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# Trend and Sustainability Analysis of Wheat in Madhya Pradesh and India

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## ABSTRACT

Researchers are conducting a study on the area, production, and yield of the wheat in Madhya Pradesh and India. The study used wheat area, production, and yield data from 1960 to 2020. A variety of models were used to examine the trend in which quadratic trends are noticeable in the area, yield, and production of wheat in Madhya Pradesh and India. Wheat production, area, and yield have all been found to be increasing with some fluctuation. Aside, from 1960 to 2020, the sustainability indexwill be discussed, with three sub-periodsin Madhya Pradesh and India. It was discovered that sustainability is higher in Madhya Pradesh. This research will be critical for determining the gap between wheat production and demand in Madhya Pradesh and India in order to better understand how wheat production has changed over time.

**Keywords: Wheat, Production, Trend and Sustainability**

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## INTRODUCTION

Agriculture plays a significant and prominent role in the global economy. Wheat is a type of grass that is commonly grown for its seed, which is used as a staple food in many countries. In addition, the world's population is increasing at an alarming rate, and as a result, there is an increasing need for food and nutrition security, which necessitates action on our part. Wheat occupies the most land of any food crop (285.17 million hectares, 2018-2019). In comparison to all other crops, wheat trade is the largest. Bread made from wheat is a good source of carbohydrate. Wheat is an excellent source of nutrients and fiber when consumed in its whole grain form. Vegetable protein in human diets is most commonly derived from wheat (Ramdas *et al.,* 2019). Contains more protein than maize (corn) and rice, two of the most important cereals. It was one of the first crops that could be grown on a large scale, and its seed could be stored for long periods of time in a dry climate. Due to wheat's ability to mine phosphorus from the soil, it may be capable of growing well even if no phosphorus is added to the fertilizer schedule (Pandey and Rai, 2019).

Indian people depend on agriculture and the allied sector. India has a net food debt and had to import wheat for domestic consumption. India has a surplus of wheat that it can sell for a profit on the global market. As a result, wheat production is expected to reach 100 million metric tonnes this year, with a larger yield expected due to favourable weather conditions compared to the previous year. According to the ICAR, wheat production should increase by 140 million metric tonnes by 2050. Uttar Pradesh, Punjab, Haryana, and Madhya Pradesh produce around 82 percent of the country's wheat (Darekar& Reddy, 2018). In India, the acreage of wheat is 31357.02 thousand hectares with production and productivity of 107860.51 metric tons and 3440kg/ha respectively in the year 2019-20. Out of which Madhya Pradesh covers about 6551-thousand-hectare area and 19607.14 thousand metric tons production with a productivity of 2993 kg/ha. (Ministry of Agriculture and Farmers Welfare, GoI, 2020).

Wheat is India's second most significant food crop, behind rice, accounting for 12 per cent of global wheat production. The majority of Indians eat a high-protein, high-calorie diet (Sahu*et al.,* 2015). It has traditionally been farmed in India's most fertile and watered northern regions. In India's northern plains, Punjab and Haryana were the leaders in wheat production, but Madhya Pradesh has the second-largest share in an area with 6.55 million-hectare (20.83 percent), and the production is 19.61 million tonnes (18.22 percent) share (Directorate of economics and statistics). Major wheat producing state107.59 million tons total wheat production of India during 2019-2020.

Madhya Pradesh is known for its best quality of "DESI" wheat crop. The location of the state is in the centre of India and is known as "Heart of India". There are medium and deep soils in these districts, which are considered to be the best for wheat farming. Some famous verities Sharbati and Durum are two well-known wheat cultivars grown in this region. Satna, Vidisha, and Raisen, Sehore, and Hoshangabad are the districts that provide such high-quality wheat (Kumar *et al.,* 2022).

From the sustainability point of view,the rate of increase in area,production and productivity of wheat should be steady or stable.But in reality,there are lots of fluctuations in thearea,production and productivity of wheat that need to bestudied. The declining trend inproductivity may affect the future competitiveness of wheat growers,and therefore it needs to be investigated. Instability in wheat production is causing a serious shock to farm income and the supply of wheat.It increases the

risk involved in wheat production and affects the price stability(ChandandRaju,2009)and it increases the vulnerability of wheat growers. Therefore, the objective of this research is to examine the trend of wheat and need to be addressed the future sustainability.

