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**Research Article**

# CLASSIFYING THE STATES OF INDIA THROUGH RICE, WHEAT, AND GROUNDNUT USING STATISTICAL GRAPHICS

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**Abstract:** The purpose of this study is to classify the states of India on the basis of three principle crops *viz.* rice, wheat, and groundnut using statistical graphics. In order to do that the three different indices of area, production, and productivity are devised at first. Thereafter a scatter plot is depicted considering 'area index' as independent variable and 'productivity index' as dependent variable and then a linear regression line is being fitted along with confidence band for classification of the states. The classification of Indian states in such a way acts as a rudimentary input to the planners and policymakers responsible for designing efficient agricultural policies, and for making significant decisions concerning procurement, storage, public distribution, import, export, and other important related issues.

**Keywords:** *Change Point, Index Number, Regression, Statistical Graphics*

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## Introduction

Agriculture, in general, is significance in terms of social, environmental and economic. It's known as a livelihood provider for about 40 percent of the world population. The developing countries are mostly dependent on agriculture directly and/or indirectly due to the huge number of rural areas percentages. In developing countries' economies, agriculture accounts for 40 percent of gross domestic product (GDP) and employs nearly 80 percent of the labour force [1].

India's economy is primarily contingent on agriculture which accounts for about 17-18 percent of India's gross domestic product (GDP) and provides sufficient employment to 50-60% of the total population. The agriculture sector is considered as the single largest contributor to income and employment generation and a essential part in the country's challenge to achieve self-sufficient in food production as well as to reduce rural poverty and foster sustainable economic development. Due to the potency of agriculture to transform the Indian economy and improve upon the living standards of the local populace, Government of India has therefore conceded the highest priority to this sector to enable India to meet these challenges and to make this sector commercially viable as well as profitable.

This study was based entirely on secondary data comprising of area, production and productivity of three principals' crops *viz.* rice, wheat, and groundnut in the states of India. India is well known all over the world as the second producer of rice and wheat after China. Groundnut is the most important oilseed crop and in terms of cultivation and production India recorded second place after China. The position of India regarding these crops has call for vital statistics on area, productivity, and production. Therefore, information on the area, productivity, and production as well as agricultural states will play a very principal role in planning and allocating resources for the development of the agricultural sector and food security.

Being able to classify the states allows us to understand food security, the ability to produce enough food to meet human needs in the future.

The states classification will also act as a rudimentary input to the planners and policymakers responsible for designing efficient agricultural policies, and for making significant decisions concerning storage, import and export, income distribution among farmers, public distribution, rural development and other important related issues.

There are several authors that have analysed the trends in terms of area, production and yield of different crops grown in different regions of the world [2-4], such information can aid the policy makers in recommending policies leading to a sustainable increase in food production [5,6]. Based on this background, the objective of this study is to classify the states of India on the basis of three major crops *viz.* rice, wheat, and groundnut using statistical graphics.

## Materials and methods

### Data Collection

The relevant secondary data for area, production and productivity of three principal crops *viz.* rice, wheat, and groundnut for the period 1966-2016 were collected from the Directorate of Economics and Statistics, Government of India.

Construction of Index Numbers

The trend of area, production and productivity of the 50 years data are converted into index number, a statistical instrument which is used to measure the difference of a phenomenon in relative changes from time to time. The usual formula for constructing an index number is defined as

*Index Number= [Current Year / Base Year] ×100* (1)

However, the base year refers to the year in which an index number begins to be calculated. Determination of base year is always a challenging problem as because it should not be affected by natural catastrophes and free from any kind of culpability. Thus, to determine a precise base year an objective approach is being adopted, which is discussed in the next section.

