

International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452

NAAS Rating (2025): 4.49

Maths 2026; 11(5): 141-146

© 2025 Stats & Maths

<https://www.mathsjournal.com>

Received: 18-03-2026

Accepted: 20-04-2026

Lokesh Kumar

Department of Physical Sciences,
MGCGV, Chitrakoot, Satna,
Madhya Pradesh, India

SS Guatam

Department of Physical Sciences,
MGCGV, Chitrakoot, Satna,
Madhya Pradesh, India

Aman Karun Ekka

Department of Physical Sciences,
MGCGV, Chitrakoot, Satna,
Madhya Pradesh, India

Dheerendra Kumar

Department of Physical Sciences,
MGCGV, Chitrakoot, Satna,
Madhya Pradesh, India

Corresponding Author:

Lokesh Kumar

Department of Physical Sciences,
MGCGV, Chitrakoot, Satna,
Madhya Pradesh, India

Growth trends and sustainability yield index of potato in Madhya Pradesh

Lokesh Kumar, SS Guatam, Aman Karun Ekka and Dheerendra Kumar

DOI: <https://www.doi.org/10.22271/math.2026.v11.i5b.2327>

Abstract

Potato is a staple food crop playing a vital role in food and nutrition security for the state of Madhya Pradesh. The current study reviews the growth trend of area, production and productivity of potato and assesses the sustainability using the Sustainability Yield Index (SYI). Time series data for the period of study were tested with various functional forms and the cubic form was found to be the optimal functional form for describing the growth trends of area and production, suggesting the existence of non-linear and varying trends over time. The findings show that potato area and production have exhibited an overall upward trend, though with some fluctuations over the years. Yield also showed a moderate increase, indicating the progress made in the production technology and the use of inputs. The calculated SYI values revealed a moderate to high level of sustainability, implying that potato production in the state has been sustainable with consistent yields during the study period. In general, the findings of the study reveal that although potato production in Madhya Pradesh is growing, the fluctuations suggest that better management and policy interventions are needed to improve the sustainability and stability of potato production.

Keywords: Trend Analysis, Potato, Area, Production, Productivity, Sustainability Yield Index (SYI), Madhya Pradesh

Introduction

Potato (*Solanum tuberosum* ssp. *tuberosum*) is an outcrossing crop with a chromosome number of $2n = 48$. It is a highly branched, herbaceous annual plant, growing to a height of 0.5-1 meter, with underground modified stems (tubers) used as food. It has a leaf structure of odd-pinnate leaves with a terminal leaflet and bears flowers in cymose panicles. Even though potato is extensively grown in India now, it is not native to the subcontinent. Potato is a native to the Andean region of South America, especially the regions near present-day Bolivia and Peru, and was domesticated almost 8,000 years ago. It was brought to India by Portuguese traders in the late 16th century via the southern coast. Potato is one of the major vegetable crops because of its high yield, short growing period and suitability to various agro-climatic zones. It has a great advantage of being a vegetative propagated crop through seed tubers, which enables farmers to retain varietal purity and low production costs. Moreover, potato is a good source of food energy per unit area and time, and an integral part of the Indian diet. Given its high productivity and nutritive value, potato is not considered just a vegetable but a food crop, which plays a crucial role in food and nutritional security and income generation for farmers (Hussain, 2016) [5].

The ideal temperature for crop growth and development is 16-25 °C, with temperatures near 40 °C being detrimental. Optimal temperature for sprout emergence is around 22-24 °C; emergence is delayed with lower temperatures (less than 20 °C). Cooler night temperatures are needed for tuber initiation (12-18 °C is optimal) (Singh *et al.*, 2022) [7]. It's typically grown 5-12 cm deep with an intra-row spacing of 15-40 cm and a row spacing of about 75 cm (Bussan *et al.*, 2007; Laznik *et al.*, 2010; Cunha *et al.*, 2011). Potato is a relatively high nutrient requiring crop, accounting for almost 30% of the total cost of production (Pishgar Komleh *et al.*, 2012; Zangeneh *et al.*, 2010; Silva *et al.*) [11, 13]. Potatoes are responsive to fertilizers