**REVIEW OF LITERATURE**

**Ferguson (2013):** The trend terms in wheat yield models in the United States Great Plains from 1932 to 1976 are analyzed. The leaps and bounds method chooses the subset of meteorological variables with the highest adjusted $R^2$. To minimize Multi-Collinearities, latent root regression is employed, and generalized ridge regression incorporates bias to give stability in the data matrix. The regression model utilized has two trends: a dependent model with a piece-wise continuous trend line and an independent model with a discontinuous trend line at the year of the slope shift. The trend lines that best-described wheat yields were found to be combinations of growing, declining, and constant trends: four for the dependent model and seven for the independent model.

**Mishra *et al.,* (2014):** Rice is one of India's most essential grains; more than 42 million hectares of land are planted in rice, adding around 90 million tonnes to the country's foodgrain basket. Therefore production behaviour stability is critical to the country's food security. After wheat, rice is the second most widely grown crop. It is primarily used and traded as a significant feed crop and staple food. The current study aims to discover trends in rice acreage, production, and productivity in India. Using data from 1950 to 2009, the study examines the change and stability in rice production behaviour in terms of area, production, yield, and sustainability yield index in India and its key states. The Autoregressive Integrated Moving Average (ARIMA) model is also used in this study to anticipate rice cropped area and production in India. Bihar has a greater level of rice sustainability than the rest of India, according to several measures of the sustainability yield index. Using various statistical methodologies, change and instability in rice area, production, and yield in India are measured. Despite reasonable development in area and production, there are distinct stages of instability across the key growing states and over different eras.

**Abbasi (2015):** Wheat and rice are essential staples in every home. This research examines the price trends for these crops over the previous 30 years and forecasts their prices from 2013 to 2017 using statistical models. To get the best fit model, various models were used. The four options were the linear trend model, quadratic trend model, exponential growth model, and S curve model.

The best-fitting model with the least error was forecasted using the minimum values of Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD), and Mean Squared Deviation (MSD). To observe the past trend, five-year average prices for the individual crop(s) were determined. The study shows that the S Curve model is recommended for price forecasting for wheat and rice (Basmati and IRRI). The study provides national policymakers with information about vital crops as well as a price reference range for the future, allowing them to properly deal with Pakistan's rising food inflation concerns.

**Dasyam *et al.*, (2015):** Wheat has long been one of humanity's most significant basic foods. It occupies a unique position in the Indian economy because to its importance in food security, trade, and manufacturing. Using annual time series data from 1961 to 2013, this study attempted to estimate and anticipate wheat output in India. Parametric regression, exponential smoothing, and Auto-Regressive Integrated Moving Average (ARIMA) models were used and evaluated in order to discover the best model to describe the country's modern wheat production pattern. Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Mean Squared Error (MSE), Akaike Information Criterion (AIC), Schwarz's Bayesian Information Criterion (SBC), and R-squared values were used to determine the best-fitted model. The 'Run test' and the 'Shapiro-Wilk test' were used to investigate the assumptions of 'Independence' and 'Normality' of error terms, respectively. The ARIMA (1,1,0) model was found to be the best fit for modeling India's wheat output in this study. Using this methodology, the anticipated figure for 2017-18 was 100.271 million tonnes (MT).

**Oladele and Kenamara *et al.*, (2015):** The study looked at developments in wheat acreage, production, and yields in India from 1970 to 2012, as well as the country's position in the world market for wheat production and export from 1996 to 2012. The data was gathered from the FAO's official website and India's "Land use statistics" and analysed using the mean, compound growth rates, and instability index. The findings found that wheat production and yield annual growth rates increased greatly before the WTO, but then decreased marginally after the WTO. On the other hand, the post-WTO period had the lowest level of volatility in terms of area, output, and wheat yield, although yield had demonstrated higher levels of instability in both the overall and pre-WTO periods. Overall, India's wheat production increased significantly, although it fell short in the export

market. Over the selected time, the compound growth rate in exports revealed a very high negative growth rate and an instability index in both export and import markets.