**Determination of Base Year using Change Point**

In determining base year, ordered sequence of data was assumed as $y1:n=y1,...,yn$ and change point (Base Year) was said to occurred within this data set when there exists a time, $T\in\{1,...,n-1\}$ such that the statistical properties of $\{y1,...,yT\}$ and $\{y(T+1),...,Tm\}$ are different in some way. Now, suppose we have a number of change point, *(say) m*, together with their positions, $T1:m=T1,...,Tm$. Each change point is an integer between 1 and $n-1$ inclusive. Let us defined $T_o=0$ and $T_{m+1}=n$, and assumed that the change points are ordered so that $Ti<Tj$. Consequently, the m change points split the data into $m+1$ segment, with the $i^{th}$ segment containing data. The parameter associated with the segment was denoted $\{\theta_i,\varphi_i\}$, where $\varphi_i$ is a set of nuisance parameters and $\theta_i$ was the set of parameter that contained the change (*i.e.*, Base Year) [7]. Once the base year is identified then the construction procedure of different indices are given below.

$$Area\ index\ (a_i)=\left(\frac{\sum_j a_{ij}}{\sum_j a_{i0}}\right)\times 100 \qquad (2)$$

where $a_{ij}$ and $a_{i0}$ represents Area under the $i^{th}$ crop during the $j^{th}$ year and Area under the $i^{th}$ crop during the base year respectively.

$$Production\ index\ (p_i)=\left(\frac{\sum_j p_{ij}}{\sum_j p_{i0}}\right)\times 100 \qquad (3)$$

where $p_{ij}$ and $p_{i0}$ denotes production of the $i^{th}$ crop during the $j^{th}$ year and production of the $i^{th}$ crop during the base year respectively.

$$Productivity\ index\ (pd_i)=\left(\frac{\sum_j pd_{ij}}{\sum_j pd_{i0}}\right)\times 100 \qquad (4)$$

where $pd_{ij}$ and $pd_{i0}$ indicates productivity of the $i^{th}$ crop during the $j^{th}$ year and productivity of the $i^{th}$ crop during the base year respectively.

**Classifications of States through Statistical Graphics**

To identify the states which are having a statistically higher or lower percentage of productivity for a given percentage of area, drawing appropriate statistical band around the fitted regression line can provide us with an objective method for the said purpose. The band would act as a guard line and helps in detect the points that differ significantly from their expected values. This band also eliminates any chance of manipulation of the scales along the y-axis, which may make a point look closer or far away from the hypothetical straight line.

The computed indices mentioned in the section 2.1 were used in the analysis of simple regression as well as graphical representation of line fitting along with confidence bands for the three major crops. In order to do that 'area index ($a_i$)' is considered as an independent variable and 'productivity index ($pd_i$)' as the dependent variable[1]. Therefore, a simple linear regression equation is fitted as

$$y=b_0+b_1x+e \qquad (5)$$

where y is the productivity index ($pd_i$) and x is the area index ($a_i$). The constants $b_0$ and $b_1$ represents intercept and regression coefficient respectively. The 'e' represents the estimate of the true value of the random term u. The variance of the linear equation model is

$$var(y)=\sigma_u^2\left\{1+\frac{1}{n}+\frac{(x-\bar{x})^2}{\sum(x-\bar{x})^2}\right\} \quad (6)$$

Where $\sigma_u^2$ represents the variance $u=\frac{\sum e^2}{(n-k)}$, $n$ and $k$ denote the number of sample observations and number of parameters to be estimated respectively.

The standard error of the model is $S_{(y)}=\sigma_u^2\sqrt{1+\frac{1}{n}+\frac{(x-\bar{x})^2}{\sum(x-\bar{x})^2}}$ and having established that, the 95% confidence interval for the true graphical representation of regression line fitting along with confidence bands (upper and lower confidence bounds for all points on a fitted line within the data range) is

$$y\pm(t_{0.025})\left[\sigma_u\sqrt{1+\frac{1}{n}+\frac{(x-\bar{x})^2}{\sum(x-\bar{x})^2}}\right]$$

So, in the scatter plot of ($a_i$, $pd_i$) along with the fitted line and the corresponding bands shall introduce us to those states of India with higher and lower productivity than others. These states of India can be viewed as those which are suffering from uneven and higher or lower levels of productivity.

