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Growth, instability and decomposition of pigeon pea production in India

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Abstract
The research study aimed to investigate and study the growth, instability and decomposition of pigeon pea. The data of area, production and productivity of pigeon pea pertaining to 30 years (1990 to 2023) were made available through the secondary source of economic and statistics division of ministry of agriculture and farmer's welfare, government of India which was further analyzed using, coefficient of variation, exponential function, Cuddy Della Valle's Index and decomposition analysis model. The results have shown that Uttar Pradesh, Telangana, Maharashtra along with Karnataka and Rajasthan have shown positive growth but other states have shown negative growth in area and production and productivity. Andhra Pradesh has shown high instability in all three period mainly in area and production only while Haryana has shown instability in area and production only in period II as same as Maharashtra have shown instability in area and production in period II. Decomposition analysis has shown that area effect was the most domination factor contributing in change in production of pigeon pea as compared to yield effect and interaction.

Keywords: Pigeon pea, productivity, growth, decomposition

Introduction
Pigeon pea is a short duration, *kharif* pulse crop grown in semi-arid parts of the tropics, also known with names as red gram, Tur, Arhar, no eye pea (*Cajanus cajan var. flvus*). India accounts for about 72% of area grown to pigeon pea (Fatokimi *et al*., 2021) [7]. Pigeon pea is highly nutritious crop having 21% protein and 57.6% carbohydrate. Its calorific value amounts upto 350 Kcal/100gm and it is home to several micro and macro nutrient and minerals, helps to provide good amount of nutrition to human body. It is the commonly intercropped with wide range of crops in India. The main generally grown high yielding varities of pigeon pea are BSMR 736, VL Arhar – 1, ICPH – 8 and IPH 09. In India pigeon pea is grown on 3.61 million ha area amount to production of 2.70 million ton with a productivity of 0.75 t per ha. The major pigeon pea growing area are Maharashtra (1.05), Uttar Pradesh (0.50), Karnataka (0.44) with others including Madhya Pradesh, Gujarat, Andhra Pradesh and Haryana (Annual Report, 2020, ICAR). Maharashtra ranks first in Pigeon production with a share of 26.29%. It produces 0.71 million ton of pigeon pea from 1.05-million-hectare area with the productivity of 0.68 ton per hectare (Agricultural Statistics in India magazine, July 2020). While the main producing area is north western India this paper is mainly focusing on the trends and decomposition of pigeon pea production in major pigeon pea producing area of India which comprises of states like Maharashtra, Uttar Pradesh, Madhya Pradesh, West Bengal, Gujarat, Bihar, Jharkhand. Instability in agricultural production is on the rise due to several factors such as erratic rainfall pattern, low irrigation coverage, and increase in frequency and severity of natural disasters. This study aims at studying the growth and instability in eight principal crops of India. These crops are selected because they are of utmost importance for the country. The study has been undertaken to examine the growth rates of area, production and productivity of pigeon pea along with instability and variation in production and productivity of pigeon pea in India. This study is mainly based on secondary source of data published by ministry of agriculture and farmers welfare and Indian council of agricultural research and other agricultural and allied national level institutes and state agricultural universities annual reports.

Selection of sampling area
India has been purposively selected as cultivation area for pigeon pea is witnessing a fluctuating trend in pigeon pea crop cultivation due to shifts in cropping patterns and fragmentation of land to other activities like industrialization and urbanization.

Selection of Period

The data were collected and segregated on area, production and productivity of Pigeon pea pertaining to the period from 1990-2023 (30 years). For the statistical analysis of growth and instability and trends, the entire study period was split into thee sub periods based on the 11 year gap period.

Period I	1990-2001
Period II	2001-2012
Period III	2012-2023
Overall time period	1990-2023

Overall data on Area, Production and Productivity on Pigeon pea

Second set of data on area, production and productivity of Pigeon pea pertaining to 2010-11 to -2020-21 from major pigeon pea producing states.

Period I	2010-2014
Period II	2014-2018
Period III	2018-2022
Overall	2010-2022

State wise data on Area, Production and Productivity on Pigeon pea

Autocorrelation is a common problem in time series data analysis. To test the presence of autocorrelation in data Durbin- Watson statistics were used. The Durbin–Watson statistic is a test statistic used in statistics to determine the presence of autocorrelation at lag 1 in regression analysis residuals (prediction errors). Durbin Watson test for overall data from 1990-2023 have shown that the data in positive serial collinearity (1.985) after comparision of calculated value with critical table value, as assumptions tells that if the watson durbin value (d) is less than 2 then there is presence of positive serial collinearity. In this situation to correct the problem of auto collinearity the Prais-winsten transformation method which is a variation of Cochran-orcutt estimator was followed to increase the efficiency.

