IRJEMS International Research Journal of Economics and Management Studies
Published by Eternal Scientific Publications
ISSN: 2583 – 5238 / Volume 3 Issue 3 March 2024 / Pg. No: 127-132
Paper Id: IRJEMS-V3I3P118, Doi: 10.56472/25835238/IRJEMS-V3I3P118

Original Article

Maize Production in Himachal Pradesh: Growth and Instability Analysis (1992-2022)

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Received Date: 11 February 2024 Revised Date: 23 February 2024 Accepted Date: 02 March 2024 Published Date: 20 March 2024

Abstract: *The study aims to analyze the growth and instability of maize production in Himachal Pradesh during a 30-year period from 1992–93 to 2021–22, separated into three sub-periods. The analysis showed a slight increase in compound growth rates for area, production, and productivity from 1992–93 to 2001–02 and from 2002–03 to 2011–12. However, from 2012–13 to 2021–22, the maize cultivation area exhibited significant negative growth (-1%), while productivity (2.9%) and production (1.8%) experienced notable positive growth. The study emphasized significant fluctuations in production (11.77%) and productivity (11.88%) during the entire time, in contrast to the comparatively lower variability in the cultivation area (6.3%). District-wise analysis indicated negative growth in the area for all districts except Chamba and Hamirpur. Chamba, Mandi, and Sirmour consistently exhibited a decline in production and yield. It is essential to focus on developing better maize varieties and using effective agroeconomic methods to improve future maize production in the region.*

Keywords: *Production Performance, Maize, Compound Growth rate, Cuddy Vella Instability Index.*

I. INTRODUCTION

Maize (Zea mays L.) is an important cereal grain all over the world, along with rice and wheat (H. M., 2019). It is the most versatile crop that can be grown in a wide range of agro-climatic and environmental situations, and it is also known as the “Queen of cereals” because of its higher yield potential compared to other cereals (Erenstein et al., 2022; Kolhe et al., 2022; R. Kumar et al., 2023; Prakash & Venkataramana, 2023; R. Kumar et al., 2023; Prakash & Venkataramana, 2023). Maize production worldwide totals around 1,137 million metric tons from 197 million hectares, achieving an average yield of 5.8 metric tons per hectare across 165 countries (Erenstein et al., 2022). The top maize-producing countries are the USA, China, Brazil, Argentina, Ukraine, and India. India is the world’s sixth-largest maize grower worldwide. It accounts for around 4% of the total maize area and 2% of the total production worldwide (Shekhar & Singh, 2021).

Maize is India’s third most significant grain crop and contributes almost 9% of India’s overall food production (R. Kumar et al., 2014; Sharma et al., 2023). It is grown on an area of 10.04 million hectares, with an annual production of 33.62 million metric tons and an average productivity of 3.35 metric tons per hectare, which is lower than the global average productivity of 5.8 metric tons per hectare. (Ministry of Agriculture, Farmer, and Welfare, India, 2021–2022). It is a crop that holds significant economic importance and is considered to be the crop of the future in India (Yadav et al., 2016). Previous studies project that maize demand will double by 2050, establishing it as the most-produced crop globally(Erenstein et al., 2022; K, 2016). Over the past few years, the demand for maize has significantly increased due to the growing preference for gluten-free and nutritious food, high-quality animal feed, and its use as a primary ingredient in numerous industrial products and biofuels. The cultivation of maize is gradually increasing among farmers due to its high prospective yield and economic return (Lenka et al., 2023). However, India’s maize production in 2022 was just 33.33 million metric tons, despite the fact that the country needed 50 million metric tons of maize in 2025 (Yadav et al., 2016). As a result, there is a need to raise crop yields in order to satisfy the ever-increasing demands. The food supply and means of subsistence for millions of farmers and people worldwide may be seriously impacted by the stagnation and lack of progress in crop yields. (Madhukar et al., 2020).

Food security and nutrition are key challenges in today’s world. In 2022, 691 to 783 million people worldwide were hungry, with 55% living in Asia due to its large population (“World Food and Agriculture – Statistical Yearbook 2023,” 2023). Although India has achieved self-sufficiency in cereal and grain production, about half of the children in the country are still suffering from malnutrition. As a result of this malnutrition, India must increase the production of staple foods to reduce malnutrition and hunger (K, 2016). Therefore, modifying the diet and growing more nutrient-rich crops in sufficient quantities are the only solutions for certain nutritional deficits. Maize is a nutritious food rich in fiber, antioxidants, vitamins, and minerals, making it a beneficial component of a balanced diet (Choudhary et al., 2021). Maize has antioxidant characteristics because it contains chemicals like carotenoids and phenolic acids that can counteract free radicals in the body, possibly lowering the chances of chronic diseases (Galani et al., 2022). However, because it is an inexpensive grain, maize could help India combat hunger by becoming more widely consumed in Indian homes. (M Choudhary, 2021).

