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Growth and Trend in Area, Production, and Yield of Wheat Crops in Uttar Pradesh: A Johansen Co-integration Approach

Amir Khan [a#], Saghir Ahmad Ansari [a++], Shoaib Ansari [a#*], Alfishan Rehmat [a#], Mohd Fateh [a#] and Mohd Shadab Khan [a#]

[a] *Department of Agricultural Economics and Business Management, Aligarh Muslim University, Aligarh 202002, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study investigated wheat crop area, production, and yield in Uttar Pradesh. Wheat crop data from 1990-91 to 2019-20 were obtained. Compound growth rate and trend analysis show that wheat crop area has reduced due to shift of rabi crops. The growth in Uttar Pradesh's per-hectare yield boosted wheat production from 1990-91 to 2019-20. The methods were calculated indicate use of semi log trend function and Johansen cointegration results, which reveal that number of irrigations affects wheat production. The study founds that cropping intensity, fertilizer, and transportation positively affected wheat production.

[#] *Research Scholars;*
[++] *Professor & Chairman;*
**Corresponding author: E-mail: shoaibamu111@gmail.com;*

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1. INTRODUCTION

Wheat is the second crop after maize; in the year 2020-21, India produced 107.6 million tonnes of wheat, which was second only to China's production of 134.3 million tonnes (WDI, 22). Wheat is a northern staple. Indian wheat-growing states include Uttar Pradesh, Punjab, Madhya Pradesh, Haryana, and Rajasthan. Uttar Pradesh had 9.85 million hectares of wheat land and 35.50 million tonnes of wheat output in 2020-21 (UPDES, 2022). Western, eastern, and central Uttar Pradesh are wheat-producing regions. Wheat is a main food and energy source in India. India is the world's second-largest wheat producer. Since independence, wheat production has risen from 6.60 to 107.6 million tonnes (WDI, 2022). Uttar Pradesh has the most land (35.1%) but the lowest productivity (2.7 tonnes/ha); hence it contributes the most to national production (35.03 percent). Wheat is grown in UP's west (3.29 million ha), east (5.24 million ha), and center (0.68 million ha). The protest and farmer fields yielded 1.35 tons/ha less. 2.7 tons/acre on 9.2 million acres. Critical production constraints in western Uttar Pradesh after growing sugarcane-wheat and potato, were decreasing soil organic carbon, mining for nutrients, inconsistent fertilization, crop waste burning that loses nutrients organic carbon, and lowering the water table and water availability [1,2].

Investigating the area's instability linked it to foodgrain output and yields. Decomposition analysis showed that dominance interaction had the most impact (Ansari. et al., 2022).

The traditional cultural cultivation practices are also harmful for rice-wheat cropping system [3]. and other crops comperioson of sugarcane instead of wheat Uttar Pradesh. The policies have helped sugarcane farming. Proper utilization of limited resources can raise production and profitability, doubling revenue and improving farmers' lives (Ansari. et al., 2022). Early-maturing sugarcane is sustainable. Mumias Sugar Company should research profitable recovery strategies, and farmers should manage well (Khaemba et al., 2021). Location affected production more than yield (Ansari. et al., 2022).

2. REVIEW OF LITERATURE

In Uttar Pradesh, the YG (difference between benchmark state yield and state average yield) is almost the same as what has been the case in India, but it is still less than what has been the case in India. As a whole, Uttar Pradesh has a smaller efficiency gap than the country as a whole, but both are close to 40% and need to be reduced [4]. The YG in wheat is caused by things like differences in how fertiliser is used in different parts of the country, inefficient and poor water management, poor use of manure, and the presence of pests and diseases. This calls for research priorities and focus [5]. On the other hand, Uttar Pradesh was one of the most consistent states in India when it came to wheat production because it was in a "comfortable zone" for all the variables that were looked at, such as area, production, and yield [6].

