco production in the country. In Andhra Pradesh, Flue-Cured Virginia (FCV) tobacco is grown in an area of 1,25,000 ha in East Godavari, West Godavari, Khammam, Krishna, Guntur, Prakasam, Nellore, Karimnagar and Warangal districts with a total production of 170 M kg of leaf. India has seven tobacco research centres, out of which five are located in Andhra Pradesh. Tobacco area, production and productivity in Prakasam district expanded at very faster rate compared to other districts in the state by replacing crops like chillies, black gram, bengal gram, etc. The yields also reported highest in the district.

Studies of temporal variations in the data imply study of variations in the data, recorded over a period of time. Singh *et al.* (2004) studied spatio-temporal variations in the area, production and productivity of rape and Indian mustard in Haryana. Patidar *et al.* (2006) analyzed the variability, growth, trends and contribution of area, yield and their interaction on production of soyabean in Madhya Pradesh using the method of graphical analysis. Kaur *et al.* (2006) determined the shift in area, production and productivity of wheat (*Triticum aestivum*) in Punjab.

Growth rate is an important indicator of development. In agriculture, it is estimated for studying the impact of developmental measures such as the technological innovations in the crop. Devraj *et al.* (2007) studied trends and growth performance in area, production and yield of chickpea in the four zones of India by using the compound growth rate function. Acharya *et al*. (2012) assessed growth in the area, production and productivity of different crops in Karnataka by using the compound growth function. Reddy *et al*. (2013) assessed the spatio-temporal variations in cotton yields in India by using the compound growth function.

Forecasting of the agricultural output is carried out on the basis of time series data recorded over the years. Hassan *et al.* (2011) found the appropriate deterministic time series model by using the latest selection criteria that could best describe the coarse rice price pattern in Bangladesh. Kumari and Kumar (2014) used ordinal logistic model based on weather data and attempted for forecasting wheat (*Triticum aestivum* L.) yield in Kanpur district of Uttar Pradesh. Tripathi *et.al.* (2014) forecasted rice area, production, and productivity of Odisha from the historical data of 1950-51 to 2008-09 by using univariate autoregressive integrated moving average (ARIMA) models.

Kulkarni and Narendranath (2008) applied spline model for forecasting the state level production of rice and jowar crops in Andhra Pradesh. Mallikarjuna *et al.* (2011) forecasted the cotton production in Dharwad district of Karnataka and Karnataka State as a whole by using spline regression model.

## MATERIAL AND METHODS

In this paper an attempt has been made to analyze the spatial and temporal variations in the Prakasam district tobacco data for bringing out results that may be useful for strategic planning. Besides, Compound Growth Rates, Production relations and forecasting of tobacco data was done based on the 28 years time series data from 1987 to 2014 on area, production and productivity of Tobacco which was collected from the website of Directorate of Economics and Statistics and the crop reports of Tobacco Board, Guntur.

The study of temporal variations is essentially identifying the impact (effect) of sources of variation that affect the time series data. In the context of agriculture, the time series data on crops such as crop production and crop productivity is generally affected by technological innovations in the crop in addition to weather. The impact, initially, is in the form of a sudden or quantal jump, which stabilizes after certain period *i.e.,* when majority of farmers in the region have adopted the technology. The knots or years of quantal jumps or shifts can be identified by applying the graphical method. The graphical approach is based on the control charts approach of quality control. The time series data on crop area, production and productivity is plotted over the years in order to obtain a line graph.

The overall average $\overline{y}$ of the data is computed and a line is drawn to represent this. Two more lines which represent upper and lower limit can also be drawn above and below this by computing the control limits (+ S) and ( – S) where S is the standard deviation of the data. If the data exhibits distinct clusters of points, which are respectively below and above, then the fluctuations can be considered to have a quantal jump, which is otherwise the point of discontinuity or knot. It is obvious that, identification of jumps or knots as outlined in the graphical procedure leads finally to the formation of several distinct sub-periods of data. The mean values of these sub-periods thus represent the level of shifts.