The primary maize-cultivating states in India include Karnataka, Andhra Pradesh, Uttar Pradesh, Bihar, Rajasthan, Maharashtra, Madhya Pradesh, Punjab, Haryana, Himachal Pradesh, West Bengal, and Jammu and Kashmir. These states collectively contribute to more than 95% of the country's maize production (Rouf Shah et al., 2016). In the northwestern Himalayan region, Jammu & Kashmir, Uttarakhand, and Himachal Pradesh are major maize-producing states (Rajoo, 2021). According to Rajoo (2021), "Maize is a golden grain of Himachal Pradesh." Maize is a significant Kharif crop in Himachal Pradesh, cultivated under rain-fed circumstances. Maize is also the staple diet of the majority of people living in the state. It also supplied four to five lakh tons of maize to other states every year after meeting its own feed and food requirements (Rajoo, 2021).

Processing maize in Himachal Pradesh has the potential to increase farmers' income by five to ten times. Agricultural expansion is essential for both economic progress and ensuring food security. It is essential to evaluate the efficacy of any crop's production, and growth and instability are the most important indicators for assessing production performance(Joshi et al., 2021). It is crucial to monitor volatility in agriculture to guarantee food security, economic stability, and the welfare of communities (Ayele et al., 2021).

Researchers globally conducted various studies (Ayele et al., 2021; Erenstein et al., 2022; Galani et al., 2022; Ikuemonisan et al., 2020; Joshi et al., 2021) on calculating growth rate and instability index. Many studies have been carried out on the relationship between the dynamics of cereal crops, the growth rate, and instability of crop in India (Ayalew & Sekar, 2016; Baviskar et al., 2020; Jain, 2018; Kiran1 et al., 2018; Kolhe et al., 2022; R. Kumar et al., 2014; Madhukar et al., 2020; Paltasingh & Goyari, 2013; Patel Jawaharlal Nehru Krishi Vishwavidyalaya et al., 2022.; Shekhar & Singh, 2021; Swaminathan et al., 2015). Previous studies either focused on short-term periods or specific crops or were carried out at the national level or in other states.

However, no study focuses on the status of maize in Himachal Pradesh. Because Himachal Pradesh is a hilly state, maize is a staple diet of the majority of people living in the state, and as well it is also the highest revenue-giving crop in HP compared to wheat and rice(RK Rajoo, 2021). If there is an increase in both growth and yield, this will also contribute to the doubling of the farmer's income. Therefore, the study aims to estimate the growth rate and variability in the harvested area, production, and productivity of maize in Himachal Pradesh from 1992–1993 to 2021–22. The time period is divided into three sub-periods, which are as follows: period-I (1992-1993 to 2001-02), period-II (2001-02 to 2011-12), period-III (2011-12 to 2021-22), and entire period (1992-93 to 2021-22). Each of these sub-periods is comprised of ten years.

II. MATERIALS AND METHOD

The study aims to estimate the growth rate and variability in the harvested area, production, and productivity of maize in Himachal Pradesh from 1992–1993 to 2021–22. The study is primarily based on secondary data. The time series data as per required for study regarding the area the area, production and yield were collected from the Department of Economics and Statistics, Government of Himachal Pradesh, as well as the Ministry of Agriculture and Farmer Welfare. The time period from 1992–1993 to 2021–22 is divided into three subperiods: period I (1992–1993 to 2001–02), period II (2002–03 to 2011–12), and period III (2012–13 to 2021-22). Each subperiod covers a decade. The districts that are major producers of maize have been selected for the study.

A) Compound Annual Growth Rate

In order to estimate the compound growth rates, the log-linear functional form was used. The formula for calculating CAGR is:

$$Y_t = ab^t u_t \tag{1}$$

Where,

Y_t = harvested area (ha)/production (t)/productivity (t/ha): t is the period in years.
a = intercept
b^t = The regression coefficient (1+r) represents the instantaneous relative change in Y for a given absolute change in an explanatory variable, where r is the growth rate and, ln is the natural logarithm
e = is the error term.

The CAGR was calculated by taking the logarithmic form of Eq. (1) and applying the following formula:

$$\text{InY} = \text{Ina} + t(\text{Inb}) + e \tag{2}$$

The compound annual growth rate (r) of harvested area (ha), production (t), and productivity (t/ha) in percentage was obtained by using the function:

$$\text{CAGR (r)} = (\text{antilog b-1}) * 100 \tag{3}$$

The significance of the regression coefficient was assessed by the student's t-test.

