Kristu Jayanti Journal of Computational Sciences Volume 1 2021, Pages 43-57

# Trends and Growth Rate Analyses of Gram Production – A Data Driven Approach

[1]Vinoth Balakrishnan, [2]Liji Sebastian and [3]Rajarathinan Arunachalam

*[1,2]Assistant Professor, Department of Statistics, Kristu Jayanti College*
*[3]Professor, Department of Statistics, Manonmaniam Sundaranar University*
*[1]vinothb@kristujayanti.com, [2]liji.g@kristujayanti.com, [3]arrathinam@yahoo.com*

**_Abstract_**

*Trends and growth rate analysis are extensively employed in the agricultural sector as these have significant policy implications. The present study was commenced to design a methodology to fit trends in the three phases of different Gram crops grown in Tamil Nadu state using nonparametric regression. Relative growth rates were calibrated based on non-parametric regression model. On average, the percentage growth rate values obtained in the years 1950-1951 to 2009-2010 for the three phases of different grams crops showed that production increased with a rate of 6.0, which has been at a rate of 2.89 and 3.21 per cent per year due to the combined effect of area and productivity.*

***Keywords:*** *Smoothing technique, nonparametric regression.*

## 1. Introduction

Gram is considered as one of the oldest pulses known and developed from ancient Asia. Archeological evidence from Uttar Pradesh suggests their presence in 2000 BC. In Sanskrit, Gram is referred to as Chanaka, suggesting that it is long cultivated in India. It is referred to as Chickpea or Gram Bengal. It is the most effective winter (Rabi) pulse crop and accounts for approximately 50 percent of India's pulse production India currently accounts for 65 per cent of the global average gram production [1].

In this paper, in the state of Tamil Nadu, we took over the production of Gram, which has major role in the overall production of Gram in India. The black gramme area in the state in 1999 was approximately 4.46 billion ha, with an output of 2.06 billion tons, reflecting a mean productivity of 461 kg / ha. The black gramme area in the state in 1999 was approximately 4.46 billion ha, with an output of 2.06 billion tons, reflecting a mean productivity of 461 kg / ha. Green grammes, in the case of the area in 1999 was approximately 1.83 billion ha, with a production rate of 0.696 billion tons, resulting in a mean productivity of 380 kg / ha.

This indicates a national average of 363 kg / ha of productivity. With an output of 2.77 million tons and a productivity of 799 Kg / ha, In India, Red Gram (Pigeonpea) presently occupies a total area of around 3.47 lakh tons. The region covered by the red gramme of Tamil Nadu is approximately 1.40 billion hectares with a production of 1.20 billion tons and a productivity of 864 kg / ha, which is higher than the national average productivity but lower than that of Uttar Pradesh (1134 kg / ha), Haryana (1145 kg / ha), Bihar (999 kg / ha), Gujarat (952 kg / ha) and Punjab (880 kg /ha). Productivity levels are lower in the following states: Compared to Tamil Nadu [2], Andhra Pradesh (383 Kg / ha), Karnataka (499 Kg / ha), Madhya Pradesh (832 Kg / ha), Maharashtra (681 Kg / ha), Orissa (361 Kg / ha) and Rajasthan (380 Kg / ha).

The biggest issue at this level is why Tamil Nadu has production only above the national average, which has been taken into account by leaving behind its strong counterparts, such as Uttar Pradesh, Haryana, etc. The answer lies in, along with the technological innovation that can help increase the yield, the analysis of the crop's the three phases data over the past decade is of paramount significance as it forms the basis for economic policy planning by the state and central governments.

The future production analysis can be only estimated by studying the trends of the three phases of the crop for a particular time period in the past. If a trend of variability can be established by appropriate statistical methods, it will have practical utility whenever the data is used.

In this paper the trends based on the three phases is studied by finding out the best fitting model among the chosen models like non-linear, parametric and non-parametric regression models. Finally it will be concluded by justifying the use of any one particular model to study the trends for the same and a suitable conclusion will be derived to increase the productivity of the crop for the years to come.

## 2. Methodology

Time-series data on three phases of different Gram crops grown in the state of Tamil Nadu between 1950-1951 and 2009-2010 were gathered from the Office of Statistics and Economics, Teynampet, Chennai-600006. The present study is aimed to design a sound statistical methodology to fit trends and to estimate growth rates in the three phases using non-parametric regression.

### 2.1. Nonparametric Regression (Hardle, 1990)

In general, non-parametric regression model is of the form, $Y = m(x) + \varepsilon$ (1)

where Y is the response variable. m(X) = E(Y/X=x) is the mean response or regression function assumed to be smooth and $\varepsilon$ is the independently identically distributed random error with mean zero.

Smoothing methods are used to non-parametric estimate the regression function (Hardle, 1990). A regression smoother is a tool for summarizing the trend in the Y response calculation as a function of one or more X predictor measurements. In order to obtain an approximation of the mean response value at point X, most smoothers combine the Y-values of the observations with Predictor values that are similar to the X goal value. The average is achieved in neighbourhoods around the goal amount. The smoothers vary primarily in the way they are averaged. The biggest choice to make in all of the smoothing strategies is to correct the scale of the area. In terms of an adjustable smoothing parameter or bandwidth, the scale of the neighbourhood is usually expressed. Intuitively, large neighbourhoods can have low variance forecasts, but potentially high bias, and, conversely, for small neighborhoods. There is also a simple trade-off, which is regulated by the smoothing parameter, between bias and variance.