(Levshin *et al.*, 2020) ^[9], and farmers frequently use large quantities of chemical fertilizers and pesticides, often more than recommended, which can have detrimental impacts on the environment (Zhong *et al.*, 2018) ^[10]. Nutrient removal studies suggest that the production of one tonne of potato crop removes around 3.8 kg N, 0.6 kg P and 4.4 kg K (Alva *et al.*, 2011) ^[11]. Potato is susceptible to many diseases, such as early and late blight, black spot, soft rot, brown rot, leaf roll virus, and potato virus Y (Kapsa, 2008) ^[6]. The principal pests are aphids, whiteflies, leafhoppers, white grubs, thrips, cutworms, mites and potato tuber moth (Venkateswarlu *et al.*, 2018) ^[12].

Uttar Pradesh was the largest producer of potatoes in India during 2022 with a production of 20,126 thousand metric tonnes, followed by West Bengal (14,508 thousand metric tonnes), Bihar (9,075 thousand metric tonnes), Gujarat (4,025.7 thousand metric tonnes), and Madhya Pradesh (3,954.91 thousand metric tonnes).

2. Methodology

The collected information was clearly secondary. The information on the area, production, and potato yield for 1960-2022 were collected from Agriculture Statistics at a Glance.

2.1 Descriptive statistics

Descriptive statistics are used to present numerical data logically and intelligibly. In a research study, we may employ a range of metrics or only one to evaluate a significant number of people. Descriptive statistics help us make sense of massive amounts of data. Each descriptive statistic distils a significant quantity of information into a brief description. Descriptive statistics are classified into three types: measures of central tendency (CT), measures of dispersion, and measures of association ship. Because of their obvious advantages over a number of other measures, the arithmetic mean, standard deviation/error, skewness, kurtosis correlation, regression, and other metrics are often used to characterise the given data. Descriptive statistics provide simple summaries of the data and metrics. The series is anticipated for the coming years based on descriptive statistics in order to take suitable measures. Maximum, minimum, mean, median, skewness, kurtosis, and other descriptive statistics studies were utilised to explain the pattern of the series and establish a consensus under consideration.

Mean

Arithmetic mean or simple mean of a set of observation is their sum divided by the number of observation, *e.g.* the arithmetic mean $\bar{x}$ of n observation $x_1, x_2, x_3, \dots, x_n$ is given by

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

In case of grouped data

$$\bar{x} = \frac{1}{\sum_{i=1}^n f_i} \sum_{i=1}^n f_i x_i$$

where x_i 's are the mid values of the classes and f_i 's are the respective frequencies. Among the three means viz. arithmetic mean (AM), geometric mean (GM) and harmonic mean (HM), AM is most widely used for its simplicity in calculation and explanation.

Standard deviation

It is more accurate and detailed estimate of dispersion because an outlier can greatly exaggerate the range. It is expressed by

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{N}}$$

Where, x_i = value of the variable for the i^{th} observation

$\bar{x}$ = the mean or average

N = the number of values

Standard Error

The standard error, abbreviated as S.E., is the standard deviation of a statistic's sampling distribution. The size of the standard error indicates the precision with which the parameter estimate was made. The formula for the standard error of the mean is,

$$S.E(\bar{x}) = \frac{\sigma}{\sqrt{n}}$$

Skewness

Skewness is defined as a lack of symmetry. We investigate skewness to get a sense of the form of the curve we can draw with the data we have. The coefficient of skewness is calculated based on moments.

$$S_k = \frac{\sqrt{\beta_1}(\beta_2 + 3)}{2(5\beta_2 - 6\beta_1 - 9)}, \text{ where } \beta_1 = \frac{m_3^2}{m_2^3} \quad \beta_2 = \frac{m_4}{m_2^2}$$

and m_2, m_3 and m_4 are the 2nd, 3rd and 4th central moments respectively.

