The Pharma Innovation Journal 2023; 12(1): 3058-3061

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(1): 3058-3061

www.thepharmajournal.com
Received: 14-10-2022
Accepted: 16-11-2022

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Growth and instability of soybean in Central India: A district-level analysis

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Abstract
Soybean, one of the most economically important crops in Madhya Pradesh, because of the erratic behavior of climatic factors, is in danger of losing its resilience. Thus, research was conducted to ascertain the risk associated with its production. The results of which revealed that the state as a whole lies in a low instability zone for area and production under crop while in a medium instability zone for productivity. The compound growth rate (CGR) for the area (1.8%), production (2.4%), and productivity (0.60%) of the soybean crop in the state were positive but it is insignificant for production and productivity. The majority of the districts under the study have shown more years in which the yield of soybean was less than the mean yield. While based on the Sustainable Yield Index (SYI) method districts having the most sustainable yield covered a 68.69% area and production of 70.92%.

Keywords: CGR, instability, SYI

Introduction
Having a substantial economic value, soybean is a prominent Kharif crop that is primarily grown in the rainfed condition in India. Moreover, soybean has a major impact on the supply of edible oils in India. India is ranking sixth in soybean production with 11.22 million tons and fourth in the area with 11.34 million hectares (2019–20). It accounts for 9.41 percent of the global area (Soybean Outlook, 2022). Currently, the production of soybeans make up 25 percent of the country's total oil production and 43 percent of its total oilseed production (FICCI Report). With 55.84 lakh ha of area, Madhya Pradesh was the largest state in terms of area under soybean cultivation, followed by Maharashtra (46.01 lakh ha), Rajasthan (10.62 lakh ha), Karnataka (3.82 lakh ha), Gujarat (2.24 lakh ha), and Telangana (1.51 lakh ha). The soybean has long been a significant crop in Madhya Pradesh. Soybean is a major rainy-season crop in the rainfed agro ecosystems of central and peninsular India (Agarwal *et. al.*, 2013) [1]. Erratic rainfall patterns, temperature variations throughout critical stages of plant growth, relative humidity, etc. not only hinder productivity but are also prone to high biotic and abiotic stress that results in reduced production levels. Because of the increasing risk in the production of soybean in Madhya Pradesh in some areas, farmers have shifted from soybeans to corn or jowar in recent years (Hugar, 2011) [8]. The monsoon is crucial to the rain-fed crop of soybean. The yield of the soybean crop is impacted by climate conditions, as well as the expansion and contraction of the area of cultivation under the crop. When the monsoons are exceptional, farmers assign more land to the crop; when conditions are worse, they reduce it, which has an impact on the overall production of soybean (Agarwal and Singh, 2015) [2]. Thus, a study was conducted to assess the risk in soybean production in major soybean-growing districts of the state of Madhya Pradesh.

Methodology
The 38 out of 51 districts having an area of more than ten thousand hectares under soybean crops in 2019-20 were considered for this study. The districts formed after 2000-01 were taken as part of the original district from which they were carved. The districts considered for the present study were Shajapur including Agar Malwa, Jhabua including Alirajpur, Shahdol including Annuppur, Guna including Ashoknagar, Barwani, Betul, Bhopal, Khandwa including Burhanpur, Chhatarpur, Chhindwara, Damoh, Dewas, Dhar, Harda, Hoshangabad, Indore, Jhabua, Khargone, Mandsaur, Narsinghpur, Neemuch, Raisen, Rajgarh, Ratlam, Rewa, Sagar, Satna, Sehore, Sheopur, Shivpuri, Tikamgarh including Niwari, Ujjain, and Vidisha. These districts account for 99 percent of the area and 98 percent of production of soybean in Madhya Pradesh. The secondary data regarding area, production, productivity were collected

from website of Ministry of Agriculture and Farmers Welfare and related to period of 20 years from 2000-01 to 2019-20. The compound growth rates (CGR) in production component of soybean were estimated using the exponential trend equation:

$Y = ab^t$

Where Y = the variable for which growth rate is calculated,
t = time variable taking the values 1, 2, 3,….., n,
a = intercept,
b = the regression co-efficient of 'Y' on t.