### 2.2. Kernel Smoothers

The kernel smoother uses an specifically defined set of local weights, defined as the kernel function, to generate an approximation for each target value. The kernel is a continuous real function K that integrates into one and has a maximum value of x=0. The standard Gaussian density is an example of kernel density function. Other popular kernels, with some theoretical justification, are

**Epanechnikov kernel**,

$$K_h = \begin{cases} 0.75(1-x^2) & for \ |x| \le 1 \\ 0 & otherwise \end{cases}$$

(Epanechnikov, 1969) which minimizes asymptotic mean square error, and the minimum variance kernel,

$$K_h = \begin{cases} 3/8(3-5x^2) & for \ |x| \le 1 \\ 0 & otherwise \end{cases}$$

This minimises the asymptotic uncertainty of the prediction. Proof from the data indicates that the choice of the kernel is comparatively insignificant compared to the choice of the bandwidth. Given data ($x_i$,$y_i$), i = 1,2,3,…,n $x \in [0,1]$, there exists a multitude of different types of kernel regression smoothers of the regression mean function m, K the kernel density function, h the smoothing parameter or bandwidth, and $K(x) = h^{-1}K(h^{-1}x)$ three important kernel type regression smoothers follow :

**Nadaraya – Watson Estimator**: At a certain point x, the Nadaraya – Watson estimator is

$$\hat{m}(x) = \sum_{i=1}^{n} y_i K_h(x - x_i) / \sum_{i=1}^{n} K_h(x - x_i) \qquad (2)$$

**Priestly – Chao Estimator**: Prestly and Chao (1972) considered the following formula

$$\hat{m}_{PC}(x) = \sum_{i=1}^{n} y_{(i)}[x_{(i)} - x_{(i-1)}]K_h[x - x_{(i)}] \qquad (3)$$

where the bracketed subscript denote the ordered X’s and their concomitant Y’s.

**Gasser – Muller Estimator** : Gasser and Muller (1984) suggested an alternative, which is

$$\hat{m}_{GM}(x) = \sum_{i=1}^{n} y_{(i)} \int_{S_{i-1}}^{S_i} K_h[x - x_{(i)}]dx \qquad (4)$$

where $x_{(i-1)} \le S_{i-1} \le x_{(i)}$ is chosen between the ordered X – data.

### 2.3. Choice of smoothing parameter

Choosing an optimal smoothing parameter or bandwidth is of considerable significance in non-parametric regression. We've shown that a broad bandwidth produces an over-smooth curve while a limited bandwidth produces an under-smooth curve. In this section some important bandwidth selection procedures are presented that optimize quadratic error measures for the regression curve such as average squared error (ASE).

The ASE of any regression smoother is defined by

$$\text{ASE(h)} = n^{-1}\sum_{i=1}^{n}[\hat{m}_h(x_i) - m(x_i)]^2 \tag{5}$$

where, h is the bandwidth and $\hat{m}_h(x_i)$ is the regression smoother.

The main concept behind much of the smoothing parameter selection algorithm is to approximate ASE or similar measurements. It is assumed that the smoothing parameter minimizing the estimate is also a good estimate of the ASE itself.

The unknown $m(x_i)$ in the above equation can be replaced by the observation $y_i$ at $x_i$ to obtain an estimate of the ASE,

$$p(h) = n^{-1}\sum_{i=1}^{n}[y_i - \hat{m}_h(x_i)]^2 \tag{6}$$

here p(h) is a biased estimate of ASE(h).

Some of the important techniques to find an unbiased estimate of ASE and subsequently to obtain the optimum bandwidth using Cross – validation is given below.

### 2.4. Cross–validation

The linear regression smoothers discussed above can be written as weighted average of *Y*–values

$$\hat{m}_h(x_j) = n^{-1}\sum_{i=1}^{n} W_{h_j}(x_i) y_i \tag{7}$$

The cross–validation or the leave-one-out method is based on regression smoothers, in which, the $j^{th}$ observation is left out.

### 2.5. Estimation of trend and growth rate (Jose *et.al.*, 2008)

The non-parametric regression model with the additive error is of the form

$$Y_i = m(x_i) + \varepsilon_i, \quad x_i = i/n, \quad \text{i=1,2,3, \dots , n} \tag{8}$$

Where Yi is the perception of the point in time,,
m is a trend function that is believed to be smooth, and
$\varepsilon_i, \sigma^2 < \infty$ these are random errors of mean zero and finite variance.

For non-parametric estimation of the trend function, the kernel weighted linear regression smoother (Fan, 1992) is used. $A_0$ is the solution to this lesser weighted problem as to the value of the local linear regression smoother at time x:

$$\sum_{i=1}^{n}\left[y_i - a_0 - a_1((x - x_i)/h)\right]^2 K_h((x - x_i)/h) \tag{9}$$

where K is a bounded symmetric kernel density function and h is the bandwidth.

Let $\hat{a}_0$ and $\hat{a}_1$ be the solutions to the weighted least squares problem.

The estimation of the trend function m(t) is given by $\hat{m}(t) = \hat{a}_0 = \sum_{j=1}^{n} W_{tj} y_j$

where

$$W_{tj} = \frac{K_j[s_2 - (x - x_j)s_1]}{s_0 s_2 - s_1^2} \qquad K_j = K\left[\frac{x - x_j}{h}\right] \text{ and } \quad s_l = \sum_{K=1}^{n} K\left(\frac{x - x_k}{h}\right)(x - x_k)^l$$

The optimum bandwidth h can be obtained by the cross-validation process.

The slope m) of m(x) can be called a simple linear growth rate at time point x. The estimate of m|(x) is given by $\hat{m}^{|}(x) = \hat{a}_1 = \sum_{j=1}^{n} W_{tj}^{|} y_j$ where $W_{tj}^{|} = \frac{K_j\lfloor (x - x_j)s_0 - s_1 \rfloor}{s_0 s_2 - s_1^2}$

Under the assumption that the trend function m is smooth and m(x) $\neq$ 0 for all x $\in$[0,1], worth of the relative growth rate time X can be written as :

$$r_x = \frac{m^{|}(x)}{m(x)}$$

Since $\hat{m}(t) \to m(t)$ and $\hat{m}^{|}(x) \to m^{|}(x)$, a consistent estimate of The relative rate of growth $r_x$ is given by : $\hat{r}_x = \frac{\hat{m}^{|}(x)}{\hat{m}(x)} \to r_x$

Taking arithmetic mean, the requisite compound growth rate over a given time-period may be obtained.