Kurtosis

It means "flatness or peakiness" of the frequency curve. It is measured by the coefficient β_2 and its deviation γ_2 given by

$$\beta_2 = \frac{\mu_4}{\mu_2^2}, \gamma_2 = \beta_2 - 3$$

Skewness and kurtosis are the two opposite phenomena of frequency distribution. If skewness refers to horizontal property the kurtosis refers to vertical property of the distribution.

2.1 Trend

A trend model could be described as a technique to depict how a process or a system acts as time goes by. Generally, Statistical models track a process and describe its statistical characteristics and outcomes. The objective is to use several trend models, which can be summed up as follows, to analyse the direction, pattern, and nature of the time series under consideration. (kumar *et al.*, 2022) ^[7].

Trend Model	Discription	Formula
Linear Model	The equation of Linear model is given by	$Y_t = b_0 + (b_1t)$
Quadratic Model	The equation of Quadratic Model is given by	$Y_t = b_0 + (b_1t) + (b_2t^2)$
Compound Model	The equation of compound model is given by	$Y_t = b_0 (b^t)$ or $\ln(Y_t) = \ln(b_0) + t \ln(b_1)$
Cubic Model	The equation of cubic model is given by	$Y_t = b_0 + (b_1t) + (b_2t^2) + (b_3t^3)$
Exponential Model	The equation of exponential model is given by	$Y_t = b_0 e^{(b_1t)}$ or $\ln(Y_t) = \ln(b_0) + (b_1t)$
Logarithmic Model	The equation of logarithmic model is given by	$Y_t = b_0 + b_1 \ln(t)$
Growth Model	The equation of growth model is given by	$\ln(Y_t) = b_0 + b_1t$

Where Y_t is the value of the series at time t and b_0 , b_1 , b_2 , and b_3 are the parameters.

2.2 Sustainability Yield Index

Sustainability is generally accepted as a complex and multifaceted concept, which is interpreted differently among various disciplines, it encompasses the interaction of biophysical, social and economic factors, and is therefore difficult to assess and quite subjective. Sustainability broadly relates to the ability of a system to function and produce over time without negatively impacting resources and the environment. For agricultural systems, such as potato, sustainability is intricately tied to the concept of continuous production and food and nutritional security. A sustainable crop system is one that is stable, robust and productive in the long run, under different environmental and socio-economic conditions. Thus, the ability to sustain yields over time is used as a measure of sustainability of a production system. While a plethora of indicators and approaches have been suggested by researchers to assess sustainability, there is no simple measure of sustainability. Rather, multiple parameters are employed to gain insight into the sustainability of agricultural systems Devi *et al.* (2021)^[4].

Sustainability Index (SI) the potato productivity data will be split into two periods for the sustainability index.

- Period -I (1960 -1990)
- Period -II (1991 - 2022)
- Whole Period (1960 - 2022)

(a) According to Singh *et al.*, (1990), the sustainability measure is as follows.

$$\text{Sustainability Index (SI)} = \frac{\bar{Y} - S}{Y_{\max}}$$

Here, $\bar{Y}$ is the mean yield of a treatment, S is the standard deviation of the yield and $Y_{\max}$ is the highest yield of a treatment in a year. A high index value indicates high stability and consistency and thus sustainability.

(a) According to Sahu *et al.*, (2005) A desirable measure of the sustainability index is a value that is closer to zero

$$SI = \frac{Y_{\max} - \bar{Y}}{\bar{Y}}$$

(b) According to Pal and Sahu (2007) when the value of the sustainability index decreases, sustainability improves.

$$SI = \frac{S_i}{\bar{Y}_i} \cdot \frac{1}{S_{\max}}$$

3. Result

3.1 Performance of Potato in Madhya Pradesh

In Table 3.1 Madhya Pradesh recorded a substantial growth in the area used for potato farming, which increased from 12,000 hectares in 1960 to 172,210 hectares in 2022. This was an amazing increase of almost 1335.08 percent throughout that time. The skewness (1.45) and kurtosis (0.82) showed the strongly positively skewed and slightly platykurtic distribution with moderate variability and the existence of some extreme values.