**Devi *et al.*,(2021)** increased volatility in farm output and agricultural sustainability is a developing serious issue, and because state-level analysis cannot portray the full picture of variable production behaviour of different crops, this article focuses on district-level research. At district level in Haryana, the study estimated instability and sustainability in three key crops during the last three decades. Gram crop area is rapidly dwindling in every district, according to the findings Cotton and mustard have had significant ups and downs over the course of the study. Sustainable production is essential to meet the demand for food and nutritional security, and certain crops produce sustainability. Sustainable production is essential to meet U demand for food and nutritional security, and the yield sustainability of chosen crops was measured at the district level using different sustainability indices.

## MATERIALS AND METHODS

The collected information are purely secondary. The information on area, Production and Yield of wheat for the period 1960-2020 were collected from *Agricultural Statistics at a Glance.*

### Trend models

The model can be described as a means of presenting a process/system. The statistical model generally traces the path of the process along with its statistical properties and implications. In the present topic, we are interested in studying the path and nature of the series under our preview through different models, which are briefly given in table 1

**Table 1: Different trend models**

| Model | Form |
|---|---|
| Linear Model | $Y_t=b_0+(b1t)$ |
| Quadratic Model | $Y_t=b_0+(b_1t)+(b_2t^2)$ |
| Compound Model | $Y_t=b_0(b^t)$ or $\ln(Y_t)=\ln(b_0)+\ln(b_1)$ |
| Cubic Model | $Y_t=b_0+(b_1t)+(b_2t^2)+(b_2t^3)$ |
| Exponential Model | $Y_t=b_0e^{(b1t)}$ or, $\ln(Y_t)=\ln(b_0)+(b_1t)$ |
| Logarithmic Model | $Y_t=b_0+b_1\ln(t)$ |
| Growth Model | $\ln(Y_t)=b_0+b_1t\ Y_t$ |

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

**Measures of sustainability**

Sustainability is a contentious, multifaceted, and variously defined (by different authors for different specialised objectives) phenomena. Despite its contentious character, there is general agreement that it is complicated and has to be evaluated in a variety of ways. It can be evaluated in its most basic form by looking at its economic, social, and biophysical characteristics. It's critical that major crops maintain their yield sustainability for guaranteed food and nutritional security. The study makes the assumption that sustainability entails perseverance and a crop's ability to produce steadily over an extended period of time. Therefore, under the current situation, a crop's ability to maintain productivity over an extended period of time denotes sustainability. Followings are the some of the measures found in literature, definitely these are not exclusive.

**Sustainability Index (SI)**

1. Sahu*et.al* (2005) a sustainability index value closer to zero is the most desirable value. $SI = \frac{Y_{\max} - \bar{Y}}{\bar{Y}}$
2. Pal and Sahu (2007) $SI = \frac{s_i}{\bar{y}_i} \cdot \frac{1}{s_{\max}}$ lower the value of the sustainability index higher is the sustainability.

**RESULTS AND DISCUSSION**

**Trend analysis of wheat in India and Madhya Pradesh**

Using a parametric trend model, the entire performance path of the series movement was tracked to parametric trend. Various parametric models such as linear, exponential, logarithmic, quadratic, cubic, compound, and growth models were employed to determine the trend in area output and yield in India and Madhya Pradesh. Based on the largest $R^2$ value, model significance, and coefficients, the best model is picked from among the competing models. The next section contains the results of these exercises (Tables 2 to 4).

The non-linear patterns are visible in India and Madhya Pradesh in Figure1 to 6. Thus, one can see from the trend analysis that quadratic trends are noticeable in the area, yield and production of wheat in India and Madhya Pradesh, indicating that in the recent past most likely series have reached maximum values and then either remained constant or decreased, which is cause for concern.

From the figure one can see that area of wheat has been increased during and after the seventies. The impact of the expansion of region can be seen in the wheat production scenario, which has increased from 1960 to 2020 with some fluctuation 10997 thousand tonnes in 1960 to 76368 thousand tonnes in 1999, after which it began to decline from 2000 to 2003 before rising throughout the year in India. But in Madhya Pradesh wheat showed some fluctuation from 1960 to 2002, then after it start rising throughout the year from 2003 (7364.6) to 2020 (21489.0) with some fluctuation. The wheat yield trend in India and Madhya Pradesh showed a modest increase, with trend yields of 730 kg/ha and 783 kg/ha in 1963, then a major fluctuation in trend to 3117 kg/ha and 1757 kg/ha in 2011, then start decreasing from 2011 to 2014 in Madhya Pradesh, but start rising in India from 2011 and Madhya Pradesh from 2014. As a consequence of the research, it is obvious that changes in area, per hectare yield, management, and other practices have influenced the production process in question.