## 3. Results and Discussion

In non-parametric regression, the basic procedure required estimation of optimum bandwidth and was computed by cross-validation method. 'Epanechnikov-kernel' has been used as a weight function. To use this kernel function the time interval pertaining to data under consideration was transformed into the interval [0,1]. Non-parametric trend function was estimated. The relative growth trend for the three phases of the whole crop was estimated for consecutive years from 1950-1951 to 2009-10. The values for each year of the three phases were also calculated as a wise year for each plan period from 1951-52 to 1955-56 and the average five-year period for each plan was calculated. The findings are discussed in sequence as under.

### 3.1. Trends and Growth Rate of Black Gram Crop

The optimum Band widths for the Black gram crop were calculated by using the cross validation technique where the area and production had the same value of 0.05 and for productivity the value was 0.18. Non-parametric estimates of the underlying growth function have been calculated at each point in time. Residual analysis showed that the premises of error independence were not violated at a 5% point of significance. The Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Square Error (MSE) and Absolute Forecasting Error Rate (AFER) values for area were 17.20, 12.48, 295.88 and 8.92, respectively similarly for production it resulted at 11.62, 7.69, 135.07 and 13.03 respectively, and 49.93, 33.44, 2493.39 and 9.27, was obtained for productivity respectively. The graph of the fitted trends in the three phases has been depicted in the Figures 1, 2 and 3, respectively.

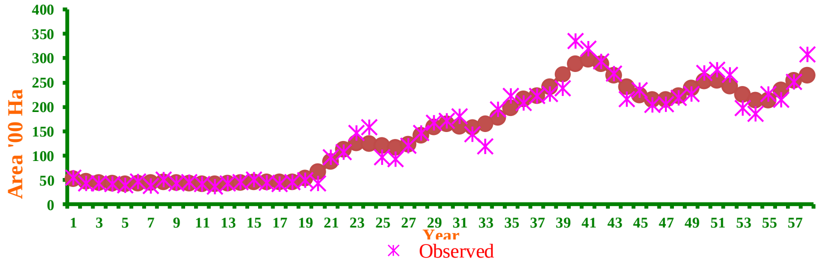


**Figure 1. Trends in Area of Black Gram**

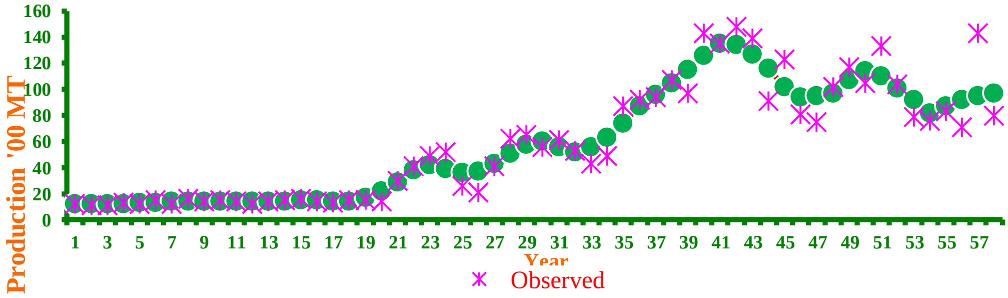


**Figure 2. Trends in Production of Black Gram**

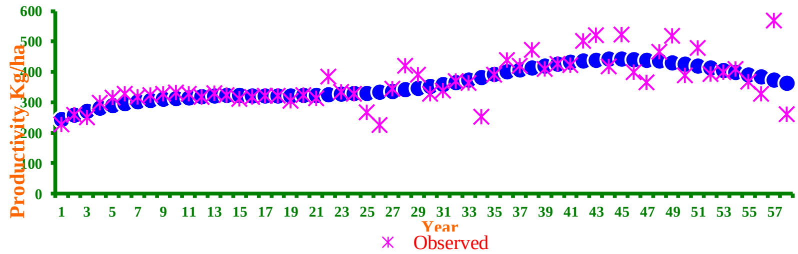


**Figure 3. Trends in Productivity of Black Gram**

The relative growth rate of the three phases was estimated for successive years from 1950-1951 to 2009-10 and, aside from this, to take a closer look at the relative growth rate, the three phases were calculated on a five-year basis beginning in the years 1951-52 to 1955-56 and so on. It is clearly depicted in table 1 and figure 4

**Table 1. Plan Period-Wise Relative Growth Rates of the three phases of Black Gram**

| Period | Area (%) | Prod$^{un}$ (%) | Prod$^{ty}$ (%) |
|---|---|---|---|
| Ist Plan for Five Years (1951-52 to 1955-56) | -0.04 | 4.12 | 2.47 |
| IInd Plan for Five Years (1956-57 to 1960-61) | -1.75 | -0.93 | 0.83 |

| | | | |
|---|---|---|---|
| IIIrd Plan for Five Years (1961-62 to 1965-66) | 1.70 | 0.93 | -0.01 |
| IV th Plan for Five Years (1969-70 to 1973-74) | 8.26 | 5.44 | 0.56 |
| Vth Plan for Five Years (1974-75 to 1978-79) | 8.47 | 12.14 | 1.25 |
| VI th Plan for Five Years (1980-81 to 1984-85) | 6.74 | 10.93 | 2.33 |
| VIIth Plan for Five Years (1985-86 to 1989-90) | 6.58 | 8.05 | 1.75 |
| VIIIth Plan for Five Years (1992-93 to 1996-97) | -1.85 | -3.50 | -0.50 |
| IX th Plan for Five Years (1997-98 to 2001-02) | -1.50 | -4.13 | -1.55 |
| X th Plan for Five Years (2002-03 to 2009-2010) | 5.70 | 4.32 | -2.06 |
| Whole Period (1950-1951 to 2009-10) | 2.48 | 3.40 | 0.53 |