The production of potato in the States also increased significantly as in 1960, production was 106 thousand metric tonnes, and in 2022, it was 3954.91 thousand metric tonnes. This was an implication of a very high growth of almost 3631.04 percent, which showed overall output improvement over the study period. The skewness (1.66) showed that the distribution was extremely skewed whereas the kurtosis (1.25) was platykurtic distribution with moderate to high variability and extreme values.

The potato productivity trend in Madhya Pradesh increased marginally from 8.8 MT/ha in 1960 to 22.97 MT/ha in 2022. The average potato productivity is 13.81 MT/ha. The positive skewness (1.03) indicated a right-skewed distribution, while the kurtosis (-0.18) indicated a platykurtic distribution with moderate variability and limited extreme fluctuations.

Table 3.1: Performance of area, production, and productivity of Potato in Madhya Pradesh during 1960-2022

Descriptive Statistics	Area (000' ha)	Production (000'MT tonnes)	Productivity (MT/ha.)
Madhya Pradesh			
Mean	51.81	906.06	13.81
Standard Error	5.79	141.50	0.56
Standard Deviation	46.02	1123.16	4.51
Kurtosis	0.82	1.25	-0.18
Skewness	1.45	1.66	1.03
Minimum	12	95	7.3
Maximum	172.21	3954.91	23.07

3.2 Trend analysis of potato in Madhya Pradesh

The overall performance path of the series movement was traced to parametric trend using a parametric trend model. To determine the trend in area production and yield of different states used various parametric model such as linear, exponential, logarithmic, quadratic, cubic and compound model. The best model is chosen from among the competing

models based on its largest R^2 value, model significance, and coefficients. The results of these exercises are presented in the following section.

Table 3.2.1, 3.2.2 and 3.2.3 exhibited the presence of non-linear patterns in Madhya Pradesh. The trend analysis indicated that the area, production, and productivity of potato followed a cubic trend, showing different phases of growth.

From figure 3.1.1, 3.1.2 and 3.1.3 it was indicted that the area under potato cultivation showed some fluctuation with increased slightly from 12 thousand hac in 1960 to 68.3 thousand hectares by 1999. A sharp decline was recorded in 2000, with the cultivation area falling to around 30 thousand hectares. There after recovered and exhibited from 40.9 thousand hectares in 2002 to 172.21 thousand hectares by 2022.

The potato Production indicate a slightly increasing trend with fluctuations from 106 thousand hectares 1960 to 870 thousand metric tonnes by late 1990s. This was followed by a sharp

decline to about 329 thousand metric tonnes in 2000 to 2011. Thereafter, the area recovered and increased with some fluctuation from 1816.7 thousand metric tonnes in 2011 to 3954.91 thousand metric tonnes in 2022.

The productivity of potato followed a cubic trend, reflecting an s shaped pattern, with an exhibited recorded at 8.8 mt/ha in 1960 and increased fluctuations up to 2010, remaining with in a moderate range. Thereafter, a significant increase was observed, increased from 20.6 mt/ha in 2011 to 22.97 mt/ha by 2022.

Table 3.2.1: Trend in Area of potato in Madhya Pradesh

MP AREA ('000ha)						
Model Summary and Parameter Estimates						
Equation	Model Summary		Parameter estimates			
	R ²	Significance	Constant	b1	b2	b3
Linear	.720	.000	-16.36	2.13		
Logarithmic	.419	.000	-53.42	32.98		
Quadratic	.900	.000	29.06	-2.06	.066	
Cubic	.940	.000	2.33	2.76	-121	.0019
Compound	.926	.000	10.09	1.04		
Exponential	.926	.000	10.09	.041		
Power	.696	.000	3.75	.722		