Statistical and analytical tools

The present study was based on time series data on area, production and productivity were collected from Ministry of Agriculture and Farmers Welfare and Indian Council of Agricultural Research annual reports and Agricultural Statistics at a glance Publication of the Ministry of Statistics and Implementation

Growth rate

CAGR is the mean annual growth rate of an investment over a specified period of time longer than one year. The compound annual growth rate (CAGR) of Pigeon pea were estimated for area, production and productivity spanning to 30 years (1989-90 to 2021-2022). The CAGR for the same were carried out using the exponential model as mentioned below-

$$Y = a.b^t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where,

Y = Depended variable for which growth rate is to be estimated

A = Intercept

b = Regression Coefficient

c = Time Variable

Transforming equation (1) as follows

$log_{y=} log_a$ + t log $_b$ …… (2)

Then the percent compound growth rate (g) was computed using the relationship.

CAGR = [Antilog (log b)-1] × 100 ……. (3)

The significance of the regression coefficient was tested using the students'' test.

Instability

Instability in agricultural crops depends on production technology, improved variety, nature, economic environment, sensitivity to weather, availability to input.

Coefficient of variation and Cuddy Della Valle's instability indices

However, a simple coefficient of variation does not explain the variation of time series data properly. Therefore, in this study the Cuddy and Della valle instability indices was used. Thus, the equation is as follows,

$$CV = \frac{\text{Standard deviation } (\sigma)}{Mean\ (\bar{x})}$$

CDVI = $CV\sqrt{(1 - R^2)}$=

$$Normal\ co\ efficient\ of\ variation * \sqrt{Unexplained\ Proportion\ of\ variation}$$

Decomposition Analysis

Variance decomposition analysis allows partitioning the total variance in an outcome variable, e.g., firm performance, into several components. In this study decomposition analysis will provide the relative contribution of area and yield to the total output of the pigeon pea crop. Decomposition model analysis used is as follows:

$P_0 = A_0 * Y_0$ and $P_n = A_n * Y_n$……(1)

A_0 and P_0 and Y_0 are abbreviated as area, production and productivity in base year.

A_n, P_n and $Y_{n\ -}$ values of the respective variable in n^{th} year item respectively. Where A_0 and A_{n-} Area, Y_o and $Y_{n\ -}$ yield,

P_n-$P_{0\ =}\ \Delta P$, A_n-$A_{o\ =}\ \Delta A$, Y_{n-} $Y_{o=}\ \Delta Y$…….(2)

Equation (1) and (2) after combination can be rewritten as,

$P_{0\ +}\ \Delta P$= ($A_{0+}\ \Delta A$) (Y_0+ ΔY). It can be *solved as*

$$P = A_0 \frac{\Delta Y}{\Delta P} * 100 + Y_0 \frac{\Delta A}{\Delta P} * 100 + \frac{\Delta Y}{\Delta P} \Delta Y * 100$$

Production = Yield effects = area effects = interaction effects

Results and Discussion

Growth rate of Pigeon pea in India

State-wise compound annual compound growth rates of area, production and productivity of Pigeon pea in India for period I, Period II and Period III and overall were worked out using appropriate statistical tools and presented in table 1. The results from the table 1 have shown that for the period (1990-2023) the area under pigeon pea is increasing along with

production while state wise calculation results shown that among major pigeon growing states Uttar Pradesh, Telangana, Mahrashtra along with Karnataka and Rajasthan are positive growth but other states have shown negative growth in area and production and productivity. The highest growth rate in pigeon pea area is shown by Uttar Pradesh (0.045) and for production and productivity is shown by Andhra Pradesh (0.217), Maharashtra (0.135) and Madhya Pradesh (0.109) respectively. The area production and productivity for whole India during this period is resulted to be for period I (-0.027, 0.026, 0.055), for period II (0.035, 0.11, 0.0731) and for period III (0.017, 0.085, 0.066) respectively.