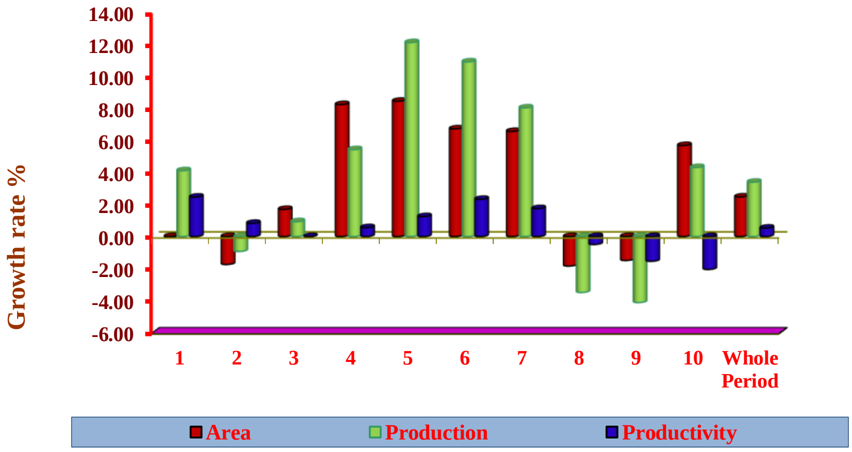


**Figure 4. Plan Period-Wise Relative Growth Rates of Black Gram**

When we give a closer look into the area production and productivity table 1 for the five year plan period of black gram we see that the production demonstrated a rising trend which had a peak at the fifth and Sixth plan periods during which production rates were 12.14 and 10.93 respectively, after which there is inconsistency. The production even faced a significant drop in its value during eight and ninth plan period, which was due to decrease in the area of cultivation as well as productivity.

Since the cultivated field was having a significantly low value it can be estimated that during that period the demand for the crop might have been lower and the farmers would have moved on to alternatives which was a necessary step to restore the demand in market as well as the land fertilization. Then tenth plan period showed good production numbers since the cultivated field was high and even though the productivity was less the output was high which might be on account of favorable weather conditions, prevailing temperature and use of technological innovations.

The percentage growth rate values obtained during the years 1950-1951 to 2009-10 for the three phases when averaged showed that production increased with a rate of 3.40, which was attributed to combined area impact and productivity with a rate of 2.48 and 0.53% per year, respectively.

### 3.2. Trends and Growth Rate of Green Gram Crop

The Green Gram also showed similar trends of optimum bandwidth values as that of black gram which was again 0.05 for area as well as for production but had slight lesser value of 0.17 for productivity when compared with the same. At each point in time, non-parametric estimates of the underlying growth function were calculated. Residual analysis showed that the premises of error independence were not violated at a 5% point of significance. The RMSE, MAE, MSE and AFER values for area were 8.24, 6.27, 67.90 and 7.64 respectively, whereas for production it was 5.88, 4.06, 34.62 and 13.56, respectively similarly for productivity it accounted to 52.13, 36.01, 2717.12 and 10.93 respectively. The graph of the fitted trends in the three phases have been depicted in the Figures 5, 6 and 7, respectively