Wheat in India had an estimated Yield Gap-I of 28.22% (the difference between potential yield and national average yield), a Yield Gap-II of 57.01% (the difference between potential yield and state average yield), and a Yield Gap-III of 0.988% (the difference between potential yield and on-farm yield) [7].

(Ansari. et al., 2022) results showed that location had a greater impact on production than yield did on the state. The study placed a strong emphasis on expanding the area planted with pulse crops and enhancing pulse crop output through technical interventions. Wheat was found to be one of the most popular crops among major food grains, with the biggest yearly growth in area, production, and yield [8-10]. This discovery led to the conclusion that wheat was one of the most important crops. In spite of this, efforts should be made to increase the area under other major food grains (rice and wheat) with high-quality seeds of improved varieties, improved food grain production technology, price, marketing support, effective extension and mechanisation in order to raise the overall productivity of major food grains (Ansari. et al., 2022,2023) The amount of land that is irrigated, the amount of land that is not irrigated, and the amount of rainfall all have a favourable impact on rice output. On the other hand, non-irrigation and average annual rainfall both indicated a favourable but statistically negligible impact on rice output during the course of the study. In the short run, all of the determinants had a negative and significant effect on the total rice production's convergence towards equilibrium, but in the long run, none of them [11-14]. It has been found that the region experiences a higher level of volatility in comparison to the production and yields of food grains. The findings of the decomposition analysis demonstrated that the dominance interaction had the most significant influence (Ansari. et al., 2022.)

A galore of literature is available on state wise performance, but limited research has been done on district wise performance in general, and Uttar Pradesh in particular as it holds the maximum area and production share among all states. Hence, there is a need to study in detail about the growth trend in the Uttar Pradesh. In the backdrop of this, the present study is an attempt to analyze the wheat crop area, production, and yield in Uttar Pradesh. Wheat crop data from 1990-91 to 2019-20 were obtained. Trends are summarised using time-series growth rates. Growth rates assess wheat productivity indices. These growth estimates inform policy.

3. MATERIALS AND METHODS

The study used secondary sources. The Uttar Pradesh Directorate of Economics and Statistics provided data on wheat area, production, and productivity from 1990-1991 to 2019-20. Johnson cointegration was used to determine wheat production parameters. This method's application in the increase of agricultural production and its determinants of growth in India [15].

This study examines semilinear growth over 30 years using compound growth rates and t-values. Excel and SPSS were used to analyse and handle data throughout.

The semi-log trend function was used to estimate Uttar Pradesh wheat crop growth.

$$\ln X = \beta_0 + \beta_1 Z + e \quad (1)$$

Where

X = dependent variable (area, yield and production);
Z = trend over specific period
β_1= coefficient of trend;
ln = naturallogarithm;
e = error term

Measures β_1 the constant proportional or relative change in x for a given absolute change in the value of the regressor z.

$$\beta_1 = \frac{\text{relative change in X}}{\text{absolute change in regressor}}$$

If 100 multiply the relative change in x, give the percentage change, or the growth rate, in x for an absolute change in z, the regressor. That is, 100 times β_1 gives the growth rate in x; 100 times β_1 is known in the literature as the semi-elasticity of x with respect to z and gives the instantaneous (at a point in time) rate of growth, to find out the compound (over a period of time) rate of growth, the following formula was applied.

$$\beta_1 = \ln (1+ r)$$

Where β_1= Instantaneous rate of growth; ln =β_1 Natural logarithm; r = Compound rate of 1, subtract growth. Hence taking antilog of β_1 from it and multiply the difference by 100, would give compound rate of growth.