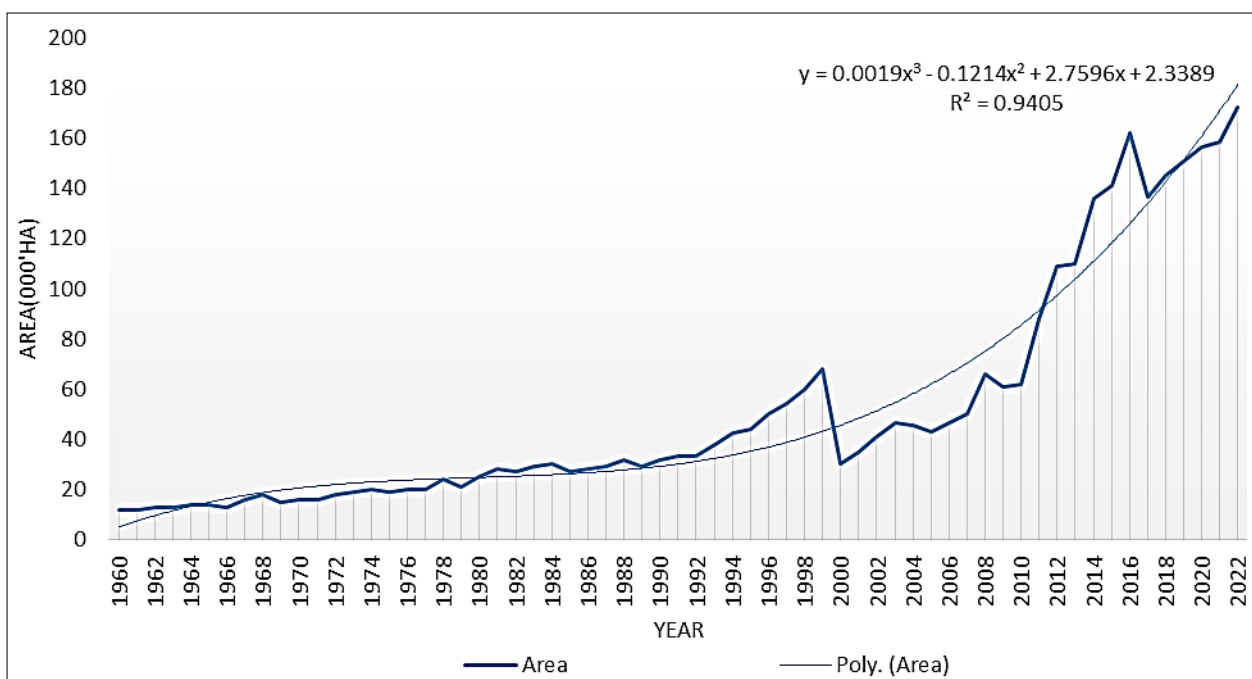


Fig 3.2.1: Observation and expected trend of Area under potato in Madhya Pradesh

Table 3.2.2: Trend in Production of potato in Madhya Pradesh

MP Production ('000MT)						
Model, Summary and Parameter Estimates						
Equation.	Model, Summary		Parameter estimates.			
	R ²	Significance	Constant	b1	b2	b3
Linear	.621	.000	-638.87	48.27		
Logarithmic	.332	.000	-1379.45	716.32		
Quadratic	.865	.000	651.48	-70.83	1.86	
Cubic	.928	.000	-164.88	76.47	-3.84	.059
Compound	.893	.000	86.34	1.056		
Exponential	.893	.000	86.34	0.55		
Power	.657	.000	23.91	.950		