The positive nature of the b2 coefficient indicates that the area and yield of wheat in India and Madhya Pradesh have increased in recent years. Farmers' interest in wheat production is increasing, as shown by the rising trend. During the study period, overall production in India and Madhya Pradesh increased, possibly due to the adoption of new technology such as hybrid crop, fertilizer usage, and so on.

**Table 2. Trends in area of wheat in India**

| AREA ('000 ha) | | | | | |
|---|---|---|---|---|---|
| **Model Summary and Parameter Estimates** | | | | | |
| **Equation** | **Model summary** | | **parameter estimates** | | |
| | **R Square** | **Significance** | **constant (b)** | **b1** | **b2** |
| **INDIA** | | | | | |
| Linear | 0.9508 | 0.00 | 10537 | 312.89 | |
| Exponential | 0.8979 | 0.00 | 0.00 | 0.016 | |
| Logarithmic | 0.8528 | 0.00 | 10381 | -13913 | |
| **Quadratic** | **0.9671** | **0.00** | 10801 | **729.35** | **- 10.375** |
| Cubic | 0.9656 | 0.00 | 915.32 | 1143.9 | 19.172 |
| compound | 0.8979 | 0.00 | 0.000 | 0.016 | |
| Growth | 0.8979 | 0.00 | 0.00 | 0.016 | |

| MADHYA PRADESH | | | | | |
|---|---|---|---|---|---|
| Linear | 0.190 | 0.00 | 3919.8 | | |
| Exponential | 0.148 | 0.00 | 0 | 0.0032 | |
| Logarithmic | 0.179 | 0.00 | 2654.3 | 594.06 | |
| **Quadratic** | **0.707** | 0.00 | **4455.4** | **-127.57** | **15.587** |
| Cubic | 0.478 | 0.00 | 421.84 | 391.49 | -10.747 |
| compound | 0.148 | 0.00 | 0 | 0.0032 | |
| Growth | 0.148 | 0.00 | 0 | 0.0032 | |