3.1 Model Specification (Johnson)

Given the nature of the data, following model is specified:

$$WP_t = \beta_0 + \beta_1 IRR_t + \beta_2 FERT_t + +\beta_3 CROP_t + \beta 2TRNt+et \quad (2)$$

Where,

t=time periods
WP_t= Wheat Production t (thousand tonne)
$IRR_t = Irrigation.$
FCT_t= fertilizer.
$CROP_t$=Cropping Intensity
TRN_t= Transportation

The data for these factors came from the Agricultural Statistics of India Yearly Book and the Indian Economic Survey. Johansen The results are obtained using cointegration. Non-stationary processes with stationary linear combinations were coined by Granger. Granger used it to check long-term econometric relationships. Long-run relationship between variables is described by cointegration. Since the 1990s, cointegration has been used to examine the link between time series variables. Soren Johansen's cointegration test tests time series variables for cointegration. It is ideal if all variables integrate in the same orde. In models with a combination of I(0), I(1), and I(2) variables, co-integrating connections may arise. 16 Vector autocorrelation model of order p performs Johanson cointegration:

$$Yt= \mu + A1\ yt\text{-}1 + . . . + Ap\ yt\text{-}1 + \varepsilon t \quad (3)$$

In above equation Yt represents n-by-1 vector of variables which are supposed to be the integrated at order 1.

The above model can also be represented in following form:

$$\Delta Y_t = \mu + \pi y_{t-1} + \sum_{i=1}^{\rho-1} r_i \, \Delta y_{t-1} + e_t \quad 4$$

Where

$$\pi = \sum_{i=1}^{\rho} A_i - I \; and \; Ri = \sum_{j=i+1}^{p} A_j \qquad 5$$

If we decrease to rank r smaller than n, we get n-by-r matrices and with the same rank of r such that equals ′ and ′y, which are stationary. r displays the number of co-integrating relationships. VEC model adjustment parameters are and. For any given r, MLE of displays yt-1 capitulates r with highest canonical correlations of yt with yt-1 when examined and corrected for lagged differences and deterministic variables. Johansen cointegration strategy uses two likelihood ratio significance tests. Trace test and maximal eighen value test.

$$J_{trace} = -T \sum_{i=r+1}^{n} \ln{(1 - \acute{P})} \qquad (6)$$

$$J_{max} = -T \sum_{i=r+1}^{n} \ln{(1 - \acute{P}_{r+1})} \qquad (7)$$

Whereas, T represents the size of sample and $\acute{P}$ denotes the ith largest canonical correlation. In case of trace test, we shall test the null hypothesis that there are r no co-integrating vectors versus the alternative hypothesis that there are n co-integrating vectors. Whereas in case of max eighen value test. Critical values for both of the tests can be observed in Johansen and Juselius tables. Although Johansen's methodology is typically used in a setting where all variables in the system are I(1). Yet, Johansen explains that before applying the test we need to test order of integration of the variables in the given system.

First study checks the level of integration of variables in the model. The Augmented Dickey Fullar (ADF) test is used in this study for this purpose. All the variables are found to be integrated at order 1.

4. RESULTS AND DISCUSSION

Trend and rate of growth in the wheat crop of Uttar Pradesh Wheat is grown extensively in India as well as in Uttar Pradesh on a subsistence basis. According to Fig. 1, the total area of land in Uttar Pradesh that was used for growing wheat in the 1990-1991 crop year was 8567.7 thousand hectares. When compared to the 9853 thousand hectares that were cultivated in the year 2019-2020, this area shows that the land area devoted to wheat cultivation has increased over the passage of time. Wheat crop production in the year 1990-1991 was 18600.1 thousand tones, and it is anticipated to expand to 15215.4 thousand tones to 33815.5 thousand tones over the year 2019-2020.Wheat production dropped to 22417.4 thousand tonnes (TT) during the crop year 2014-2015 (July-June) as a result of insufficient rainfall and unseasonably warm and dry weather conditions. And finally, this suggests that the yield for wheat crops in Uttar Pradesh during the year 1990-1991 was 2171 per hectare, but the yield for wheat crops during the year 2019-20 was 3234 per hectare.