The variation in the crop data attributed to the shifts can be quantified on the basis of the mean values of the sub-periods formed by the jumps *i.e.,* knots, as follows

$$\text{Shift (\%)} = \left[\frac{P_i - p_{i-1}}{P_{i-1}}\right] \times 100$$

Where,

$P_i$, $P_{i-1}$ are the mean values of the crop data of $i^{th}$ and $(i-1)^{th}$ period, respectively.

### Compound Growth Rate

Mathematically, Compound Growth Rate is synonymous to the well known Compound Rate of Interest computed on the basis of the principal over a period of time (years):

$$A = P\left[1 + \frac{r}{100}\right]^t \quad ............(1)$$

Where,

A = Amount at the end of $t^{th}$ year.

P = Principal

$\frac{r}{100}$ = Compound Rate of Interest t = Time

In the context of agricultural data recorded over a period of years, the Compound Growth Rate (CGR) is derived on the basis of the above relation (1), as an exponential equation,

$Y = ab^t$ ………….. (2)

Where,

Y = Crop area/production/productivity

t = Time (years) and (a, b) = Parameters

A comparison of the relations (1) and (2) clearly indicate that

$$Y = A \text{ and } a = P \text{ and } b = \left(1 + \frac{r}{100}\right)$$

Hence the compound growth rate (CGR) = (r) = (antilog b-1) x 100

It is thus clear that the expression for the CGR is derived from the fundamental mathematical relation (1) and the relation (2) is the transformation.

## Role of Area and Productivity in Crop Production

Area and productivity are the major determinants of crop production. The role of these factors can be studied by fitting a simple regression separately for area and productivity. The coefficient of determination '$R^2$' indicates the role of these variables in explaining the variations in the dependent variable, i.e., crop production.

### Forecasting Model for Agricultural Production

Forecasting was carried out by using the Spline models and the conventional trend fitting models. The models were fitted to the production data of 26 years of production data covering the years 1987 to 2012. Forecasting efficiency of the models was also studied by obtaining forecasts for the future years of 2013 and 2014.

### Conventional models:

These are the most commonly applied models not only for forecasting purpose but also for measuring the growth. The approach involved is to fit an appropriate trend equation to the time series data on agricultural output with time as the independent variable. Several types of equations are fitted to the agricultural data. Some of the commonly applied equations are:

$Y = a + bt + e$ (Linear model)

$Y = a + bt + ct^2 + e$ (Quadratic model)

$Y = a + bt + ct^2 + dt^3 + e$ (Cubic model)

where,

Y = Agricultural output in the $t^{th}$ year and t = time (years)

### Spline Regression Model

Splines are Piece-wise polynomials of order 'k'. The joint points of the pieces are usually referred as knots. Spline is a continuous function with (k-1) continuous derivatives. Generally, a cubic spline is adequate to represent the data (Montgomery and Peck, 1982).

A cubic spline with 'k' knots can be described as:

$$E(Y) = \Sigma_{j=0}^{3} \beta_{oj} X_j + \Sigma_{i=0}^{k} 1\beta_{\iota} (X-t_i)^3$$

Where,

Y = Production of the crop

β'S = Parameters of the model and

$$(X-t_i) = \begin{cases} (X-t_i), \text{ when } (X-t_i) > 0 \\ 0, \text{ when } (X-t_i) \le 0 \end{cases}$$

The basic cubic spline model can be conveniently modified to polynomials of different order by imposing different continuity restrictions at the knots. Identification of knots or points of discontinuity is the basic step in formulating the Splines. In the context of production data, these points can be conveniently identified by applying the approach of control charts, as outlined by Kulkarni and Pandit (1988).