**Figure 1. Observed and expected trends of Area under wheat in India**

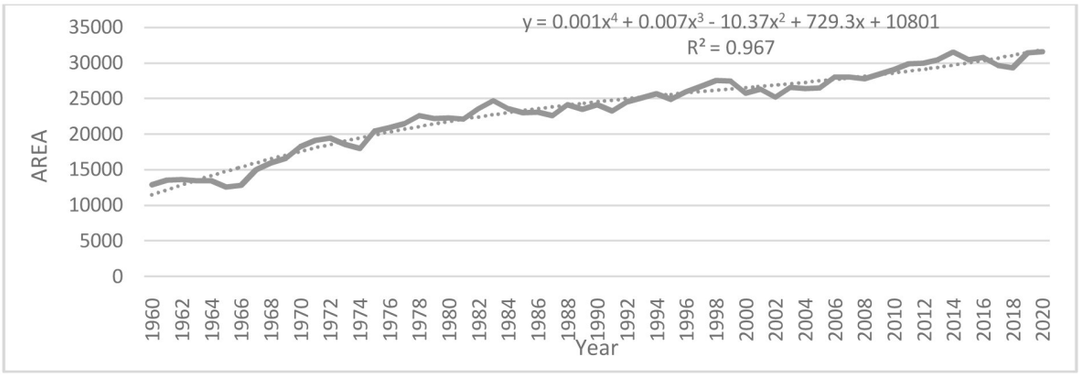



**Figure 2. Observed and expected trends of Area under wheat in Madhya Pradesh**

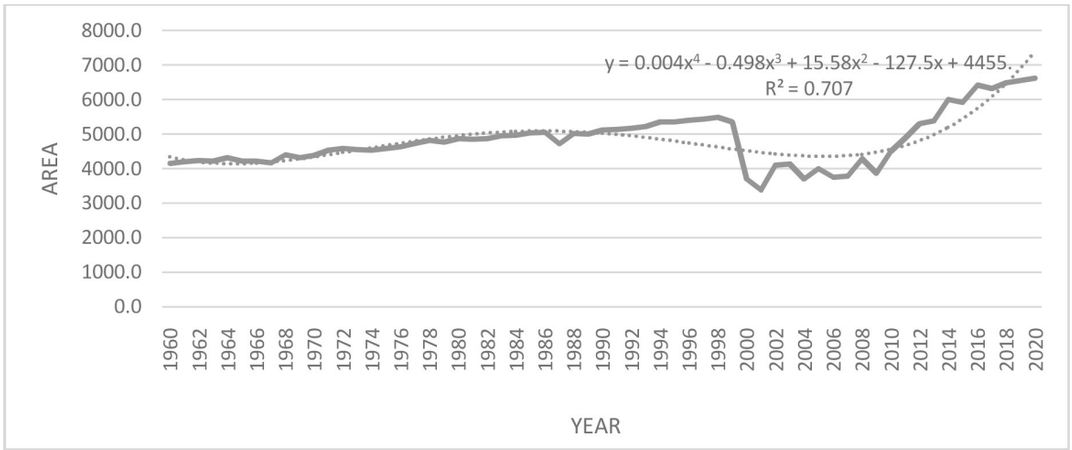


**Table 2. Trends in production of wheat in India**

| Production ('000' tons) | | | | | |
|---|---|---|---|---|---|
| **Model Summary and Parameter Estimates** | | | | | |
| **Equation** | **Model summary** | | **parameter estimates** | | |
| | **R Square** | **Significance** | **constant (b)** | **b1** | **b2** |
| **INDIA** | | | | | |
| Linear | 0.9738 | 0.00 | -12608 | 1624.3 | |
| Exponential | 0.9149 | 0.00 | 0.00 | 0.038 | |
| Logarithmic | 0.9183 | 0.00 | -140372 | 53929 | |
| **Quadratic** | **0.9872** | **0.00** | **11011.00** | **-304.42** | **132.89** |
| Cubic | 0.9836 | 0.00 | -9773.10 | 1489.3 | 0.21 |
| compound | 0.941 | 0.00 | 0.00 | 0.041 | |
| Growth | 0.941 | 0.00 | 0.00 | 0.041 | |
| **MADHYA PRADESH** | | | | | |
| Linear | 0.7337 | 0.00 | 3132.2 | 228.81 | |
| Exponential | 0.894 | 0.00 | 0 | 0.0384 | |
| Logarithmic | 0.5883 | 0.00 | 19123 | 7037.5 | |
| **Quadratic** | **0.9342** | **0.00** | **3002** | **-459.48** | **44.9** |
| Cubic | 0.894 | 0.00 | -5002.3 | 718 | 21.068 |
| compound | 0.894 | 0.00 | 0 | 0.0384 | |
| Growth | 0.894 | 0.00 | 0 | 0.0384 | |