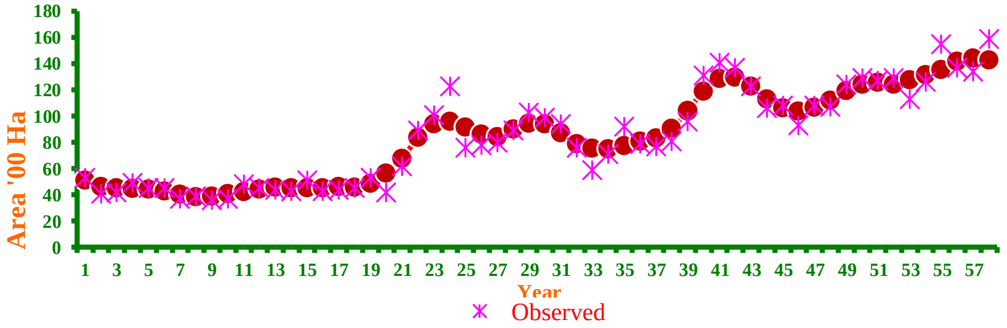


**Figure 5. Trends in Area of Green Gram**

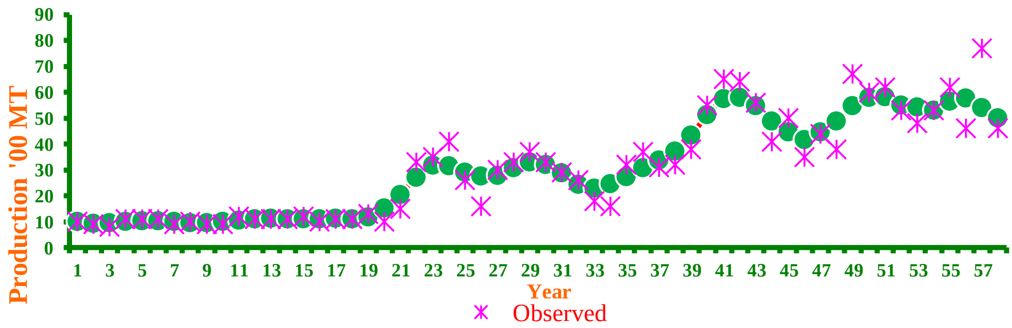


**Figure 6. Trends in Production of Green Gram**

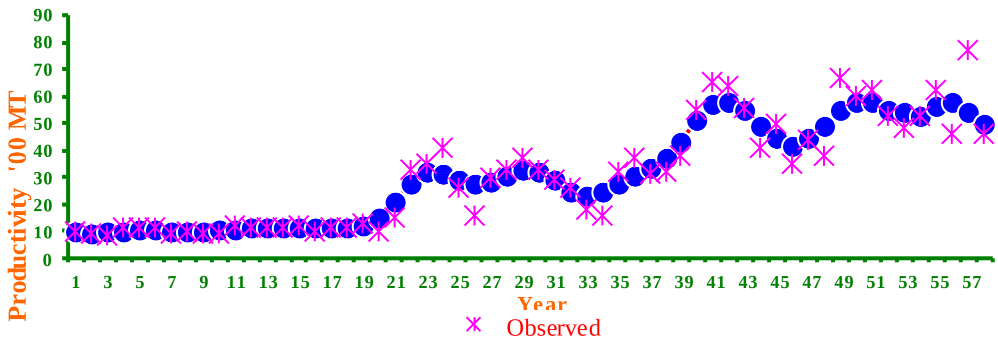


**Figure 7. Trends in Productivity of Green Gram**

Relative growth rates of the three phases of the Green Gram have been calculated for consecutive years from 1950-1951 to 2009-10 focused on the non-parametric regression model. The relative growth rate for each year for productivity was also measured on an annual basis, for every fifth plan period starting from 1951-52 to 1955-

56, and the average five-year period for each plan was estimated and shown in Table 2 and shown in Figure 8.

**Table 2. Plan Period-Wise Relative Growth Rates of Green Gram**

| Period | Area (%) | Prod^un (%) | Prod^ty (%) |
|---|---|---|---|
| Ist Plan for Five Years (1951-52 to 1955-56) | -2.87 | 0.98 | 2.25 |
| IInd Plan for Five Years (1956-57 to 1960-61) | 2.85 | 2.88 | 0.72 |
| IIIrd Plan for Five Years (1961-62 to 1965-66) | 0.39 | -0.01 | 1.17 |
| IV th Plan for Five Years (1969-70 to 1973-74) | 7.47 | 9.33 | 2.43 |
| Vth Plan for Five Years (1974-75 to 1978-79) | 1.87 | 3.54 | 0.95 |
| VI th Plan for Five Years (1980-81 to 1984-85) | -0.38 | 4.34 | 2.29 |
| VIIth Plan for Five Years (1985-86 to 1989-90) | 10.10 | 12.09 | 2.09 |
| VIIIth Plan for Five Years (1992-93 to 1996-97) | -0.13 | 0.25 | 0.21 |
| IX th Plan for Five Years (1997-98 to 2001-02) | 1.79 | 0.31 | -0.98 |
| X th Plan for Five Years (2002-03 to 2009-2010) | 2.95 | 0.03 | -3.16 |
| Whole Period (1950-1951to 2009-10) | 1.52 | 2.26 | 0.74 |

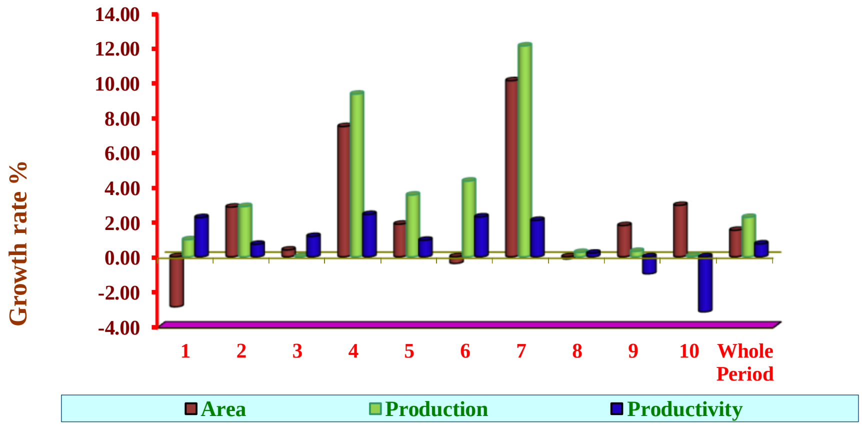


**Fig.8. Plan Period-Wise Relative Growth Rates of Green Gram**

The Table 2 clearly depicts the rate of production of green gram to be having an inconsistent trend as it sees many oscillations initially until seventh plan period after which the vales were not satisfactory since it was almost close to zero. In the ninth and tenth plan period it significantly had low production figures in spite of some considerable area under cultivation. It might have been less because of the low productivity of the land, since productivity showed negative values of -0.98 and -3.16 respectively. The low productivity might have accounted cause of very high production value in eighth plan period which might have absorbed the nutrients of the soil.

Also from table 2 it can be concluded that the production rate was directly proportional to under crop field in most of the cases, provided the productivity of the soil was good. The soil should be given time to replenish its nutrients by switching the crops or by following some external fertilization practices, in order to maintain high productivity.

The percentage growth rate values obtained during the years 1950-1951 to 2009-10 for the three phases when averaged showed that production increased with a rate of 2.26, which was attributed to the combined impact of area and productivity with a rate of 1.52 and 0.74 per cent per year, respectively.

### 3.3. Trends and Growth Rate of Red Gram Crop

Unlike Black and Green Gram the optimum bandwidth values for Red Gram had distinct values of 0.07, 0.10 and 0.05 for the three phases respectively. At each point in time, nonparametric estimates of the underlying growth function were calculated. Residual analysis showed that the premises of error independence were not violated at a 5% point of significance. The RMSE, MAE, MSE and AFER values for area were 7.30, 5.29, 53.23 and 7.92, respectively, similarly for production it showed 7.08, 5.16, 50.15 and 13.37 respectively, while for productivity the values were 61.33, 39.79, 3761.47 and 6.71, respectively. The graph for the fitted trend in the three phases has been depicted in Figures 9, 10 and 11, respectively.