**Results**

The first approach of the methodology is to identification of the base year using change point. Based on the methodology of change point discussed above, the base years of area, production and productivity for the crop rice are 2000, 2011 and 2003 respectively. The graphical representations of change point identification can be seen in Appendix-1. Similarly, the base years of area, production and productivity for the crop wheat are 2011, 2003 and 2015 respectively. Its graphical representations are presented in Appendix-2. Finally, the base years of area, production and productivity for the crop groundnut are 2003, 2013 and 1997 respectively. Its graphical representations are presented in Appendix-3. Thus, the calculated indices of area, production and productivity for the crops rice, wheat, and groundnut of Indian states are given in the [Table-1, Table-2, and Table-3] and their graphical representation respective below.

The indices values enable us to arrive at a single representative value which indicates relative movements of the data with respect to time (*i.e.* base year). The indices value greater than 100 indicates the relative increase and less than 100 indicates the relative decrease of a phenomenon with respect to time. For example, to interpret an index value 110.7 means there is a 10.7 % increase in the phenomenon with respect to the base year. After computing the indices of area, production and productivity for rice, wheat, and groundnut crops, a simple linear regression analysis is performed considering 'area index' as independent variable and 'productivity index' as dependent variable [Table-4, Table-5 and Table-6].

Table-1 *Indices of area, production and productivity for rice of Indian states*

| India States/UT | Rice | | |
|---|---|---|---|
| | Area | Production | Productivity |
| Andhra Pradesh | 49.6 | 57.8 | 117.6 |
| Arunachal Pradesh | 110.5 | 86.3 | 129.5 |
| Bihar | 91.3 | 115.0 | 162.0 |
| Assam | 77.8 | 104.7 | 113.8 |
| Chhattisgarh | 101.6 | 133.5 | 144.5 |
| Goa | 71.3 | 92.9 | 85.8 |
| Gujarat | 143.4 | 107.8 | 121.9 |
| Haryana | 131.5 | 118.5 | 116.9 |
| Himachal Pradesh | 91.4 | 111.4 | 132.7 |
| Jammu & Kashmir | 116.1 | 105.0 | 104.0 |
| Jharkhand | 115.8 | 122.7 | 132.2 |
| Karnataka | 69.7 | 65.9 | 106.1 |
| Kerala | 49.3 | 76.8 | 61.0 |
| Madhya Pradesh | 134.0 | 189.8 | 181.4 |
| Maharashtra | 101.6 | 109.5 | 109.3 |
| Manipur | 155.4 | 72.8 | 73.0 |
| Meghalaya | 104.3 | 93.8 | 99.8 |
| Mizoram | 71.1 | 113.3 | 86.7 |
| Nagaland | 137.8 | 88.0 | 101.8 |
| Orissa | 86.9 | 143.4 | 144.4 |
| Punjab | 111.0 | 109.9 | 108.2 |
| Rajasthan | 118.9 | 178.7 | 138.5 |
| Sikkim | 70.4 | 94.3 | 128.1 |
| Tamil Nadu | 69.4 | 31.8 | 71.1 |
| Telangana | 102.4 | 100.3 | 93.0 |
| Tripura | 114.8 | 113.4 | 135.3 |
| Uttarakhand | 83.5 | 106.1 | 124.3 |
| Uttar Pradesh | 101.4 | 98.1 | 104.9 |
| West Bengal | 101.1 | 104.8 | 111.2 |
| Andaman and Nicobar Islands | 45.0 | 52.5 | 88.6 |
| Dadra and Nagar Haveli | 104.4 | 172.0 | 133.2 |
| Delhi | 98.4 | 58.4 | 169.2 |
| Daman & Diu | 90.0 | 60.6 | 52.6 |
| Pondicherry | 62.1 | 124.0 | 120.6 |