CGR percent was expressed as:

CGR percent = (Antilog b - 1) x 100

The CGR value was tested for its significance with the 't' statistic. The range of CGR was purposively distributed as:

- Low growth rate = less than 5
- Medium growth rate = 5 to 10
- High growth rate = 10 and above

The method suggested by Cuddy Della Valle (1978) [3] was used to compute the instability index in the production component. Krishan and Chanchal (2014) [10], Deb and Pramanik (2015) [4], and Vekariya *et al.* (2020) [14] also employed Cuddy Della Valle Index to measure instability and considered the coefficient of determination from a time-trend regression adjusted by the number of degrees of freedom.
The Cuddy Della Valle Index (CDVI) was calculated as follows:

$$CDVI = \frac{\text{Standard Deviation } (\sigma)}{\text{Mean } (\bar{X})} * 100 * \sqrt{1 - \bar{\bar{R}}}$$

Where, $\bar{\bar{R}}$ is the adjusted coefficient of determination and the Instability Index ranges from:

- Low instability = 0 to 15
- Medium instability = Greater than 15 and less than 30
- High instability = 30 and above

Results

Growth and Instability in soybean production components

The growth in the area, production, and productivity of soybean is worked out and data on the same are presented in table 1. The state lies in a low instability zone with a significantly positive CGR of 1.8 percent for the area under soybean. The highest instability was observed in Sheopur for the area under the soybean crop. While highest CGR of 11.00 was recorded in the Shahdol district which is positive and significant at one percent. For Chhindwara, Harda, Hoshangabad, Narsinghpur, Rewa, and Tikamgarh negative growth rate in the area was observed which is significant for Chhindwara, Hoshangabad, and Narsinghpur while insignificant for other districts. The state lies in a low instability zone with a positive but insignificant CGR of 2.4 percent for production under soybean crop. The highest instability in production was observed in the Barwani district while the highest CGR was observed in Shahdol for production under soybean and it was positive and significant. Although this is not a major soybean-growing district and it is emerging as a prospective district for increasing the production of soybean in the state. The negative CGR was observed for districts of Bhopal, Chhindwara, Harda, Hoshangabad, Narsighpur, Raisen, and Tikamgarh but it is significant for Hoshangabad, Narsighpur, and Tikamgarh districts only. For the state medium instability and insignificant and low CGR (0.6%) for productivity under soybean crop was observed. The highest instability for productivity was observed in the Satna district. Significantly, the positive and highest CGR of 6.90 percent was observed for the Barwani district.

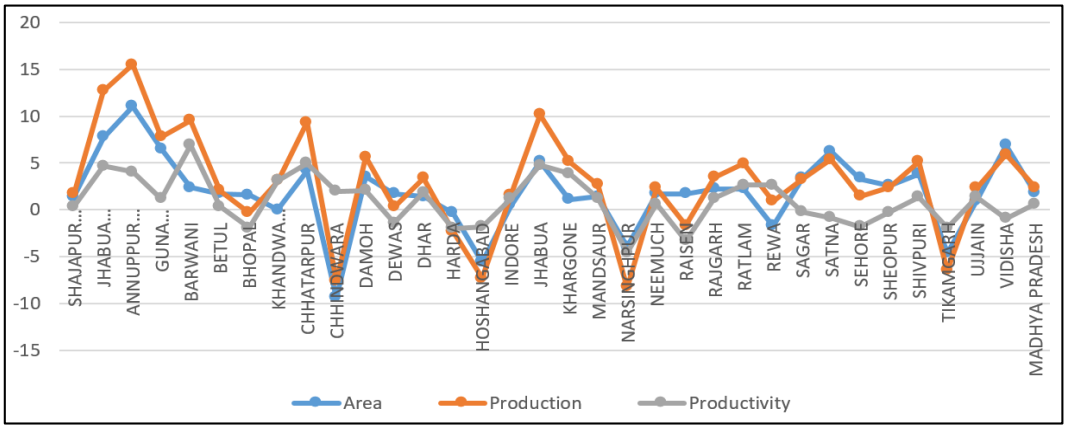
Table 1: Instability and growth in area, production, and productivity of soybean crop in Madhya Pradesh