The forecasting efficiency is measured through the expression:

$$\text{Bias (\%)} = \frac{Y - \bar{Y}}{Y} \times 100$$

Where,

Y = observed production and $\bar{Y}$ = forecasted production

## RESULTS AND DISCUSSION

To analyze the temporal variations of Tobacco in Prakasam district of Andhra Pradesh during the period from 1987 to 2014, time series data on area, production and productivity of Tobacco in Prakasam district of Andhra Pradesh was analyzed by using the graphical approach. The shifts in the area, production and productivity of

**Table 1. Shifts in Area, Production and Productivity of Tobacco in Prakasam district.**

**1.1 Area Shifts**

| Period | Year | Average (ha) | |
|---|---|---|---|
| 1 | 1987-2003 | 51658.88 | ($\bar{Y}_1$) |
| 2 | 2004-2014 | 73601.09 | ($\bar{Y}_2$) |
| Shift (%): 2-1 | | 42.47% | |
| Overall | 1987-2014 | 60279.04 | ($\bar{Y}$) |

**1.2 Production Shifts**

| Period | Year | Average (ha) | |
|---|---|---|---|
| 1 | 1987-2007 | 54.15 | ($\bar{Y}_1$) |
| 2 | 2008-2014 | 140.83 | ($\bar{Y}_2$) |
| Shift (%): 2-1 | | 160.07% | |
| Overall | 1987-2014 | 75.82 | ($\bar{Y}$) |

**1.3 Productivity Shifts**

| Period | Year | Average (ha) | |
|---|---|---|---|
| 1 | 1987-2007 | 1013.34 | ($\bar{Y}_1$) |
| 2 | 2008-2014 | 1767.55 | ($\bar{Y}_2$) |
| Shift (%): 2-1 | | 84.42% | |
| Overall | 1987-2014 | 1233.68 | ($\bar{Y}$) |

**Table 2. Growth Rates for Area,Production and Productivity of Tobacco in Prakasam district.**

| Period | Year | Average | CV (%) | CGR (%) |
|---|---|---|---|---|
| **2.1 Area (ha)** | | | | |
| 1 | 1987-2003 | 51658.88 | 33.04 | 0.61 |
| 2 | 2004-2014 | 73601.09 | 16.18 | 2.43 |
| Overall | 1987-2014 | 60279.04 | 30.78 | 2.55 |
| **2.2 Production (M. Kg)** | | | | |
| Period | Year | Average | CV (%) | CGR (%) |
| 1 | 1987-2007 | 54.15 | 32.37 | 3.34 |
| 2 | 2008-2014 | 140.83 | 17.11 | 4.44 |
| Overall | 1987-2014 | 75.82 | 56.24 | 5.69 |
| **2.3 Productivity (kg/ha)** | | | | |
| Period | Year | Average | CV (%) | CGR (%) |
| 1 | 1987-2007 | 1013.34 | 27.79 | 1.70 |
| 2 | 2008-2014 | 1767.55 | 12.64 | 5.75 |
| Overall | 1987-2014 | 1201.89 | 33.75 | 3.11 |

tobacco as identified through the graphical approach over the 28 years from 1987-2014 are presented in Table 1.

**Shifts in Area**

The line graph of area under tobacco indicated that there was gradual increase in the area under the crop during 2004. The year 2004 was also identified from the graphical analysis as a point of discontinuity (Fig.1).

The overall mean of the crop area of 28 years from 1987-2014 was 60279.04 ha.

It can be observed that this mean value distinctly formed two sub-groups. The first sub-group constituted the first 17 years of 1987 to 2003. The level of area during this period was below the overall mean. The second period sub-group consists of area under the crop during the remaining 11 years of 2004 to 2014. The level of area during this period was above the overall mean (Table 1.1).

It can be observed from Table 1.1 that there was a considerable increase in the area under tobacco from 51658.88 ha during the first sub-period to 73601.09 ha during the second sub-period. The shift in area of second sub-period over the first sub-period was positive (42.475 per cent).