**Figure 3. Observed and expected trends of Production under wheat in India**

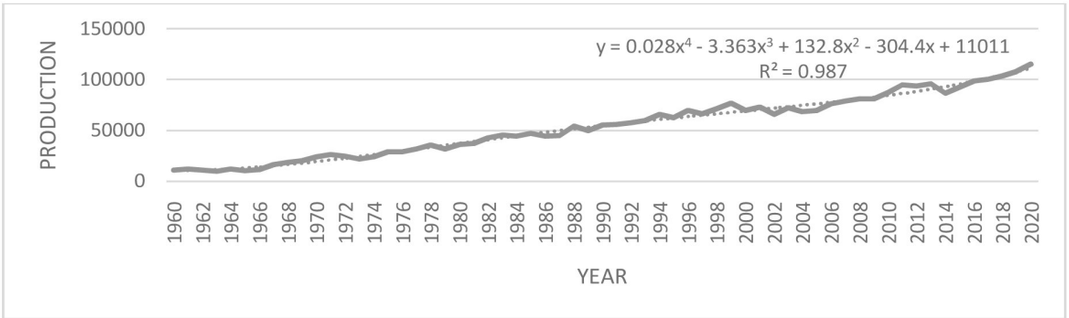


**Figure 4. Observed and expected trends of Production under wheat in Madhya Pradesh**

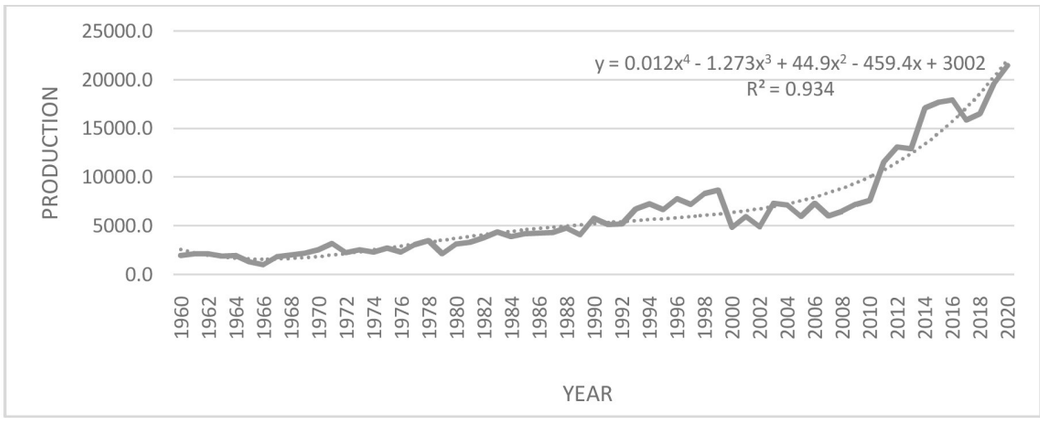



**Table 3. Trends in yield of wheat in India**

| PRODUCTIVITY (Kg/ha) | | | | | |
|---|---|---|---|---|---|
| **Model Summary and Parameter Estimates** | | | | | |
| **Equation** | **Model summary** | | **parameter estimates** | | |
| | **R Square** | **Significance** | **constant (b)** | **b1** | **b2** |
| **INDIA** | | | | | |
| Linear | 0.9699 | 0.00 | 283.29 | 44.907 | |
| Exponential | 0.9475 | 0.00 | 0 | 0.03 | |
| Logarithmic | 0.9404 | 0.00 | -3349 | 1518.9 | |
| **Quadratic** | **0.9808** | **0.00** | **877.74** | **-18.7** | **4.9853** |
| Cubic | 0.9741 | 0.00 | 204.55 | 43.336 | 0.2723 |
| compound | 0.9475 | 0.00 | 0 | 0.03 | |
| Growth | 0.9475 | 0.00 | 0 | 0.03 | |
| **MADHYA PRADESH** | | | | | |
| Linear | 0.498 | 0.00 | -49.513 | 29.217 | |
| Exponential | 0.5372 | 0.00 | 0 | 0.021 | |
| Logarithmic | 0.3563 | 0.00 | -1912.7 | 848.84 | |
| **Quadratic** | **0.9172** | **0.00** | **902.82** | **- 80.769** | **7.6161** |
| Cubic | 0.8508 | 0.00 | -925.76 | 181.84 | 5.866 |
| compound | 0.5372 | 0.00 | 0 | 0.021 | |
| Growth | 0.5372 | 0.00 | 0 | 0.021 | |