Districts	CDVI (%)			CGR (%)		
	Area	Production	Productivity	Area	Production	Productivity
Shajapur	03.98	00.72	15.31	1.40**	1.70	0.30
Jhabua	04.84	13.96	11.03	7.70**	12.70**	4.70**
Shahdol	23.86	42.94	15.10	11.00**	15.50**	4.00**
Guna	03.58	08.92	12.87	6.50**	7.80**	1.20
Barwani	43.71	66.11	18.85	2.40	9.50**	6.90**
Betul	06.05	23.92	21.78	1.70**	2.10	0.40
Bhopal	02.94	13.16	10.04	1.60**	-0.40	-1.90*
Khandwa	13.17	16.34	12.99	0.00	30	3.10*
Chhatarpur	23.38	36.52	16.20	4.20*	9.30**	4.90**
Chhindwara	18.63	36.51	18.49	-9.40**	-7.60	1.90
Damoh	17.72	20.98	14.86	3.50*	5.70*	2.10
Dewas	01.22	13.35	12.05	1.70**	0.30	-1.40
Dhar	00.71	07.84	08.80	1.40**	3.30**	1.80*
Harda	06.47	22.07	19.75	-0.30	-2.30	-2.00
Hoshangabad	08.82	20.99	20.65	-5.60**	-7.30**	-1.80
Indore	01.15	11.41	11.14	0.40**	1.50	1.20
Jhabua	02.39	11.02	10.87	5.10**	10.10**	4.80**
Khargone	07.08	18.24	14.84	1.10	5.10**	3.90**
Mandsaur	02.20	18.41	18.12	1.40**	2.70	1.20
Narsinghpur	14.17	19.13	16.25	-3.90*	-8.30**	-4.50*
Neemuch	01.66	18.27	18.69	1.70**	2.30	0.60
Raisen	17.87	25.48	14.72	1.70	-1.70	-3.30*
Rajgarh	01.54	13.92	17.00	2.20**	3.50*	1.20

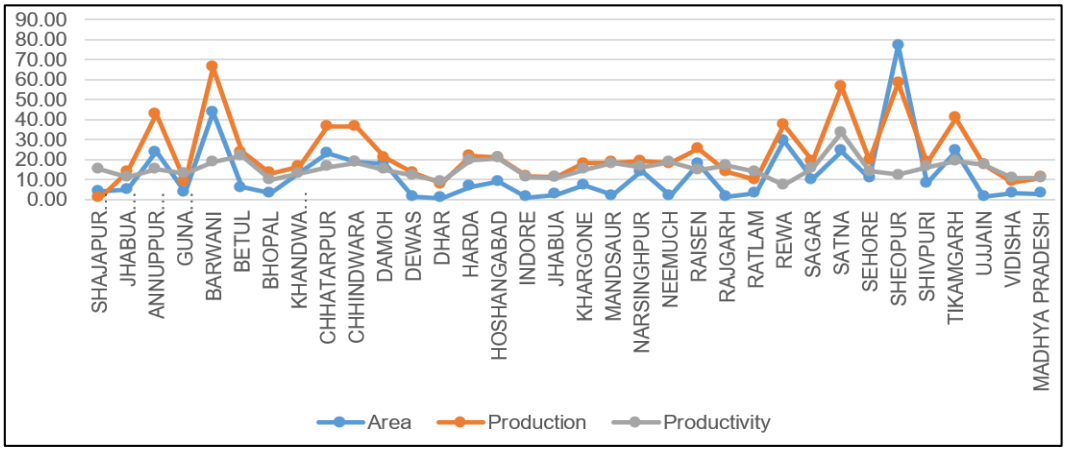
Ratlam	02.97	09.69	14.06	2.20**	4.90**	2.70*
Rewa	29.34	37.53	07.17	-1.70	0.90	2.70**
Sagar	10.15	19.31	15.69	3.40**	3.20*	-0.20
Satna	24.17	56.53	33.64	6.30*	5.40	-0.90
Sehore	10.71	19.60	14.25	3.30	1.40	-1.80
Sheopur	77.12	58.47	12.33	2.60	2.40	-0.20
Shivpuri	08.27	18.37	16.24	3.80**	5.10*	1.30
Tikamgarh	24.11	40.74	19.35	-4.60	-6.40*	-1.90
Ujjain	01.33	17.41	17.49	1.00**	2.30**	1.30
Vidisha	03.02	08.60	10.60	6.90**	5.90*	-0.90
Madhya Pradesh	03.98	00.72	15.31	1.80**	2.40	0.60