Table 1 presents the findings of the semi-log model for the area, production, and yield of wheat crops from the years 1990-1991 to 2019-2020. The findings of the F-static test indicate that the models were significant for the number of wheat area crops, wheat production, and wheat yield in Uttar Pradesh. The findings showed that the trend co-efficient for wheat area, production, and yield was positive. The positive sign of the compound growth rate indicates that the area, production, and yield of the wheat crop were falling and then increasing at a rate of 0.39 percent per year, 0.15 percent per annum, and 1.12 percent per annum; accordingly, during the period of study. The area, production, and yield of wheat crops fell at rates of 0.78 percent, 0.73 percent, and 0.62 percent, respectively, as shown by the r square.

It indicates that the model is a good fit for the data.

As can be seen in Table 2, all of the variables that were utilised in the research were included in the same manner. Following the testing for the study's unit root, the Johansen Co-integration test is used to investigate the study's variables in terms of their long-term relationships.Before appling the Johenson Co-integration test, study finds the optimal lag length.

Table 3 indicates that the AIC criteria recommend setting the best lag length to be equal to two; hence, the study makes use of two lags in its investigation of the cointegration of the variables.

Table 4, presents the two co-integrating vectors along with their trace statistics. This provides compelling evidence for a long-run link between the model's variables.

Table 1. Trend and growth rate of area, production and yield of wheat in Uttar Pradesh

Particular	Area	Production	Yield
F-Statistic	104.81**	78.20**	47.24**
Trends Coefficient	9.077	9.90	7.73
t- Statistics	10.23**	8.84**	6.87**
Instantaneous Growth Rate	0.39	0.15	1.12
Compound Growth Rate	0.40	1.5	1.1
R- Square	0.789	0.736	0.627
Adjusted R^2	0.781	0.726	0.614

***Significant at 1 percent level of significance **Significant at 5 percent level of significance
Area (thousands hectare); Production (thousands tonne); Yields (kg per hectare)

Table 2. Unit root test (ADF) at 1st difference

At First Difference						
		d(LNWP)	d(LNIRR)	d(LNFER)	d(LGCR IN)	d(LNTRAN)
With constant	t-Statistic	-6.3009	-7.1953	-6.5809	-5.5893	-5.9995
	Prob.	0.0000 ***	0.0000 ***	0.0000 ***	0.0001 ***	0.0000 ***
With constant & trend	t-Statistic	-6.1688	-7.6554	-6.6589	-6.3029	-5.8788
	Prob.	0.0001 ***	0.0000 ***	0.0000 ***	0.0001 ***	0.0003 ***
Without constant & trend	t-Statistic	-6.1108	-5.4789	-5.6578	-6.6358	-7.533
	Prob.	0.0000 ***	0.0000 ***	0.0000 ***	0.0000 ***	0.0000 ***

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Table 3. VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-932.9452	NA	1.03e+24	69.47742	69.71739	69.54878
1	-864.3214	106.7482	4.21e+22	66.24603	67.68585*	66.67416
2	-830.1967	40.44414*	2.65e+22*	65.57012*	68.20979	66.35503*

** indicates lag order selected by the criterion*
LR: sequential modified LR test statistic (each test at 5% level); FPE: Final Prediction Error; AIC: Akaike Information Criterion; SC: Schwarz Information Criterion; HQ: Hannan-Quinn information criterion

Table 4. Johenson cointegration test (trace statistics)

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.780778	101.5622	76.97277	0.0002
At most 1 *	0.680944	60.58509	54.07904	0.0118
At most 2	0.474292	29.74060	35.19275	0.1720
At most 3	0.278053	12.37934	20.26184	0.4154
At most 4	0.124264	3.582643	9.164546	0.4778

Trace test indicates 2 cointegratingeqn(s) at the 0.05 level
** denotes rejection of the hypothesis at the 0.05 level*

Table 5; presents, only two co-integrating vectors that can be found in the model; these vectors are strong evidence for the model's variables having a long-term link with one another. Now, let's talk about the model's long-run coefficients in the study.