Table 1: Distribution of compound annual growth rate on area, production, productivity of pigeon pea from (a) 1990-2023, (b) state wise growth rate from 2010-2022

S. No	Particulars		Period 1	Period 2	Period 3	Overall
1.	India	Area	0.001	0.017	0.013	0.007
		Production	-0.006	0.014	0.020	0.015
		Productivity	-0.007	-0.002	0.027	0.009
2	Andhra Pradesh	Area	-0.112	0.165	0.009	
		Production	-0.022	0.120	0.214	
		Productivity	0.100	-0.038	0.217	
3	Assam	Area	-0.038	0	0	
		Production	0.046	-0.044	0	
		Productivity	0.067	-0.030	0.019	
4	Bihar	Area	-0.040	-0.026	-0.015	
		Production	-0.006	0	-0.059	
		Productivity	0.043	0.018	-0.032	
5	Chhattisgarh	Area	-0.018	0.022	-0.073	
		Production	0.066	0.007	0.015	
		Productivity	0.086	-0.014	0.060	
6	Gujarat	Area	-0.066	0.060	-0.014	
		Production	-0.064	0.094	-0.006	
		Productivity	0.002	0.031	-0.001	
7	Haryana	Area	-0.225	-0.096	-0.159	
		Production	-0.201	-0.130	-0.159	
		Productivity	0.021	-0.0002	0.001	
8	Jharkhand	Area	0.173	-0.002	0.009	
		Production	0.303	0.026	0.006	
		Productivity	0.110	0.030	0.031	
9	Karnataka	Area	-0.019	0.050	0.006	
		Production	0.026	0.126	0.037	
		Productivity	0.046	0.072	0.037	
10	Madhya Pradesh	Area	-0.012	0.055	0.008	
		Production	0.191	0.131	0.111	
		Productivity	0.207	0.072	0.109	
11	Maharashtra	Area	-0.032	0.006	0.003	
		Production	0.014	0.116	0.138	
		Productivity	0.048	0.109	0.135	
12	Odisha	Area	0.007	0	-0.021	
		Production	0	0	0.001	
		Productivity	-0.005	-0.0002	0.017	
13	Punjab	Area	-0.069	0	0	
		Production	-0.069	0.106	0	
		Productivity	-0.008	0.027	0.016	
14	Rajasthan	Area	-0.096	-0.019	-0.054	
		Production	-0.133	0.067	0	
		Productivity	-0.03	0.084	-0.025	
15	Tamil Nādu	Area	0.136	-0.091	0.050	
		Production	0.246	-0.084	0.044	
		Productivity	0.099	0.006	-0.023	
16	Telangana	Area	-0.061	0.106	0.015	
		Production	-0.020	0.246	0.088	
		Productivity	0.045	0.126	0.0545	
17	Uttar Pradesh	Area	-0.032	-0.00438	0.047	
		Production	-0.032	0.174	0.015	
		Productivity	0.0005	0.180	-0.021	
18	West Bengal	Area	-0.159	0.257	0	
		Production	0	0.189207	-0.03514	
		Productivity	0.001	-0.024	-0.064	
19	Others	Area	0	0	-0.331	
		Production	-0.159	0.189	-0.300	
		Productivity	-0.041	0.054	-0.031	
20	All India	Area	-0.027	0.035	0.017	
		Production	0.026	0.111	0.085	
		Productivity	0.055	0.0731	0.066	

Instability Analysis

The growth rate alone won't reveal instability because it simply explains the rate of growth over the course of the time, whereas instability determines if the growth performance is stable or unstable for the period for the relevant variable. With the aid of the statistical tools like coefficient of variation and Cuddy Vella instability index, the instability is assessed in order to understand the area, production, and productivity of the pigeon pea crop. Instability of production, area, and productivity of wheat crop have been worked out as per the three period from 2010-2022 discussed in methodology in order to facilitate a better understanding of the magnitude and pattern of changes in the level of production, cropped area, and productivity of crop in the various pigeon pea growing states. Results from Table 2 have revealed that the among the major pigeon pea growing states Andhra Pradesh has high instability in all three period mainly in area and production only while Haryana has shown instability in area and production only in period II as same as Maharashtra have shown instability in area and production in period II but West Bengal is the only state as per the results, which has shown instability in productivity in Period II (0.422 and 0.499, CV and CVDI respectively).