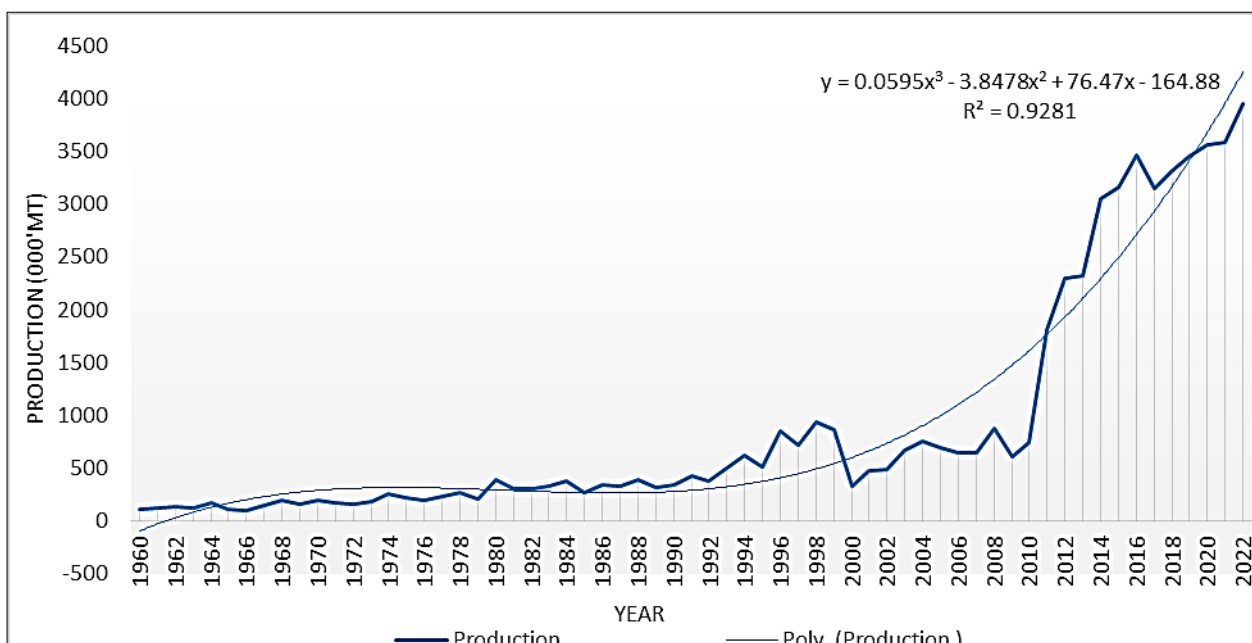


Fig 3.2.2: Observation and expected trend of Production under potato in Madhya Pradesh

Table 3.2.3: Trend in Productivity of potato in Madhya Pradesh

MP Productivity (MT/ha)						
Model, Summary and Parameter Estimates						
Equation.	Model, Summary		Parameter estimates.			
	R ²	Significance	Constant	b1	b2	b3
Linear	.656	.000	7.42	.200		
Logarithmic	.412	.000	3.57	3.21		
Quadratic	.771	.000	10.99	-.129	.005	
Cubic	.803	.000	8.65	.293	-.011	.000
Compound	.679	.000	8.56	1.01		
Exponential	.679	.000	8.56	.013		
Power	.468	.000	6.39	.227		