The indices of area, production, and productivity of rice presented in the [Table-2] and its graphical representation in [Fig-1] shown that a few states discerned increased in rice area namely; Arunachal Pradesh, Gujarat, Haryana, Jammu & Kashmir, Jharkhand, Madhya Pradesh, Manipur, Nagaland, Punjab, Rajasthan, Tripura, Dadra and Nagar Haveli. The state that recorded maximum change in area is Manipur. States that recorded declined in area are Andhra Pradesh, Bihar, Assam, Goa, Himachal Pradesh, Karnataka, Kerala, Mizoram, Orissa, Sikkim, Tamil Nadu, Uttarakhand, Andaman and Nicobar Islands, Delhi, Daman & Diu, Pondicherry. In the case of productivity only few states that show declined namely; Goa, Karela, Manipur, Meghalaya, Mizoram, Tamil Nadu, Telangana, Andaman and Nicobar Islands, Daman & Diu. The state that recorded maximum change in productivity is Madhya Pradesh.

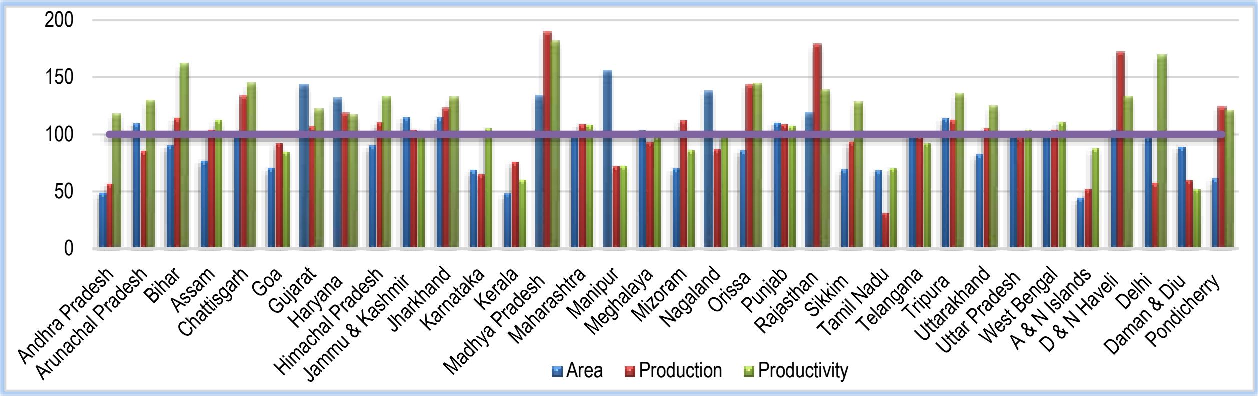


Fig-1 Graphical representation of Indices values for rice of Indian states

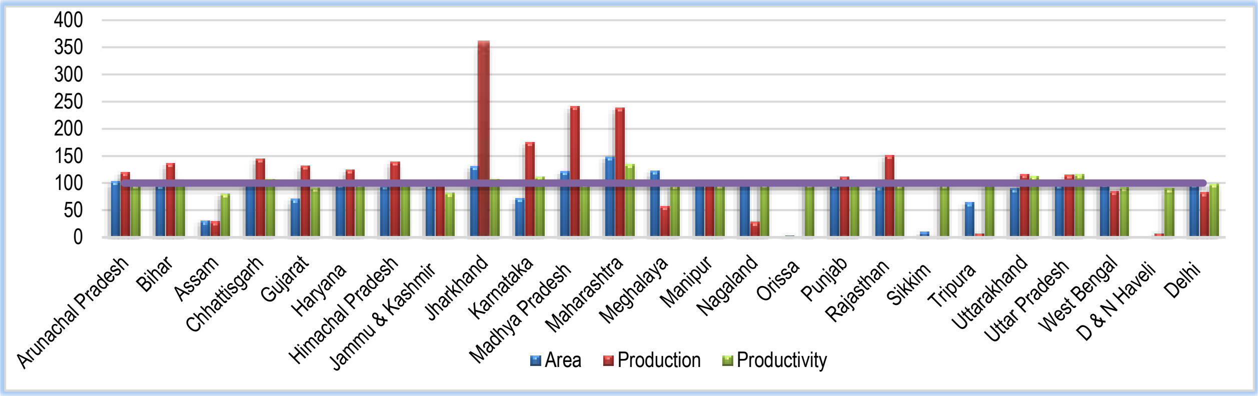


Fig-2 Graphical representation of Indices values for wheat of Indian states

Table-2 *Indices of area, production and productivity for wheat of Indian states*