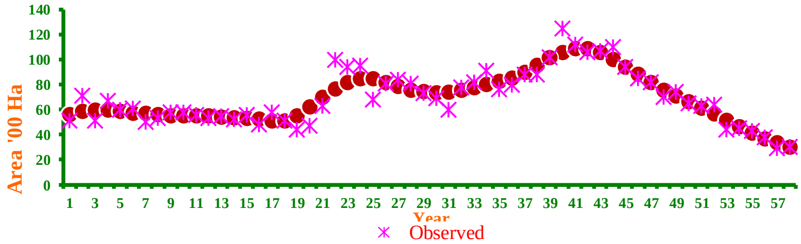


**Figure 9. Trends in Area of Red Gram**

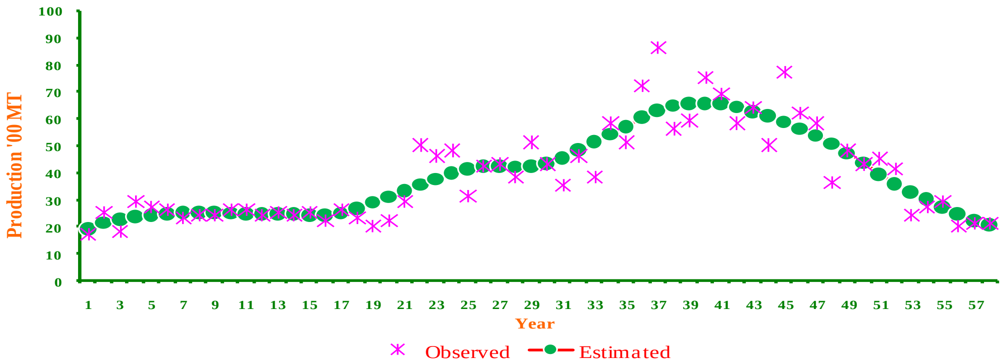


**Figure 10. Trends in production of Red Gram**

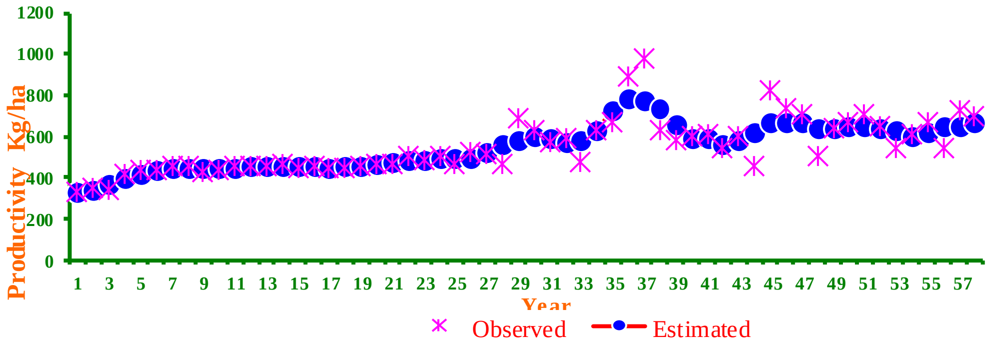


**Figure 11. Trends in Productivity of Red Gram**

Again the Relative growth rates of the three phases of Red Gram have been estimated for the consecutive years starting from 1950-1951to 2009-10 based on the nonparametric regression model. The relative growth rate for each year for productivity was also measured on a yearly basis, for every fifth plan period starting from 1951-52 to 1955-56, and the average five-year period for each plan was estimated and shown in Table 3 and shown in Figure 12.

**Table 3. Plan Period-Wise Relative Growth Rates of Red Gram**

| Period | Area (%) | Prod$^{un}$ (%) | Prod$^{ty}$ (%) |
|---|---|---|---|
| Ist Plan for Five Years (1951-52 to 1955-56) | -1.48 | 2.11 | 4.64 |
| IInd Plan for Five Years (1956-57 to 1960-61) | -0.40 | -0.23 | 0.43 |
| IIIrd Plan for Five Years (1961-62 to 1965-66) | -1.35 | -0.34 | -0.21 |
| IV th Plan for Five Years (1969-70 to 1973-74) | 5.06 | 5.77 | 1.20 |
| Vth Plan for Five Years (1974-75 to 1978-79) | -2.81 | 0.63 | 4.29 |
| VI th Plan for Five Years (1980-81 to 1984-85) | 3.01 | 6.75 | 7.49 |
| VIIth Plan for Five Years (1985-86 to 1989-90) | 5.24 | 0.33 | -6.98 |
| VIIIth Plan for Five Years (1992-93 to 1996-97) | -7.06 | -4.97 | 1.11 |
| IX th Plan for Five Years (1997-98 to 2001-02) | -8.06 | -9.07 | -0.22 |
| X th Plan for Five Years (2002-03 to 2009-2010) | -10.83 | -9.73 | 2.29 |
| Whole Period (1950-1951to 2009-10) | -1.30 | -0.17 | 1.37 |