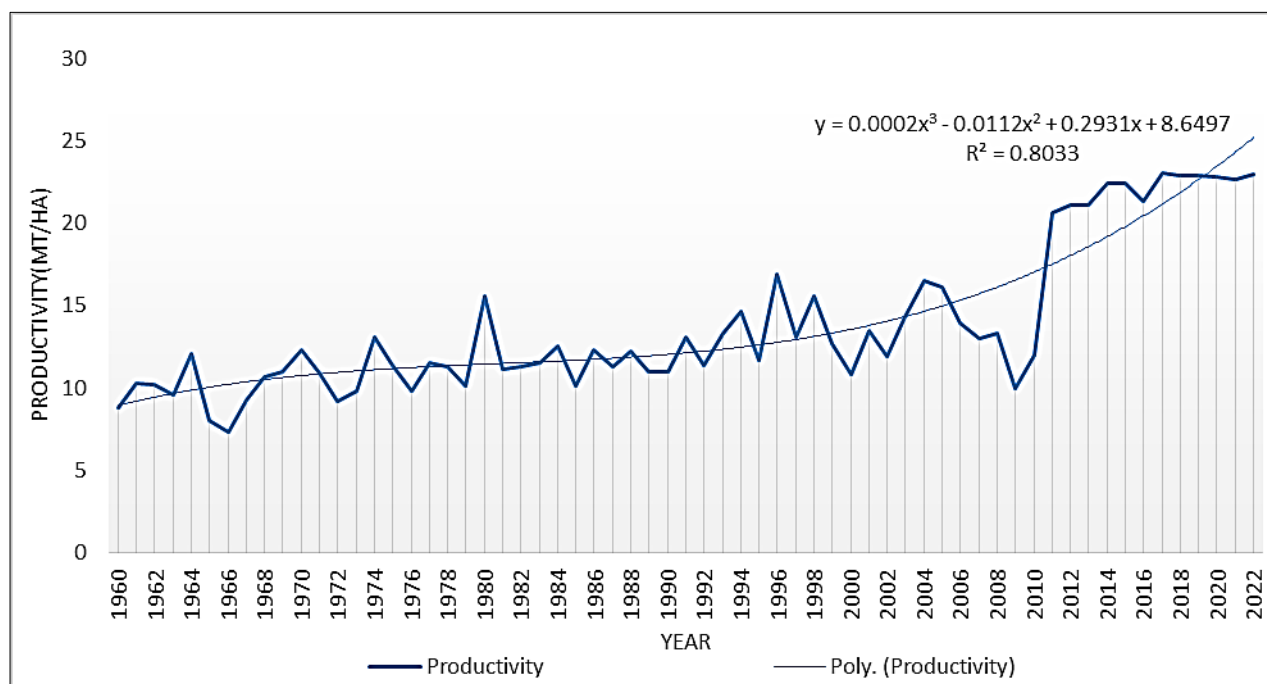


Fig 3.2.3: Observation and expected trend of Productivity under potato in Madhya Pradesh

3.3 Sustainability yield index

As Presented in figure and table 3.2.1, the sustainability of potato yield in west Madhya Pradesh was analyzed over two sub period, 1960 to 1990 (period 1) and 1991 to 2022 (period 2)

and the overall period (1960 to 2022). The result of SI_1 was clearly indicated SI_1 values decreased from 0.594 in period 1 to 0.523 period 2, reflecting enhanced yield stability and higher sustainability in later period (period 2).

However, the lower value observed for the overall period (0.403) suggested that long term fluctuations adversely affected overall suggested despite recent improvement. In case of SI_2 a decline in values from 0.436 in period 1 to 0.382 period 2, was observed, indicating reduced variability and improved stability, as lower SI_2 values signify higher sustainability. However, the overall period recorded a higher value (0.669), implying greater variability when the entire

duration was considered.

Similarly, SI_3 values increased from 0.0317 in period 1 to 0.059 period 2 and overall period 0.071. As lower SI_3 values represent better sustainability, the increasing trend suggests a gradual deterioration in yield stability over time Overall, the results demonstrated that potato yield sustainability in Madhya Pradesh improved significantly during the first period (1991-2022) compared the second period.

Table 3.3.1: Sustainability yield index of potato in Madhya Pradesh

Periods	Singh (SI)	Sahu (SII)	pal (SIII)
Period I (1960-1990)	0.594327	0.43672	0.031764
Period II (1991-2022)	0.523805	0.382731	0.059936
Period III (1960-2022)	0.403061	0.669627	0.071093