| India States/UT | Wheat | | |
|---|---|---|---|
| | Area | Production | Productivity |
| Arunachal Pradesh | 105.4 | 122.2 | 100 |
| Bihar | 98.3 | 138.5 | 108.2 |
| Assam | 33.3 | 32.2 | 82.3 |
| Chhattisgarh | 105.7 | 146.9 | 109.5 |
| Gujarat | 73.6 | 134.4 | 93.8 |
| Haryana | 101.4 | 126.7 | 102.4 |
| Himachal Pradesh | 97.1 | 141.4 | 103.8 |
| Jammu & Kashmir | 98.0 | 103.5 | 84.1 |
| Jharkhand | 133.4 | 360.3 | 109.6 |
| Karnataka | 74.7 | 177.8 | 113.5 |
| Madhya Pradesh | 123.3 | 243.6 | 101.5 |
| Maharashtra | 150.9 | 241.02 | 136.9 |
| Meghalaya | 125 | 60 | 98.0 |
| Manipur | 104.5 | 103.7 | 100 |
| Nagaland | 106.3 | 31 | 100.5 |
| Orissa | 6.7 | 1.3 | 100.7 |
| Punjab | 99.1 | 113.5 | 102.6 |
| Rajasthan | 96.4 | 152.9 | 100 |
| Sikkim | 12 | 3.7 | 98.5 |
| Tripura | 66.7 | 9.8 | 102.9 |
| Uttarakhand | 92.4 | 118.4 | 114.6 |
| Uttar Pradesh | 99.2 | 117.6 | 118.1 |
| West Bengal | 101.9 | 87.5 | 94.9 |
| Dadra and Nagar Haveli | 0 | 10 | 92 |
| Delhi | 101.0 | 85.2 | 100.3 |

To recognize the trends of area, production and productivity in terms of wheat for different states of India, the three different indices were constructed for area, production and productivity by using each base year respectively and these indices of area, production, and productivity of wheat are presented in the [Table-2] and its graphical representation in [Fig-2].

It has been discovered that only few states recorded increased in the wheat area namely Jharkhand, Madhya Pradesh, Maharashtra, Meghalaya and Nagaland. The remaining states show declined in area and Orissa and Sikkim states are the worst in terms of area.

Table-3 *Indices of area, production and productivity for groundnut of Indian states*

| India States/UT | Groundnut | | |
|---|---|---|---|
| | Area | Production | Productivity |
| Arunachal Pradesh | 600 | 83.3 | 158.5 |
| Andhra Pradesh | 77.3 | 87.2 | 105.7 |
| Bihar | 140.0 | 77.8 | 86.0 |
| Chhattisgarh | 73.8 | 101.1 | 127.6 |
| Goa | 84.8 | 104.5 | 147.9 |
| Gujarat | 80.1 | 60.1 | 135.6 |
| Haryana | 226.7 | 59.7 | 120.2 |
| Himachal Pradesh | 100.0 | 50 | 56.6 |
| Jammu & Kashmir | 0 | 100 | 209.9 |
| Jharkhand | 111.9 | 91.4 | 189.7 |
| Karnataka | 83.8 | 95.2 | 114.4 |
| Kerala | 250.0 | 144.4 | 170.2 |
| Madhya Pradesh | 97.2 | 101.9 | 156.7 |
| Maharashtra | 83.0 | 95.1 | 111.8 |
| Manipur | 200 | 61.5 | 235.1 |
| Nagaland | 40 | 88.9 | 101.5 |
| Odisha | 74.2 | 91.0 | 132.9 |
| Punjab | 38.6 | 125 | 173.3 |
| Rajasthan | 154.0 | 89.2 | 168.4 |
| Tami Nadu | 60.3 | 100.1 | 158.6 |
| Telangana | 119.2 | 90.1 | 142.6 |
| Tripura | 85.7 | 100 | 96.8 |
| Uttarakhand | 33.3 | 91.7 | 110.7 |
| Uttar Pradesh | 99.7 | 102.3 | 108.2 |
| West Bengal | 154.2 | 75.8 | 170.2 |
| Pondicherry | 30.8 | 88.9 | 147.7 |