**Shifts in Production**

The graphical analysis indicated that the time series data of tobacco production exhibited a single shift during the year 2008. This led to formation of two subgroups of production data below and above the overall mean production (Fig 2).

The sub-periods corresponding to these two sub-groups were 1987 to 2007 and 2008 to 2014 respectively (Table 1.2).

It can be observed that there was a positive shift of 160.07 per cent in the average production during second period over the first period. This increase in the production level may be attributed to the impact of positive shift in area.

**Shifts in Productivity**

The productivity data indicated that there was only a single point of discontinuity during the year 2008. This point of discontinuity formed two subgroups *i.e.,* 1987 to 2007 and 2008 to 2014 (Fig 3).

It can be observed from Table 1.3 that there was a considerable increase in the average productivity of the second period over the first period. Thus, accounting for a shift of 74.42 per cent. This increase in the productivity level in the second period may be attributed to the adoption of the technological innovations in the tobacco crop.

***Growth rates of area, production and productivity of tobacco in Prakasam district:***

**Growth in Area**

The time series data indicated existence of discontinuity during the year 2004. Hence the growth rate was measured separately within the periods 1987 to 2003 and 2004 to 2014 (Table 2.1).

The average area during the first period was 51658.88 ha with a c.v. of 33.04 per cent and during the second period, it was 73601.09 ha with a c.v %of 16.18 per cent. It can be observed that there was a gradual increase in the average level of area during the second period over the first period. Among these two periods the second period was relatively more consistent *i.e.,* with less variability in the area level (c.v %= 16.18 per cent).

It can be observed that during both the sub-periods there was an increase in the area under crop. The first period recorded a compound growth rate of 0.61 per cent; while the rate of increase was 2.43 per cent during the second sub-period.

The present status of the area in this district indicated that there was a considerable increase in the level of area over the years from 2004 to 2014. The growth was also increasing at the rate of 2.43 per cent.

**Growth in Production**

The production data indicated evidence of discontinuity during the year 2008. Due to this point of discontinuity, the entire data was grouped into two sub-periods. The growth rate was therefore measured separately within the periods formed by the year of discontinuity. The results are presented in the Table 2.2.

The average production during the first sub-period was 54.15 M. kg with a c.v % of 32.37 percent and during the second sub-period, it was 140.83 M. kg with a c.v % of 17.17 per cent. Among these two periods the second period was relatively

**Table 3. Tobacco Production Relations in Prakasam (1987-2014).**

| Independent Variable | | Area (ha) | | Productivity (kg/ha) | |
|---|---|---|---|---|---|
| Period | Year | Correlation coefficient | $R^2$ | Correlation coefficient | $R^2$ |
| 1 | 1987-2007 | 0.860** | 0.740 | 0.449* | 0.201 |
| 2 | 2008-2014 | 0.659 | 0.434 | 0.686 | 0.470 |
| Overall | 1987-2014 | 0.831** | 0.697 | 0.902** | 0.813 |

* Significant at 5% level of Probability ** Significant at 1% level of Probability

**Table 4. Forecasting Model for Production of Tobacco in Prakasam – Spline Model**

Model: $Y=A+BT+CT^2+D\,T^3 + [E\,(T-22)^3]$.

| Parameter | Estimate | SE | t |
|---|---|---|---|
| A | 30.44941 | 17.34094 | 0.89 |
| B | 15.76836 | 5.92823 | 1.99 |
| C | -1.17064 | 0.54879 | -2.13* |
| D | 0.03746 | 0.01454 | 2.58** |
| E | -1.04201 | 0.50810 | -2.05* |
| $R^2$ | 0.7780 | | |

* Significant at 5% level of Probability ** Significant at 1% level of Probability

**Table 5. Forecasting Model for Production of Tobacco in Prakasam – Conventional Model**

Model: $Y=A+BT+CT^2$

| Parameter | Estimate | SE | t |
|---|---|---|---|
| A | 46.220 | 12.539 | 3.686** |
| B | -1.958 | 2.140 | -0.915 |
| C | 0.205 | 0.077 | 2.662** |
| $R^2$ | 0.706 | | |