B) Instability Index

In order to determine the degree of instability, the Cuddy-Della Valle Index (CDVI) was utilized. This index is superior to the coefficient of variation in terms of its ability to predict the degree of instability in agriculture (CUDDY & VALLE, 1978). Several researchers (Ayele et al., 2021; Joshi et al., 2021; S. Kumar et al., 2014) have utilized the CDVI method to assess instability in time series data in order to address the issue of overestimation of instability levels using the coefficient of variation. Cuddy and Valle (1978) provide the following estimation for CDVI:

$$\text{CDVI} = \text{CV} * \sqrt{(1 - R2adj} \qquad (4)$$

Where, CV represents the coefficient of variation as a percentage, while R^2 denotes the coefficient of determination derived from a time-trend regression that has been adjusted for its degrees of freedom.

III. RESULTS AND DISCUSSION

A) Compound Growth of the Harvested Area, Production, and Productivity of Maize in Himachal Pradesh

The data in Table 1 revealed that during the first period from 1992–93 to 2001–02, there were positive and statistically significant growth rates of 0.2 percent for the area, 1.2 percent for production, and 1.5 percent for yield in Himachal Pradesh. The growth rate of maize production and productivity increased significantly by 1.7% and 1.8% throughout the period from 2002–03 to 2011–12. The growth rate of the harvested area remained constant at 0.2 percent from 2002–03 to 2011–12. From 2012–13 to 2021–22, the maize harvested area experienced a 1% reduction in growth, but production and productivity increased by 1.8% and 2.9%, respectively. The overall trend from 1992–93 to 2021–22, area, production, and productivity growth were (-) 0.6%, 0.4%, and 1%. This indicates a slight decrease in area and a notable increase in productivity for maize cultivation in the region.

Table 1: Compound Growth Rate (%) of Harvested Area, Production, and Productivity of Maize in Himachal Pradesh

Study period	Harvested area (ha)	Production (t)	Productivity (t/ha)
1992 -93 to 2001-02	0.2*	1.2*	1.5*
2002-03 to 2011-12	0.2*	1.7*	1.8*
2012-13 to 2021-22	-1*	1.8*	2.9*
1992-93 to 2021-22	-0.6*	0.4*	1*

Note: *Significance at * 1 per cent level.*
Source: *Statistical abstract of Himachal Pradesh & Author's Calculation.*

Table 2: Instability Index for the Harvested Area, Production and Productivity of Maize in Himachal Pradesh

Study Period	Harvested area (ha)	Production (t)	Productivity (t/ha)
1992-93 to 2001-02	8.8	6.39	12.34
2002-03 to 2011-12	0.67	13.15	12.94
2012-13 to 2021-22	5.8	13.56	5.16
1992-93 to 2021-22	6.03	11.7	11.88

Source: *Statistical abstract of Himachal Pradesh & Author's calculation.*

Table 3: District-wise compound growth rate (%) of harvested area, production, and productivity of maize in Himachal Pradesh

District Wise CAGR												
Study period	**1992 -93 to 2001-02**			**2002-03 to 2011-12**			**2012-13 to 2021-22**			**1992-93 to 2021-22**		
Districts	**A (ha)**	**P (t)**	**Y (t/ha)**	**A (ha)**	**P (t)**	**Y (t/ha)**	**A (ha)**	**P (t)**	**Y (t/ha)**	**A (ha)**	**P (t)**	**Y (t/ha)**
Bilaspur	0.8*	3.1*	2.3*	1.2*	2.8*	1.6*	0.2*	1.8*	1.6*	-1.8*	1.3*	1.5*
Chamba	3*	0.4*	-2.5*	0.1*	3.7*	3.6*	1.6*	1.9*	1.4*	0.1*	-0.1*	-0.2*
Hamirpur	0.5*	1.3*	0.8*	-0.3*	0*	0.3*	-2.1*	1.5*	3.7*	0.1*	0.9*	0.8*
Kangra	0*	2.8*	2.8*	0*	2.3*	2.4*	-0.8*	4.6*	5.5*	-0.4*	0.4*	0.8*
Kullu	3.6*	1.3*	5*	-0.5*	5.7*	6.1*	-4.7*	-6.4*	-0.9*	-1.3*	0.7*	2*
Mandi	-0.3*	1.1*	1.3*	-0.3	-0.2*	0.1*	-0.9*	2.3*	3.3*	-0.2*	-0.3*	-0.1*
Sirmour	0.1*	-0.7*	-0.9*	-0.5*	-0.1*	0.3*	-0.4*	3.6*	3.6*	-1.6*	-0.4*	1.2*
Solan	-0.5*	1.4*	1.9*	-0.3*	3.4*	3.7*	-2.1*	-1.2*	-1.6*	-0.6*	0.9*	1.3*
Una	0*	2.6*	2.6*	0.3*	3.4*	3.1*	-0.1*	1.2*	1.3*	0.1*	1.3*	1.1*