Table 6, demonstrates long-term variable relationships. It reveals that fertiliser boosts wheat output slightly better irrigation boosts wheat production. it means Improved seeds boost wheat production by 0.03 percent per tonne. and wheat production is hampered by cropping Intensity. Transport also affects wheat output. One conveyance boosts wheat productivity by 0.12 percent.

Table 5. Johenson cointegration test (maximum eigen values)

Hypothesized No. of CE(s)	Eigen value	Maximum Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.780778	40.97710	34.80587	0.0081
At most 1 *	0.680944	30.84449	28.58808	0.0253
At most 2	0.474292	17.36126	22.29962	0.2123
At most 3	0.278053	8.796700	15.89210	0.4559
At most 4	0.124264	3.582643	9.164546	0.4778

Maximum Eigen test indicates 2 cointegratingeqn(s) at the 0.05 level
** denotes rejection of the hypothesis at the 0.05 level*

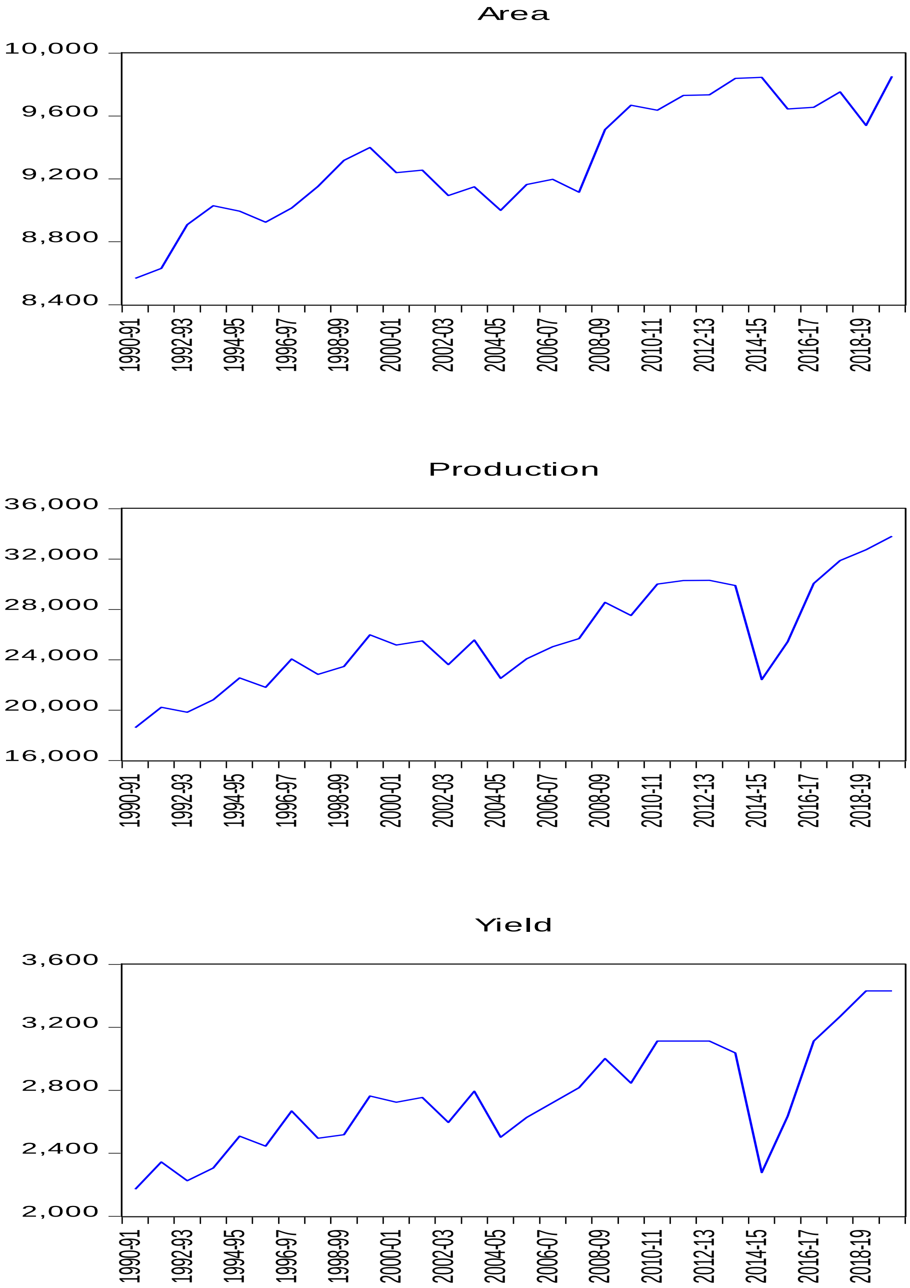

Fig. 1. Trends of wheat crop in Uttar Pradesh
Area (thousands hectare); Production (thousands tonne); Yields (kg per hectare)
Source: Handbook of statistics on Indian states - Reserve Bank of India

Table 6. Long run coefficients

Cointegrating Eq:	Coint Eq1
WHEAT_PRODUCTION(-1)	1.000000
IRRIGATION(-1)	0.036085 (0.96839) [0.03726]
FERTILIZER(-1)	-47.43265 (25.0032) [-1.89706]
CROPING_INTENSITY(-1)	1506.256 (482.496) [3.12180]
TRANSPORTATION(-1)	-0.127959 (0.03376) [-3.79065]
C	-232476.2 (70049.3) [-3.31875]