It is also recorded from the result that few states observed increased in productivity namely Bihar, Chhattisgarh, Jharkhand, Karnataka, Maharashtra, Uttarakhand, and Uttar Pradesh. The Maharashtra state recorded the maximum change in both area and productivity.

These indices of area, production, and productivity of groundnut presented in the [Table-3] and its graphical representation in [Fig-3] proven that a few states discerned increased in the area namely; Arunachal Pradesh, Bihar, Haryana, Jharkhand, Kerala, Manipur, Rajasthan, Telangana, and West Bengal. The state that recorded the maximum change in area is Arunachal Pradesh.

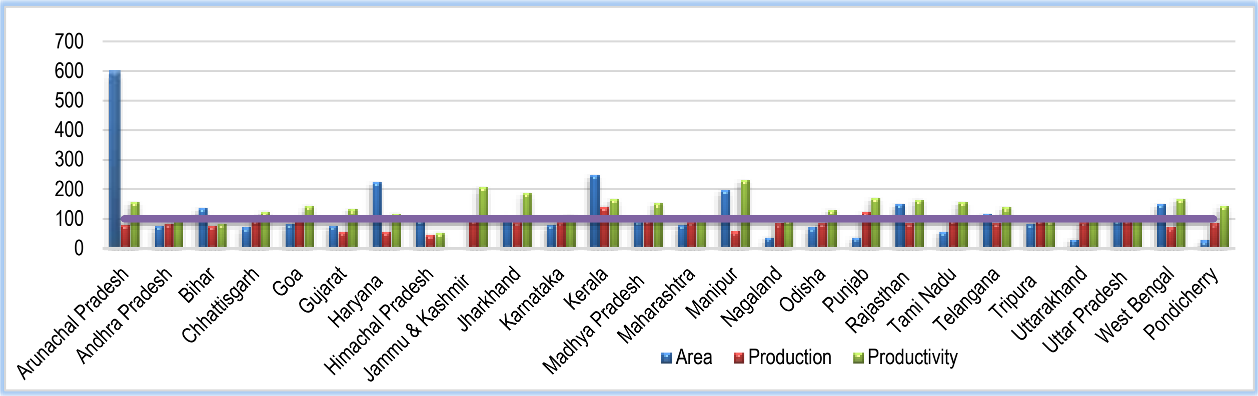


Fig-3 Graphical representation of Indices values for groundnut of Indian states

It is observed also from the result that only few states recorded declined in productivity namely; Andhra Pradesh, Bihar, Himachal Pradesh, Nagaland, and Tripura. Manipur and Himachal Pradesh recorded the maximum and minimum change in productivity respectively.

Afterwards, a simple linear regression analysis is performed for both crops by considering area as independent variable and productivity as dependent variable and the main objective of this regression analysis is to examine whether area plays a prime role to determine the productivity or not.