Table 2: Instability in area, production and productivity of Pigeon pea (State wise, Period (2010-2022)

S. No	Particulars		Period 1			Period 2			Period 3		
			A	P	P	A	P	P	A	P	P
1	Andhra Pradesh	CV	0.249	0.280	0.262	0.338	0.232	0.199	0.049	0.352	0.357
		CVDI	0.199	0.342	0.187	0.258	0.219	0.197	0.059	0.363	0.370
2	Assam	CV	0.08	0.163	0.130	0	0.104	0.052	0	0	0.032
		CVDI	0.061	0.154	0.054	0	0.057	0.016	0	0	0.017
3	Bihar	CV	0.086	0.150	0.190	0.120	0.119	0.043	0.058	0.145	0.066
		CVDI	0.067	0.179	0.192	0.130	0.145	0.040	0.053	0.091	0.038
4	Chhattisgarh	CV	0.038	0.169	0.197	0.098	0.118	0.137	0.187	0.095	0.115
		CVDI	0.350	0.114	0.116	0.111	0.132	0.167	0.145	0.116	0.103
5	Gujarat	CV	0.118	0.117	0.086	0.224	0.246	0.054	0.072	0.160	0.090
		CVDI	0.025	0.090	0.103	0.214	0.195	0.019	0.088	0.194	0.108
6	Haryana	CV	0.397	0.365	0.039	0.360	0.556	0.085	0.4	0.4	0.046
		CVDI	0.069	0.051	0.030	0.769	0.680	0.103	0.309	0.309	0.053
7	Jharkhand	CV	0.331	0.471	0.181	0.095	0.121	0.098	0.018	0.045	0.055
		CVDI	0.159	0.190	0.080	0.114	0.115	0.094	0.007	0.051	0.006
8	Karnataka	CV	0.124	0.255	0.178	0.284	0.498	0.321	0.040	0.108	0.074
		CVDI	0.139	0.305	0.181	0.294	0.456	0.309	0.045	0.105	0.053
9	Madhya Pradesh	CV	0.068	0.295	0.289	0.122	0.216	0.117	0.071	0.195	0.186
		CVDI	0.079	0.233	0.158	0.079	0.043	0.030	0.087	0.152	0.091
10	Maharashtra	CV	0.057	0.070	0.109	0.081	0.430	0.363	0.030	0.221	0.209
		CVDI	0.008	0.073	0.068	0.092	0.397	0.309	0.033	0.058	0.010
11	Odisha	CV	0.022	0.044	0.055	0.007	0.015	0.008	0.051	0.016	0.054
		CVDI	0.024	0.052	0.067	0.008	0.018	0.009	0.048	0.018	0.055
12	Punjab	CV	0.153	0.153	0.050	0.4	0.387	0.080	0	0	0.037
		CVDI	0.119	0.119	0.052	0.473	0.407	0.093	0	0	0.021
13	Rajasthan	CV	0.168	0.233	0.143	0.208	0.418	0.296	0.109	0.255	0.192
		CVDI	0.021	0.174	0.173	0.253	0.434	0.254	0.044	0.309	0.235
14	Tamil Nādu	CV	0.267	0.417	0.157	0.160	0.295	0.215	0.094	0.097	0.088
		CVDI	0.170	0.246	0.108	0.054	0.267	0.262	0.026	0.090	0.077
15	Telangana	CV	0.115	0.217	0.247	0.256	0.487	0.288	0.049	0.147	0.134
		CVDI	0.037	0.264	0.245	0.190	0.272	0.170	0.039	0.111	0.150
16	Uttar Pradesh	CV	0.057	0.089	0.086	0.107	0.373	0.315	0.080	0.038	0.045
		CVDI	0.017	0.090	0.105	0.127	0.236	0.103	0.036	0.027	0.041
17	West Bengal	CV	0.400	0.285	0.422	0.387	0.296	0.079	0.117	0.162	0.236
		CVDI	0.309	0.338	0.499	0.182	0.139	0.064	0.139	0.194	0.272
18	Others	CV	0	0.285	0.074	0	0.621	0.516	0.769	0.738	0.071
		CVDI	0	0.221	0.056	0	0.704	0.613	0.421	0.738	0.066
19	Overall	CV	0.054	0.076	0.110	0.153	0.309	0.185	0.035	0.138	0.109
		CVDI	0.032	0.060	0.042	0.150	0.239	0.124	0.015	0.025	0.042

Decomposition analysis

In this study attempt has been made to identify the contribution of area and productivity for change in production of pigeon pea. The study period has been divided in three sub periods and overall taking into consideration the important of each sub period as discussed in methodology. Results from the table 3 has revealed that area effect is the main effect for contributing in production change in major pigeon pea cultivating states in India. Highest area effect have seen in states like Maharashtra (350193.1), Bihar (220000) and Karnataka (53083.3) while the highest yield effect have been observed in Chhattisgarh (318000), West Bengal (143400) and in Haryana (121100) respectively. For interaction effect, the highest is observed in Andhra Pradesh (201140), Telangana (55825) and Jharkhand (24776.8) which have contributed in changing the production of the crop. The results of overall India for decomposition analysis have shown that highest area effect (75420.2) has occurred in period III while yield effect (28707.3) has occurred in period II and highest interaction effect (9372.2) has also occurred in period II.