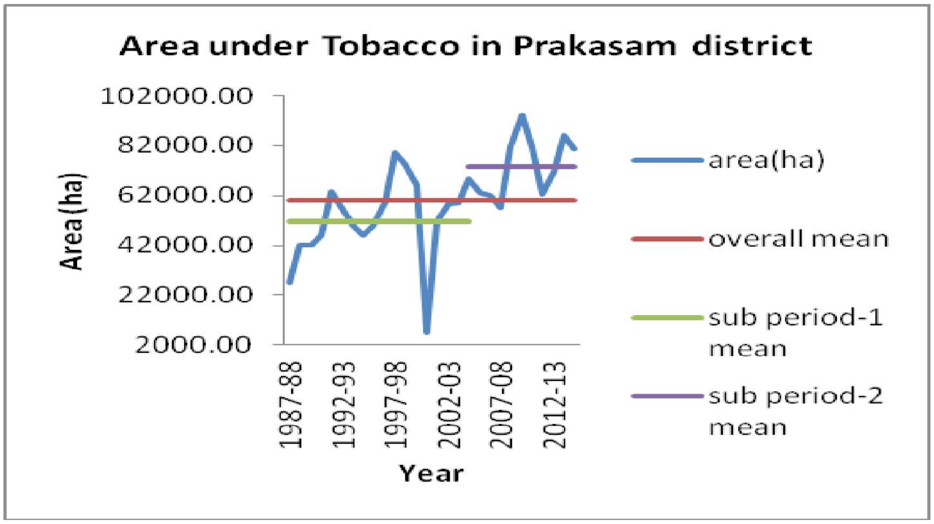
* Significant at 5% level of Probability and ** Significant at 1% level of Probability

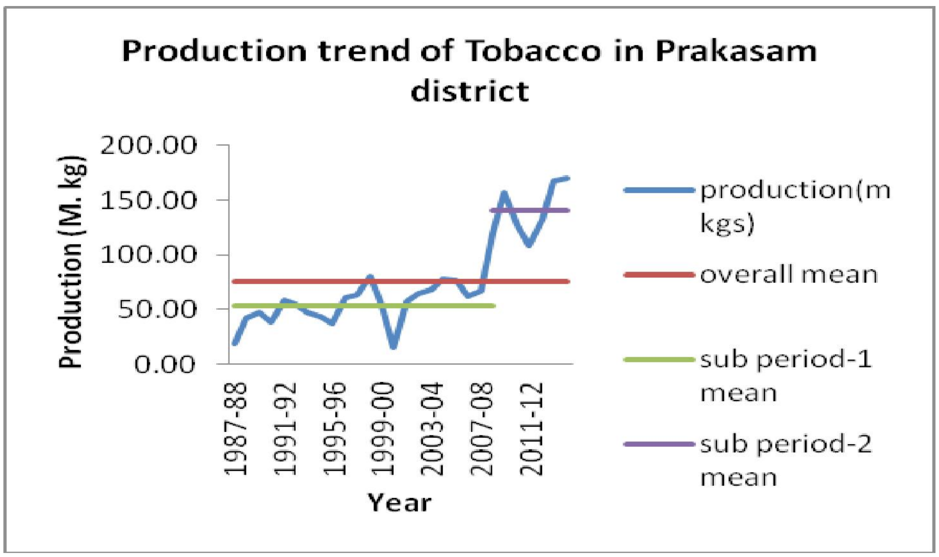
**Table 6. Forecasts for Production of Tobacco in Prakasam district.**