Note: *significance at * 1 per cent level of significance.*
Source: *Statistical abstract of Himachal Pradesh & Author's calculation*

Table 4: District-Wise Instability Index for the Harvested Area, Production and Productivity of Maize in Himachal Pradesh

Instability Index												
Study period	**1992 -93 to 2001-02**			**2002-03 to 2011-12**			**2012-13 to 2021-22**			**1992-93 to 2021-22**		
Districts	**A (ha)**	**P (t)**	**Y (t/ha)**	**A (ha)**	**P (t)**	**Y (t/ha)**	**A (ha)**	**P (t)**	**Y (t/ha)**	**A (ha)**	**P (t)**	**Y (t/ha)**
Bilaspur	5.48	13.27	13.89	7.16	24.23	20.36	8.06	20.44	17.31	7.54	19.65	16.55
Chamba	8.17	9.98	12.11	2.22	21.44	21.68	5.16	24.03	21.69	7.62	22.96	23.59
Hamirpur	2.85	5.77	6.82	7.61	12.86	13.52	7.49	21.8	18.99	7.49	15.5	16.25
Kangra	1.73	13.78	14.32	1.96	16.41	17.81	7.3	17.92	11.5	4.55	17.58	16.98
Kullu	4.89	15.41	20.61	2.3	26.11	29.33	12.76	28.6	24.3	13.8	27.93	5.73
Mandi	4.89	12.79	15.7	3.53	12.55	11.36	5.61	37.15	38.26	4.63	23.03	25.11
Sirmour	5.19	11.41	11.81	4.57	8.23	16.11	11.3	18.53	13.34	7.72	36.2	17.59
Solan	4.44	7.62	10.1	2.6	15.53	14.21	7.34	21.77	22.39	5.41	18.06	5.55
Una	3.6	8.32	9.81	2.72	15.97	14.4	10.39	24.27	19.7	6.56	17.68	15.61

Source: *Statistical abstract of Himachal Pradesh & Author's calculation.*

B) Instability of the Harvested Area, Production, and Productivity of Maize in Himachal Pradesh

Table 2 represents the Instability Index for the harvested area, production, and productivity of maize crops in Himachal Pradesh. The results demonstrated that there was an 8.8% area variability, a 6.39 % production variability, and a 12.34 % productivity fluctuation during 1992-93 to 2001-02. Between 2002-2003 and 2011-2012, the harvested area had minimal volatility at 0.67%, while productivity increased by 12.94% and production by 13.15%. From (2002-03 to 2011-12), the area exhibited very low instability, 0.67 percent, followed by moderate instability in production, 13.15 percent and productivity, 12.94 percent. In spite of this, the instability in Period III was 5.8 percent of the harvested area, which was higher than in Period II. Additionally, the instability of output was the same at 13.56 percent, but the variability of productivity was 5.16 percent, which was lower than in period II. The study period from 1992-93 to 2021-22 showed that there was volatility in the area, production, and productivity of maize farming in Himachal Pradesh, with rates of 6.03%, 11.7%, and 11.88%, respectively.

C) District-wise compound growth rate (%) of harvested area, production, and productivity of maize in Himachal Pradesh

Table 3 displays the compound growth rates for area, production, and yield of maize in the main maize-producing districts of Himachal Pradesh. During the period from 1992–93 to 2001–03, Bilaspur, Hamirpur, Kangra, and Kullu experienced substantial positive growth in all three variables. While all other districts experienced negative growth in at least one variable, Chamba had significant negative growth in yield, Mandi and Solan in area, and Sirmour in both production and yield. From 2002–03 to 2011–12, all districts saw significant increases in yield. However, except for Chamba, Bilaspur, and Una, most districts recorded a decrease in growth in the harvested area. Mandi and Sirmour specifically had substantial drops in production, with rates of -0.2% and -0.1%, respectively. Between 1992–93 and 2021–22, Bilaspur, Kangra, Kullu, Mandi, Solan, and Sirmour they have had declines in maize harvested areas with growth rates of -1.8%, -0.4%, -1.3%, -0.2%, -0.6%, and -1.6%, respectively. Districts Chamba, Mandi, and Sirmour saw a significant decline in production, with rates of -0.1%, -0.3%, and -0.4%, respectively. Only the Mandi and Chamba districts had a decrease in yield growth rate from 1992–93 to 2021–2022. From 1992–93 to 2021–2022, Bilaspur, Hamirpur, Kangra, Kullu, Solan, and Una experienced significant rises in both production and productivity. During the period of 2012–13 to 2021–22, Kangra recorded the highest growth rates of 4.6% and 5.5% in area and production. The analysis of maize growth in the district indicates a decrease in growth rate for the maize area, but output and yield experienced a slight increase. However, during the study, the total increase rate of maize output, area, and yield revealed a cyclical trend.