Table 3: Percent contribution of area, production and productivity and their interaction for change in production of pigeon pea in different states.

S. No	Particulars		Period 1	Period 2	Period 3
1.	Andhra Pradesh	Area effect	-5286.6	-25052.3	1350
		Yield effect	614.2	146327.3	3370.3
		Interaction	201140	-21236.4	4037.0
2.	Assam	Area effect	149800	64800	33500
		Yield effect	0	0	0
		Interaction	-21400	0	6700
3.	Bihar	Area effect	-683800	220000	56342.8
		Yield effect	75700	-287600	26457.1
		Interaction	78900	-22000	-3314.2
4.	Chhattisgarh	Area effect	136714.3	-185500	435200
		Yield effect	-25142.9	318000	-432000
		Interaction	-9942.8	-17500	-115200
5.	Gujarat	Area effect	-3895.3	30421.5	28575
		Yield effect	103221.9	61358.8	211545
		Interaction	942.18	8102.941	-1575
6.	Haryana	Area effect	-15000	200	-1800
		Yield effect	108000	73200	121100
		Interaction	9600	-66.66	900
7.	Jharkhand	Area effect	27707.4	114927.3	804650
		Yield effect	47610.4	47200	152100
		Interaction	24776.8	-1172.7	20400
8.	Karnataka	Area effect	179710.2	53083.3	99855.3
		Yield effect	-67454.2	35488.5	15762
		Interaction	-13513.6	11447.9	2491.3
9.	Madhya Pradesh	Area effect	110749.7	50193.9	97307.3
		Yield effect	-4843.11	37684.7	6233.6
		Interaction	-5446.7	12139.02	2491.3
10.	Maharashtra	Area effect	350193.1	93007.4	97582.6
		Yield effect	-208190	4626.86	2223.26
		Interaction	-43303.4	2382.8	1470.3
11.	Odisha	Area effect	-54000	-13700	108000
		Yield effect	366400	89800	-122640
		Interaction	-8000	-100	-90000
12.	Punjab	Area effect	12800	21400	7400
		Yield effect	92900	92300	107400
		Interaction	-3200	10700	7400
13	Rajasthan	Area effect	33600	-365300	-91000
		Yield effect	76100	-24533.3	-188200
		Interaction	-11200	-9366.6	18200
14.	Tamil Nādu	Area effect	32294.12	-9078.2	-46330
		Yield effect	46729.41	106400	112320
		Interaction	21529.41	2900	-10170
15.	Telangana	Area effect	-247225	43285.71	58061.54
		Yield effect	283616.7	35357.14	15760.26
		Interaction	55825	21642.8	3726.9
16.	Uttar Pradesh	Area effect	-810.5	104014.6	-131406
		Yield effect	31485.71	-1929.9	325200
		Interaction	226.3	-1812.1	-26700
17.	West Bengal	Area effect	1200	-8933.34	136125
		Yield effect	-142300	143400	-192875
		Interaction	-600	-13400	45375
18.	Others	Area effect	30000	38000	18157.8
		Yield effect	0	0	120210.5
		Interaction	0	0	-14526.3
19.	All India	Area effect	22442.8	61851.1	75420.2
		Yield effect	-96889.8	28707.7	18834.8
		Interaction	-23371.9	9372.3	5503.1

Conclusion

Results of the study revealed that growth rates for area and production are increasing but for productivity of the pigeon pea it is steady in India. Pigeon pea area and production in many states is found to be highly instable overtime. Various sources of instability and growth is affecting the agricultural sector, so it is very necessary to identify those factors. For the decomposition analysis it was observed that the area affect was more prevalent than yield and interaction effect for contributing in changing the production of pigeon pea. The efforts are needed to be made to increase the production and cultivated area of pigeon pea. More research and agricultural policy support are needed to increase the production and productivity and reduce the instability. Major policy support

for stabilizing the agricultural situation includes ensuring remunerative price to the farmers for pulses and along with this supply of enough and quality inputs to the farmer's field, could prove the potential of Indian agricultural system.

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