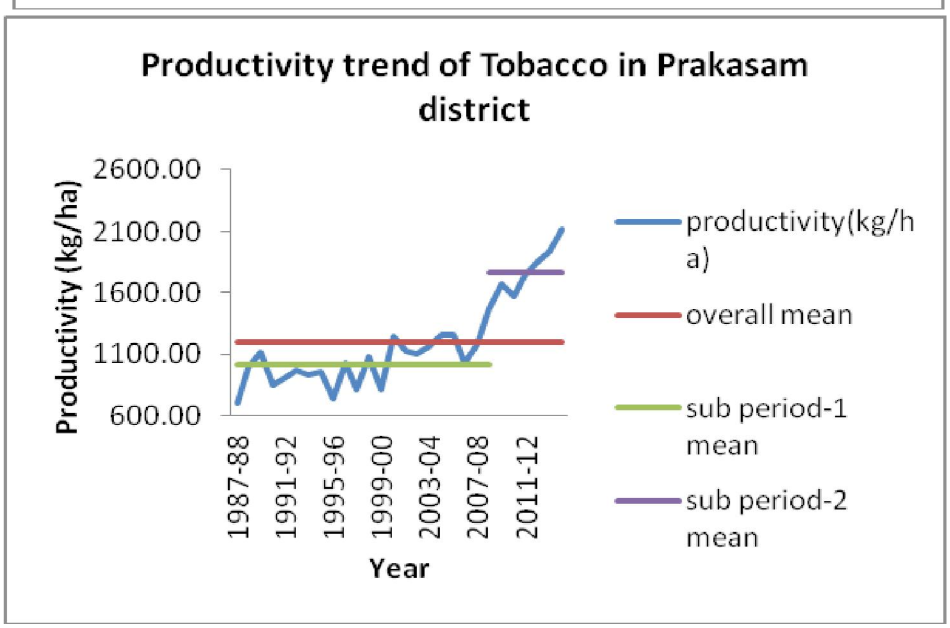
| Year | Observed | Forcast with: | |
|---|---|---|---|
| | | Spline | Conventional |
| 2013 | 167.35 | 182.862<br>(-9.26) | 142.799<br>(14.67) |
| 2014 | 170.96 | 165.482<br>(3.20) | 152.116<br>(11.02) |

Figures in parenthesis are the bias (%) in the forecast

Graphs of Spatial and Temporal Variations of Area, Production and Productivity of Tobacco in Prakasam District



more consistent *i.e.,* with less variability in the production level (c.v %= 17.17 per cent).

It can be observed that the production data of both the sub-periods recorded a positive growth of 3.34 per cent and 4.44 per cent respectively. The growth in the second period, however, was based on only seven years of data from 2008 to 2014.

The result of the second period reveals the status of tobacco production in the production level from 2008-09 onwards (Fig 2). Several factors can be attributed to this increase such as increase in the area under tobacco, which was supplemented by the decrease in the area under the crops of different category.

**Growth in Productivity**

The productivity data indicated evidence of discontinuity during the year 2008. Hence the growth rate was measured separately within the two period formed by the year of discontinuity and results are presented in the Table 2.3.

The average productivity during the first period was 1013.34 kg/ha with a c.v % of 27.80 per cent and during the second period, it was 1767.55 kg/ha with a c.v % of 12.64 per cent. Among these two periods the productivity level of the second period was relatively more consistent *i.e.,* with less variability (c.v %= 12.64 per cent).

The point of discontinuity also indicated that, it is not appropriate to measure the overall growth based on 28 years of data. The rate of growth during the second period was relatively higher i.e., 5.75 per cent, than the first period i.e., 1.70 per cent.

The present status of the tobacco productivity in the district can be studied through the results of the second period. The results thus indicate that the productivity was increasing at the rate of 5.75 per cent.

The area under the crop accounted for 69.76 per cent of the variation in the tobacco production when the overall period was considered; while during the periods of production shifts, the contribution varied from 74.00 per cent in first period to 43.46 per cent during the second period. On the contrary, the role of productivity was relatively low during the first sub-period, where as it was relatively high during the second and overall period *i.e.,* 47 per cent, 81.3 per cent respectively (Table 3).