D) District-wise Instability Index for the harvested area, production and productivity of Maize in Himachal Pradesh

Table 4 shows the instability index values for the area, production, and yield of Himachal Pradesh districts. The instability index values of harvested areas in districts were highest in the following periods and districts: Period-I: Chamba (8.17%), Bilaspur (5.48%), and Sirmour (5.19%); Period-II: Hamirpur (7.61%), Bilaspur (7.16%), and Sirmour (4.57%); Period-III: Kullu (12.76%), Una (10.39%), and Sirmour (11.3%). Kangra (1.73%), Hamirpur (2.85%), and Una (3.6%) had the lowest instability in period I; Kangra (1.96%), Chamba (2.22%), and Kullu (2.3%) in period II; and Chamba (5.16%), Mandi (5.61%), and Solan (7.34%) in period III. A study revealed that the level of instability has risen during this period. Analysis showed that Kullu (13.8%), Chamba (7.62%), Bilaspur (7.54%), Hamirpur (7.49%), and Sirmour (7.72%) exhibited the highest levels of instability in the harvested area over the entire period. Production instability was highest in period-I in Kangra (13.78%), Kullu (15.41%), and Bilaspur (13.27%); in period II in Bilaspur (24.23%), Chamba (21.44%), and Kullu (26.11%); and in period-III in Mandi (37.15%), Kullu (31.05%), and Chamba (20.44%). Hamirpur (5.77%), Solan (7.62%), and Una (8.32%) had the lowest levels of instability in period I; Hamirpur (12.86%), Mandi (12.55%), and Sirmour (8.23%) in period II; and Kangra (17.92%), Sirmour (18.53%), and Bilaspur

(20.44%) in period III. According to the yield instability index, the districts with the highest levels of instability were Kullu (20.61%), Kangra (14.32%), and Mandi (15.7%) in period I; Bilaspur (20.36%), Chamba (21.68%), and Kullu (29.33%) in period II; and Solan (22.39%) and Mandi (38.26%) in period III. The districts with the lowest levels of instability during period I were Hamirpur (6.82%), Solan (10.1%), and Una (9.81%); during period II were Mandi (12.55%), Hamirpur (13.52%), and Solan (14.21%); and during period-III were Kangra (17.92%), Sirmour (13.34%), and Bilaspur (17.31%). It was observed that the instability of production had increased from period I to period III in all districts. This implies that the yield and production were more volatile and uncertain compared to the area. Variation in maize production or any crop occurs mainly in response to distribution, timelines, rainfall and other climatic factors, as well as the expected price and availability of crop-specific units(A Sharma, 2014; M Pradeep, 2020).

IV. CONCLUSION

The overall result of the study shows that a considerable decline in maize harvesting was found from 1992 to 2022. From 1992-93 to 2001-02 and 2002-03 to 2011-12, trends were good, but from 1992 to 2022, they were negative. Production and yield reveal a cyclical pattern with minor positive growth rates of 0.4% and 1%, indicating inadequate maize output in Himachal Pradesh over the research period. District-level maize cultivation decreased. Yield and production rise cyclically. Maize harvested area fluctuated less than production and productivity across time and subperiod. District-level production and yield instability index exceed 15, suggesting substantial volatility due to rainfall, input availability, and climate. High-yielding seed types and improved agricultural methods are needed to prevent output instability and growth rate dependence on area expansion. This method can increase productivity without increasing cultivated areas, boosting sustainable agriculture production. Maize production in Himachal Pradesh may fall if trends and instability persist. To enhance maize productivity, government priorities should be priorities: Agronomic methods, disease-resistant seed varieties, extension services, and farmer training. The study found a 0.4% decline in maize-cultivated areas' compound growth rate. Only high-yielding seed types and enhanced agroeconomic methods can boost productivity.

Authors' Contribution

Conceptualization and designing of the research work (SK, RS), Data collection and data cleaning (SK); Analysis of data and interpretation (SK, RS); Preparation of manuscript (SK, RK)

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