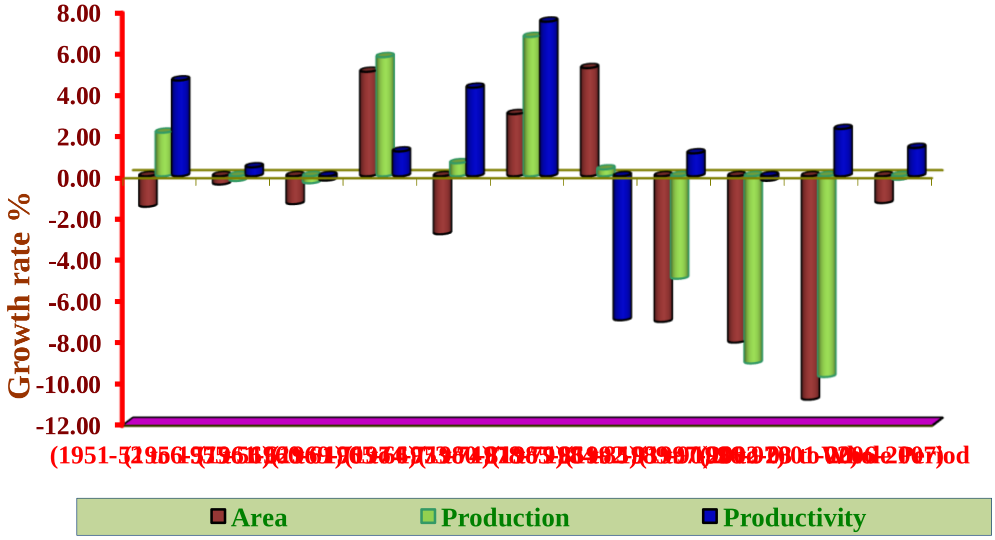


**Figure 12. Plan Period-Wise Relative Growth Rates of Red Gram**

Examining Table 3 for the three phases during the five year plan period of the Red Gram crop, it revealed dramatic results. Apart from fourth, sixth and seventh period the area under cultivation for the crop was negative. This clearly gives us many conclusions. Firstly it showed that the farmers were not much interested in planting the crop since it might not have satisfactory demand in the market. Secondly it can be inferred that as the years passed by the use and the price of Red Gram in market might have dropped since the area and production showed large negative numbers after seventh plan period.

The reason for low production figures was clearly due to less area under cultivation which was on account of the various factors that were discussed above which might have been the reason but from the fourth and sixth plan period it can be inferred that when the cultivated field was increased it showed good production, owing to the decrease in the demand in the marketplace the production was restricted.

The per cent growth rate values obtained for the consecutive years during 1950-1951to 2009-10 for the three phases when averaged showed that the area and production had decrease at a rate of 1.30 and 0.17, respectively but the productivity increased at a rate of 1.37.

### 3.4. Trends and Growth Rate of Horse Gram Crop

The Optimum bandwidth calculated using cross validation technique showed similar value of 0.5 for area, production as well as for productivity. At each point in time, nonparametric estimates of the underlying growth function were calculated. Residual analysis showed that the premises of error independence were not violated at a 5% point of significance. The RMSE, MAE, MSE and AFER values for area were 10.43, 8.29, 108.74 and 5.58, respectively, also for production they were 6.68, 4.94, 44.66 and 12.51, respectively and 38.73, 25.38, 1499.74 and 7.88 for productivity respectively. The graph of the fitted trends in the three phases have been depicted in the Figures 13, 14 and 15, respectively

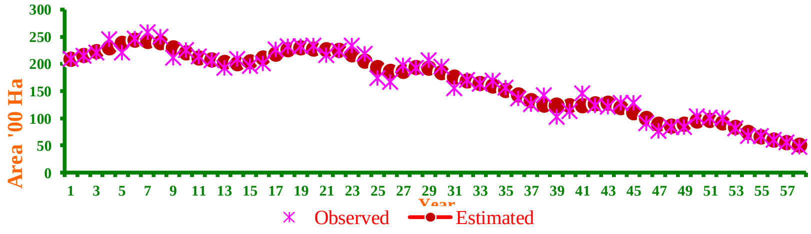


**Figure 13. Trends in Area of Horse Gram**

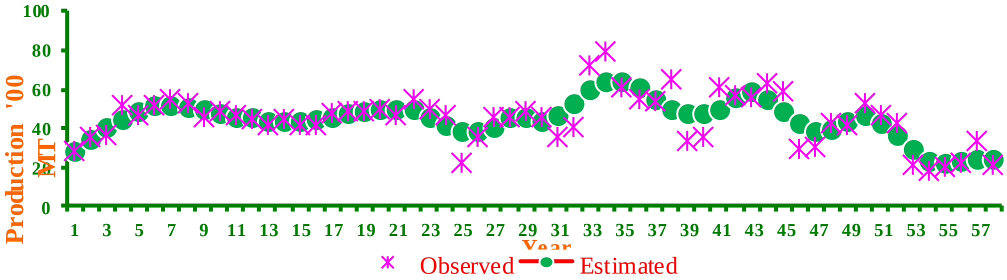


**Figure 14. Trends in Production of Horse Gram**

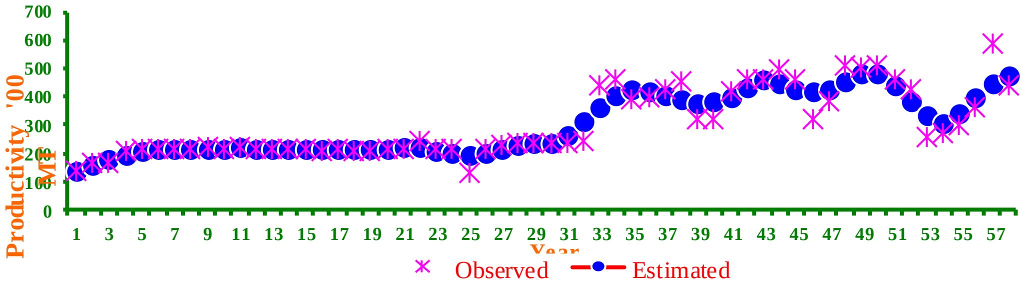


**Figure 15. Trends in Productivity of Horse Gram**

Relative growth rates of the three phases of Horse Gram have been estimated for the consecutive years starting from 1950-1951to 2008-09 based on the nonparametric regression model. The relative growth rate for each year for productivity was also measured on a yearly basis, for every fifth plan period starting from 1951-52 to 1955-56, and the average five-year period for each plan was estimated and shown in Table 4 and shown in Figure 16.