It can be observed that in all the periods only area had influenced the production and in the overall period productivity had influenced the production.

***Forecasting Models for Tobacco Production in Prakasam:***

The time series data of production of tobacco exhibited a production range of 54.15 M. kg during 1987 to 140.83 M. kg during 2012. It was noticed from the graphical analysis that there was only a single point of discontinuity during the year 2008, which was represented by 22$^{nd}$ year (Fig.2).

This year of discontinuity *i.e.,* 2008 was duly considered in developing the spline model. It can be observed that the variation in the dependent variable was explained to the extent of 77 per cent with the spline model (Table 4).

In the conventional approach, the second degree polynomial model was found to be suitable and it explained 70 per cent of the variations in the production data (Table 5).

The results of the models revealed that the spline model was relatively better with regard to explanatory power adjusted $R^2$ than the second degree polynomial equation model. The efficiency of these two models can be verified on the basis of the bias in the forecast from these models (Table 5). It can be observed that the forecasts obtained from the spline model had close analogy with the observed ones as compared to those with the conventional model.

The bias in the forecast with the spline model was -9.26 per cent in 2013 and 3.20 percent in 2014; whereas in the conventional model, the bias in the forecast for these years was respectively 14.67 per cent and 11.02 per cent (Table 6). The assumption of discontinuity was duly considered in the spline model as against the conventional trend fitting approach.

## LITERATURE CITED

**Acharya P S, Basavaraja H, Kunnal B L, Mahajanashetti B S and Bhat S R A 2012** Growth in area, production and productivity of major crops in Karnataka. *Karnataka Journal of Agricultural Sciences,* 25(4): 431-436.

**Devraj, Singh K, Kumar H and Reddy A A 2007** Growth performance of chickpea: a zone-wise analysis. *Agricultural Situation in India,* 64(7): 297-301.

**Hassan F M, Islam A M, Imam F M and Sayem M S 2011** Forecasting coarse rice prices in Bangladesh. *Progress Agriculture,* 22(1 & 2): 193 – 201.

**Kaur P, Singh H and Hundal S S 2006** Spatio-temporal changes in area, production and productivity of wheat (*Triticum aestivum*) in Punjab. *Indian Journal of Agricultural Sciences,* 76(1): 52-54.

**Kulkarni B S and Narendranath V V 2008** Spline regression models for forecasting of agricultural production. *Journal of Research ANGRAU,* 36(2&3): 28-38.

**Kumari V and Kumar A 2014** Forecasting of Wheat (*Triticum aestivum*) yield using ordinal logistic regression. *The Indian Journal of Agricultural Sciences*, 84(6).

**Mallikarjuna H B, Naik V, Nethrayini K R and Goudappa S B 2011** Spline models for forecasting of cotton production. *International Journal of Commerce and Business Management,* 4(2): 231-234.

**Montgomery D C and Peck E A 1982** Introduction to Linear Regression Analysis, John Wiley and Sons, New York.

**Patidar M, Sharma H O and Jain M P 2006** Contribution of area and productivity towards growth of soybean production in Madhya Pradesh. *Soybean Research,* 4(1/6): 54-62.

**Reddy A R, Yelekar S M and Agarwal I 2013** Cotton productivity variations in India: An assessment. *Cotton Research Journal*, 5(2).

**Singh D, Pahadia K K and Rao V U M 2004** Spatio-temporal changes in area, production and productivity of rapeseed and mustard in Haryana. *Journal of Agrometeorology,* 6(10):115-118.

**Tripathi R, Nayak K A, Raja R, Shahid M, Kumar A, Mohanty S, Panda B B, Lal B and Gautam P 2014** Forecasting Rice productivity and production of Odisha, India, using Autoregressive Integrated Moving Average models. *Advances in Agriculture,* 1-9.

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