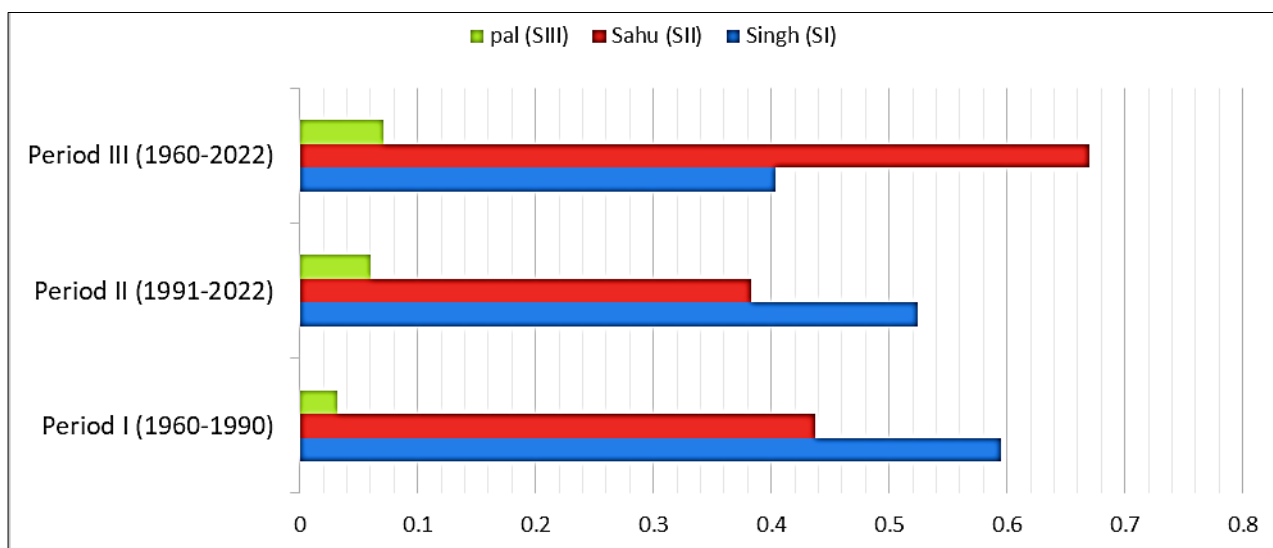


Fig 3.3.1: Sustainability yield index of potato in Madhya Pradesh

References

- Alva A, Fan M, Qing C, Rosen C, Ren H. Improving nutrient-use efficiency in Chinese potato production: experiences from the United States. *J Crop Improv.* 2011;25(1):46-85.
- Bussan AJ, Mitchell PD, Copas ME, Drilias MJ. Evaluation of the effect of density on potato yield and tuber size distribution. *Crop Sci.* 2007;47(6):2462-2472.
- Cunha JPAR da, Martins DH, Cunha WG da. Operational performance of the mechanized and semi-mechanized potato harvest. *Engenharia Agrícola.* 2011;31(4):826-834.
- Devi M, Kumar J, Malik DP, Mishra P. Forecasting of wheat production in Haryana using hybrid time series model. *J Agric Food Res.* 2021;5:100175.
- Hussain T. Potatoes: ensuring food for the future. *Adv Plants Agric Res.* 2016;3(6):1-10.
- Kapsa JS. Important threats in potato production and integrated pathogen/pest management. *Potato Res.* 2008;51(3-4):385-401.
- Kumar L, Mishra P, Singh RB, Sayyed M, Rath D, Srivastava AB. Forecasting of area, production and productivity of wheat crop in Madhya Pradesh. *Indian J Econ Dev.* 2022;18:1-10.
- Laznik Ž, Tóth T, Lakatos T, Vidrih M, Trdan S. Control of the Colorado potato beetle (*Leptinotarsa decemlineata* [Say]) on potato under field conditions: a comparison of the efficacy of foliar application of two strains of *Steinernema feltiae* (Filipjev) and spraying with thiamethoxam. *J Plant Dis Prot.* 2010;117(3):129-135.
- Levshin A, Gasparyan I, Ivashova O, Gasparyan S, Deniskina N. Competitiveness of early potato production in two-crop culture. *Adv Econ Bus Manag Res.* 2020;147:208-212.
- Zhong N, Liu N, Zhao P, Cai D, Song S, Chao Y. Current status and challenges for potato chemical fertilizer and pesticide reductions in China. *Chin Sci Bull.* 2018;63(17):1693-1702.
- Pishgar-Komleh SH, Ghahderijani M, Sefeedpari P. Energy consumption and CO₂ emissions analysis of potato production based on different farm size levels in Iran. *J Clean Prod.* 2012;33:183-191.
- Venkateswarlu V, Jandrajupalli S, Nagesh M, Malik K. Pest management for healthy potato production. In: *Advances in quality potato production and post-harvest management.* Agrotech Publishing Academy; 2018. p. 204-217.
- Zangeneh M, Omid M, Akram A. A comparative study on energy use and cost analysis of potato production under different farming technologies in Hamadan province of Iran. *Energy.* 2010;35(7):2927-2933.