Level of significance at 1 percent ** and 5 percent*

The results indicated that districts where an area is highly (Barwani and Sheopur) and moderately (Shahdol, Satna, Damoh, Chhatarpur, and Chhindwara districts) instable are mainly nontraditional soybean growing areas. On the contrary, it was more stable in traditional soybean-growing areas of the Malwa region. In Bundelkhand, agro-climatic region production of soybean is highly instable while it is more stable in Malwa and Nimar agroclimatic zones. In the case of productivity, it is more stable as compared to area and production in almost all the districts but the major problem is low and negative growth in productivity.



CGR in production component of soybean crop in districts of Madhya Pradesh



Instability Index in production component of soybean crop in districts of Madhya Pradesh

Paradox of Growth v/s Instability in soybean production

The paradox of growth versus instability was developed and information on the same is presented in table 2. The information shows that the maximum area and production of the soybean in the state is confined to the box where production instability is in the medium range and growth in production is in the range of low CGR. Out of 38 selected districts, one-third of districts fall under this box of paradox, and on average per district, the area was around 1.98 lakh ha and production of 1.56 lakh tons showing average productivity of 788 kg/ha in recent years. Another seven important soybean growing districts fall under the paradox box of low instability and low growth rate in production and the average area of these districts is 2.93 lakh ha and production is 2.90 lakh tons with average productivity of 990 kg/ha. Another important area with 7.59 lakh ha of area and production of 7.29 lakh tons falls into paradox of medium growth in production with low instability. The average productivity of this box was 960 kg per ha. The paradox box of medium growth in production and medium instability with three districts shows average productivity of 845 kg per ha.

Table 2: Paradox of growth v/s instability in production of the soybean crop in Madhya Pradesh

Production Instability Index	CGR of production		
	Low	**Medium**	**High**
Low	Shajapur, Bhopal, Dewas, Dhar, Indore, Rajgarh, Ratlam (Area:2050.74 Production: 2036.26)	Guna, Vidisha (Area: 759.38 Production:729.19)	Jhabua (Area: 93.03 Production:85.40)
Medium	Betul, Khandwa, Harda, Hoshangabad, Mandsaur, Narsinghpur, Neemuch, Raisen, Sagar, Sehore, Ujjain (Area: 2180.27 Production: 1723.58)	Damoh, Khargone, Shivpuri (Area: 253.37 Production:214.07)	-
High	Chhindwara, Rewa, Sheopur, Tikamgarh (Area: 68.76 Production: 67.49)	Barwani, Chhatarpur, Satna (Area: 85.78 Production: 71.53)	Shahdol (Area: 11.08 Production: 6.29)

Figures in parentheses represent the area in thousand ha and production in thousand Tons (TE 2019-20)

Jhabua district having an area of 0.93 lakh ha with a production of 0.85 thousand tons with average productivity of 918 kg per ha falls in the category of high growth of soybean production with low instability. Only 1.65 lakh ha of the area of the state falls under high production instability and 42 percent of this area is under low production growth rate while 52 percent of this area falls under medium production growth rate and the remaining 6 percent falls under high growth rate in the production area.

Conclusion

It is visible that in the major area of soybean production the average productivity is less than the state average of about 1000 kg/ha. Thus by bridging this yield gap of 200 kg per ha the production of soybean can be increased in Madhya Pradesh. Policy measures should be directed towards the stabilization of soybean production in the state and popularizing the crop in non-traditional areas also.

SYI considers mean yield, standard deviation, and maximum yield, and therefore this can be a better measurement of yield risk rather than considering only actual and mean yield.

Acknowledgement

The author is appreciative to the Department of Agricultural Economics and Farm Management, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur. The author is also appreciative of Environmental Planning & Coordination Organisation (EPCO), Bhopal, Madhya Pradesh for their financial assistance and mentorship.

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