Table-4 *Regression analysis for the crop rice*

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept ($b_0$) | 54.585 | 20.544 | 2.657 | 0.012 |
| Area ($b_1$) | 0.504 | 0.204 | 2.463 | 0.019 |

Table-5 *Regression analysis for the crop wheat*

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept ($b_0$) | -19.746 | 31.345 | -0.629 | 0.534 |
| Area ($b_1$) | 1.521 | 0.327 | 4.652 | 0.000 |

Table-6 *Regression analysis for the crop groundnut*

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept ($b_0$) | 137.865 | 8.405 | 16.402 | 1.52765E-14 |
| Area ($b_1$) | 0.002 | 0.003 | 0.692 | 0.495 |

From the above tables, it has been observed that the p-value corresponding to area in [Table-4 and Table-5] are less than 0.05. It indicates that area has some significant impact to determine the productivity. The p-value recorded in [Table-6] corresponding to area is 0.495 which is greater than 0.05 (*i.e.* 0.495 > 0.05). Thus, we can conclude that area has no significant impact to determine the response variable productivity of groundnut. Also, the positive coefficient values of area in all the tables strongly point out that there is a positive relationship between area and productivity which means that if area increases then productivity will also increase. Therefore, we fitted a regression line along with confidence bands for the crop rice [Fig-4], wheat [ Fig-5], and groundnut [Fig-6].

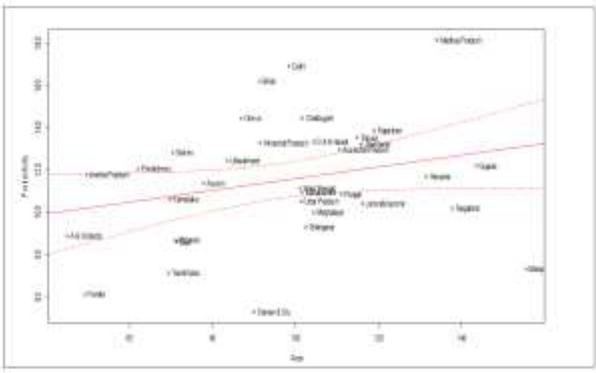

Fig-4 Fitting of regression line along with confidence bands for rice

From the above scatter plot along with fitted regression line and confidence bands, one can easily identify the states which have less productivity despite of being adequate increasing area trend. There are total seven (7) states that are having significantly higher area but lower in terms of productivity. They are Manipur, Meghalaya, Telangana, Nagaland, Punjab, Jammu & Kashmir, and Uttar Pradesh. Moreover, amongst all the states of India, Madhya Pradesh stands best and Kerala stands worst in terms of area as well as productivity for Rice.

However, there are ten states that have performed reasonably well in terms of productivity despite of being decreasing trend of area. They are Andhra Pradesh, Pondicherry, Karnataka, Sikkim, Assam, Uttarakhand, Orissa, Bihar, Delhi and Himachal Pradesh.

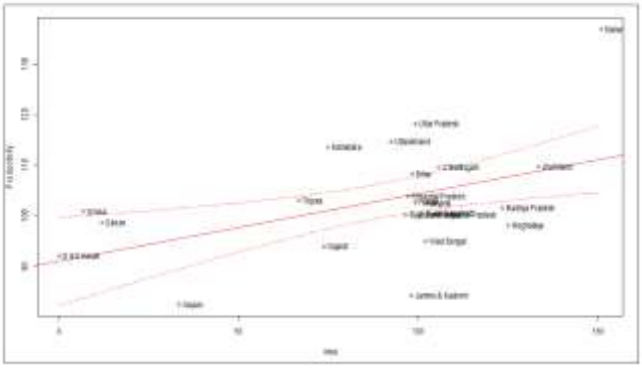

Fig-5 Fitting of regression line along with confidence bands for wheat

From the graph, it can easily be discerned that there are nine (9) states that are having significantly higher area but lower in terms of productivity. They are Meghalaya, West Bengal, Rajasthan, Nagaland, Delhi, Arunachal Pradesh, Jammu & Kashmir, Madhya Pradesh, and Manipur. Also, amongst all the states, Maharashtra stands best and Assam stands worst in terms of area as well as productivity for wheat. Nevertheless, there are twelve states that have performed well in terms of productivity despite of being decreasing trend of area. They are Haryana, Himachal Pradesh, Sikkim, Tripura, Dadra and Nagar Haveli, Punjab, Orissa, Karnataka, Bihar, Chhattisgarh, Uttar Pradesh, and Uttarakhand.