**Figure 5. Observed and expected trends of yield under wheat in India**

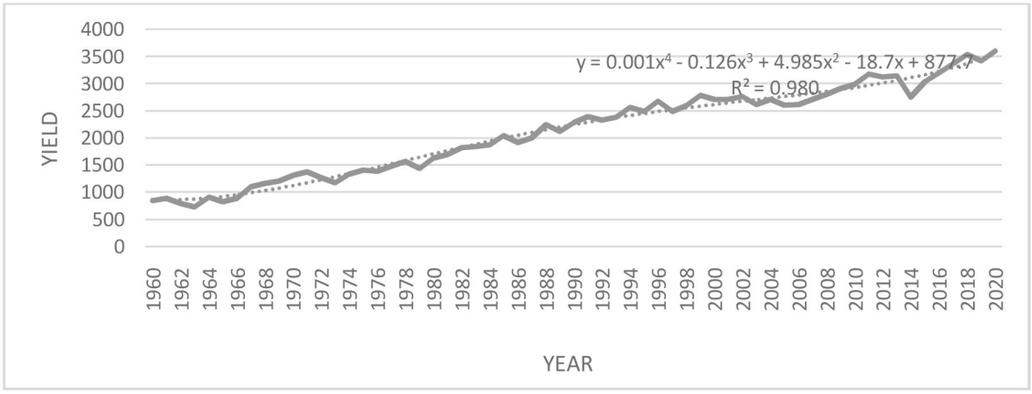
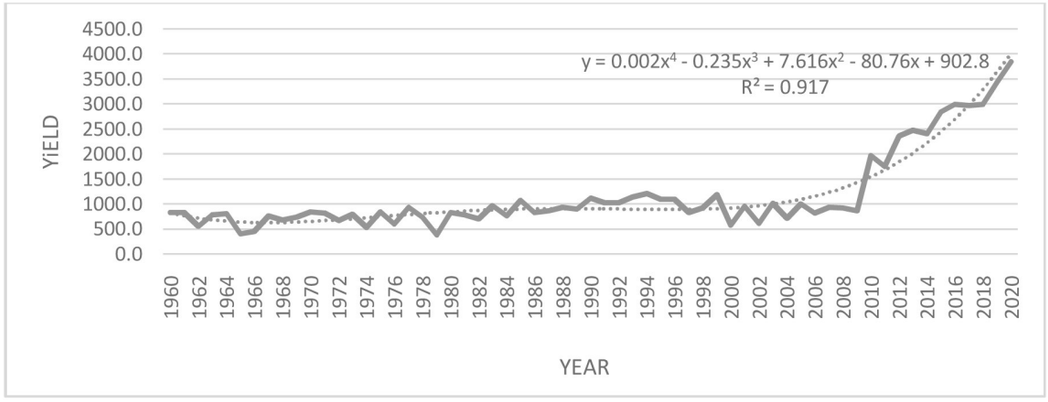



**Figure 6. Observed and expected trends of yield under wheat in Madhya Pradesh**




**Sustainable Index**

Sustainability in productivity of wheat has been measured with the help ofsustainability index as described in material and methods section in which the study period was divided into three sub periods for calculating sustainability index (i.e., Period I 1960-1990, Period II 1991-2020, and Period III 1960-2020 means overall period). The sustainability of wheat productivity from table 5 clearly depicted that the Sustainability index is decreased in India, from (period 1) to (period 2) and the sustainability index in Madhya Pradesh is increased from (period 1) to (period 2) in SI-1 and SI-2, in which both showed the same result. Therefore, sustainability index for wheat productivity in Madhya Pradesh was increased which is undesirable as higher value of sustainability index meanslowerwillbe theenvironmentalbalanceandnaturalsustainability. But in India, clearly demonstrating that we can meet our own needs without compromising the ability of future generations.

**Table 5. Sustainability Yield Index**

| Sustainability Index | Period 1 (1960-1990) | Period 2 (1991-2020) | Period 3 (1960-2020) |
|---|---|---|---|
| **INDIA** | | | |
| **SI 1** (Sahu*et al.,*2005) | 0.58637 | 0.26770 | 0.69194 |
| **SI 2** (Pal and Sahu, 2007) | 0.00070 | 0.00013 | 0.00047 |
| **MADHYA PRADESH** | | | |
| **SI 1** (Sahu*et al.,*2005) | 0.45841 | 1.40214 | 2.26504 |
| **SI 2** (Pal and Sahu, 2007) | 0.00050 | 0.00062 | 0.00083 |

## CONCLUSION

The above discussion highlighted fact trend analysis the quadratic trends are noticeable in the area, yield and production of wheat in Madhya Pradesh and India. As can be seen from the figures, the trend of wheat area, production and productivity in Madhya Pradesh and India is found to be increasing with some fluctuation. The sustainability index for wheat productivity in India is decreased, clearly demonstrating that we can meet our own needs without compromising the ability of future generations. But in Madhya Pradesh sustainability index was increased which is undesirable as higher value of sustainability index means lowerwillbe theen viron mental balance and naturals us tainability. As a result, in order to boost wheat production, policymakers will need a new mission driven approach. In addition, farmers' facilities and incentives for grain production, and wheat production in particular, are necessary.

**Conflict of interest:** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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