**Table 4. Plan Period-Wise Relative Growth Rates of Horse Gram**

| Period | Area (%) | Prod$^{un}$ (%) | Prod$^{ty}$ (%) |
|---|---|---|---|
| Ist Plan for Five Years (1951-52 to 1955-56) | 2.05 | 6.70 | 4.78 |
| IInd Plan for Five Years (1956-57 to 1960-61) | -3.67 | -3.24 | 0.32 |
| IIIrd Plan for Five Years (1961-62 to 1965-66) | 1.98 | 1.32 | -0.57 |

| | | | |
|---|---|---|---|
| IV th Plan for Five Years (1969-70 to 1973-74) | -4.16 | -6.88 | -2.99 |
| Vth Plan for Five Years (1974-75 to 1978-79) | -0.42 | 3.71 | 4.36 |
| VI th Plan for Five Years (1980-81 to 1984-85) | -4.12 | 4.54 | 8.51 |
| VIIth Plan for Five Years (1985-86 to 1989-90) | -1.33 | -1.16 | 0.15 |
| VIIIth Plan for Five Years (1992-93 to 1996-97) | -7.38 | -6.66 | 0.53 |
| IX th Plan for Five Years (1997-98 to 2001-02) | -1.98 | -11.29 | -9.80 |
| X th Plan for Five Years (2002-03 to 2009-2010) | -10.06 | 1.50 | 11.82 |
| Whole Period (1950-1951to 2009-10) | -2.45 | -0.30 | 2.12 |

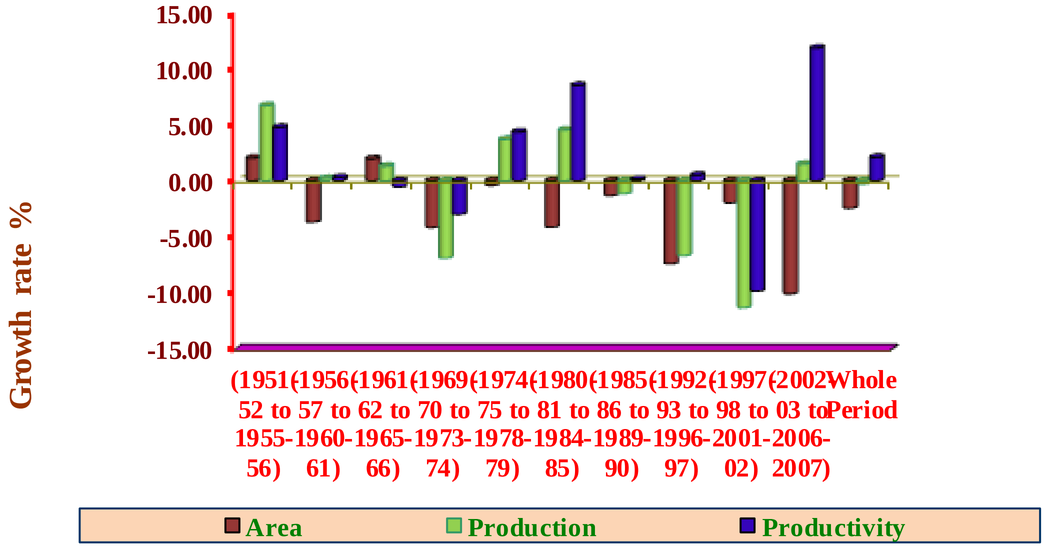


**Figure 16. Plan Period-Wise Relative Growth Rates of Horse Gram**

As seen in the Red Gram case, the Horse Gram table 4 also shows similar dramatic results, leaving the first and third plan period, all other plan period showed negative value of the cultivated field, which again clearly states that the farmers were least interested in allotting their lands for cultivating the Horse Gram, but in the fifth and the sixth plan period the production was high owing to the high productivity of the land during that period and good technological innovations might have prevailed.

The Productivity of the land was only periodically high, i.e. first plan period then again fifth and sixth plan period and later at tenth plan period. When the rate or productivity was high the production was also significantly more, despite of area under cultivation being negative. This shows that even when the area under cultivation is less the production can be high provided there is high rate of land productivity which is periodic, and by using good farming practices.

## 4. Conclusion

After thorough analysis it can be clearly justified that the non-parametric regression model is an apt model for fitting the trend in the three phases of Gram Crop. Since the estimation of the production of crop in future can be done only by studying its growth rate in past, a suitable statistical tool was required to do the same by fitting the trends in growth rate of the crop and with valid justification we proved that nonparametric regression model is an apt tool for doing the same owing to the fact that it had the least values of RMSE, MAE, MSE and AFER which is desirable.

The per cent growth rate values obtained for the consecutive years during (1950-1951to 2009-2010), for the three phases when averaged which showed that an increase in the area (2.89) and productivity (3.21) contributed for high growth rate in production (6.00) of Gram crop across the state of Tamil Nadu.

Today, the primary aim of this paper is to develop a holistic understanding of the issues affecting the overall production of pulse, the value chain, agro-food policy reforms, an increased need for more input-side R&D and food processing, awareness-raising and interest of consumers, policy makers, the food industry and NGOs in the pulse sector and their health, nutrition and the environment.

## References

A paper on Agronomy by Dr. I.P.S Ahlawat, Head- Dept. Of Agronomy, IARI, New Delhi. http://nsdl.niscair.res.in/bitstream/123456789/505/1/GRAM+-+.

Dr. S Kannaiyan, published in "Centre for Plant Breeding and Genetics", Tamil Nadu Agricultural University, Coimbatore. http://www.tnau.ac.in/tech/pulsesbook.pdf

V. Epanechnikov, "Nonparametric estimate of multivariate probability density", Theory of probability and its applications, vol. 14, (1969), pp. 153-158.

J. Fan, "Design adaptive nonparametric regression", J. Amer. Statist. Assoc., vol. 87, (1992), pp. 998-1004.

T. Gasser, and H.G. Muller, "Estimating regression functions and their derivatives by the kernel method" Scandinavian Journal of Statistics, vol. 11, (1984), pp. 11-185.

W. Hardle, "Applied Nonparametric Regression" Cambridge Univ. Press, (1990).

C.T. Jose, B. Ismail, and S. Jayasekhar, "Trend, Growth rate, and Change point Analysis – A Data Driven Approach", Communications in Statistics- Simulations and Computation, vol. 37, (2008), pp. 498-506.

M.B. Prestely, and M.T. Chao, "Nonparametric function fitting", Journal of Royal Statistical Society, Series B, vol. 34, (1972), pp. 385-39.