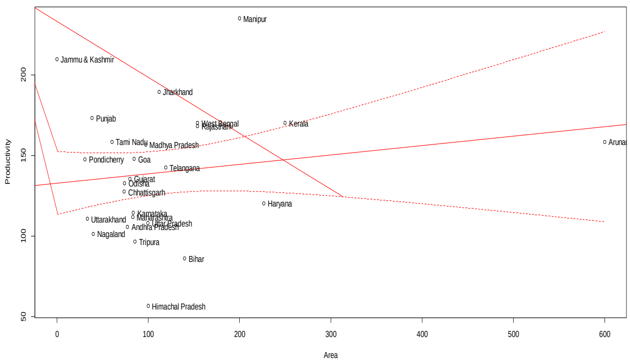


Fig-6 Fitting of regression line along with confidence bands for groundnut

From the above graphical depiction, it is confirmed that some states recorded less productivity despite of being adequate increasing area trend statistically. There are ten (10) states that are having significantly higher area but lower in terms of productivity.

They are Uttarakhand, Tripura, Karnataka, Andhra Pradesh, Uttar Pradesh, Maharashtra, Nagaland, Bihar, Haryana, and Himachal Pradesh. Amongst all the states, Manipur stands best and Himachal Pradesh stands worst in terms of area as well as productivity for groundnut.

Nonetheless, there are 16 states that have significantly performed well in terms of productivity despite of being decreasing/increasing trend of area statistically. They are Arunachal Pradesh, Chhattisgarh, Goa, Gujarat, Odisha, Telangana, Pondicherry, Rajasthan, Manipur, Kerala, West Bengal, Jharkhand, Jammu & Kashmir, Punjab, Tami Nadu, and Madhya Pradesh.

**Discussion**

The decreased in both area and productivity for the crops rice, wheat, and groundnut recorded by some states are may be due to several factors, such as like lack of utilization of available technologies, non-adoption of available hybrid seeds, poor management of pest and disease, holding onto the traditional system of farming, and effect of natural disasters especially flood which is very usual in most of the states in India. It was recorded that some states also witnessed a serious dry spell or flood at a certain period of the years during production which affected the area and productivity. Maharashtra, West Bengal, Uttar Pradesh, Madhya Pradesh, Rajasthan, Karnataka, Assam, Andhra Pradesh, Gujarat, and Bihar are known to be the most vulnerable to the natural disasters in India.

The inefficient and ineffective utilization of the available technologies by producers always resulted in lower efficiencies of productivity and this fact has been highlighted in many studies, especially on cereals and pulses [8-17]. This is an indication that the states that recorded area decreased but increased productivity is as result of efficient and effective use of available technologies.

Another significant factor that may accounted for decreased productivity in some states of India is the transformation of agricultural lands into non-agricultural uses which has also resulted in a decreased in the area under cultivation.

There are inadequate government policies in the agricultural sector affecting productivity. Classifies agricultural policies into two groups: those that correct for market failures, lower transaction costs, or enhance productivity, and other policies that result from manipulation by special interest groups.

However, it is not an indication that an increase in the area will cause productivity to increase as because some states have recorded an increase in productivity even though there is a decrease in area.

**Application of research:** This study would be helpful for the investors in the agricultural chain, policymakers, and government in allocating resources and implementing policy measures in the agricultural sector.

**Research Category:** Agricultural Statistics

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Research project name or number: MSc Thesis

**Author Contributions:** All authors equally contributed

**Author statement:** All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

**Study area / Sample Collection:** Assam, India

**Cultivar / Variety / Breed name:** Rice, Wheat, and Groundnut

**Conflict of Interest:** None declared

**Ethical approval:** This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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