Table 7. Vector error correction model

Error Correction:	D(WP)	D(IRR)	D(FER)	D(CR IN)	D(TRAN)
CointEq1	-0.45109 (0.24012) [-1.87864]	-0.000586 (0.03229) [-0.01814]	-0.00332 (0.00052) [-6.41869]	-0.000145 (0.00020) [-0.71512]	5.611920 (3.36740) [1.66654]
D(WP(-1))	0.356658 (0.38214) [0.93333]	-0.045487 (0.05139) [-0.88512]	0.002928 (0.00082) [3.55660]	0.000110 (0.00032) [0.34286]	-3.86734 (5.35909) [-0.72164]
D(WP(-2))	0.057239 (0.24959) [0.22933]	-0.008921 (0.03357) [-0.26578]	0.002661 (0.00054) [4.94832]	-0.000155 (0.00021) [-0.73886]	-4.990176 (3.50031) [-1.42564]
D(IRR(-1))	-2.434157 (1.81192) [-1.34341]	-0.010858 (0.24367) [-0.04456]	-0.00808 (0.00390) [-2.07003]	-0.000312 (0.00153) [-0.20444]	48.16056 (25.4105) [1.89530]
D(IRR(-2))	0.424331 (1.92822) [0.22006]	0.030664 (0.25931) [0.11825]	-0.017093 (0.00415) [-4.11499]	0.002675 (0.00163) [1.64554]	22.89785 (27.0415) [0.84677]
D(FER(-1))	106.7169 (53.5691) [1.99214]	1.058989 (7.20415) [0.14700]	-0.173676 (0.11540) [-1.50502]	-0.039536 (0.04517) [-0.87529]	-109.7153 (751.257) [-0.14604]
D(FER(-2))	-47.15094 (71.1352) [-0.66284]	19.33908 (9.56651) [2.02154]	0.036139 (0.15324) [0.23583]	0.024891 (0.05998) [0.41499]	512.0481 (997.605) [0.51328]
D(CR IN(-1))	147.2608 (293.348) [0.50200]	25.10379 (39.4505) [0.63634]	3.662599 (0.63192) [5.79594]	-0.112387 (0.24735) [-0.45436]	-60.9803 (4113.94) [-0.01482]
D(CR IN(-2))	426.3344 (271.753) [1.56883]	30.55314 (36.5463) [0.83601]	1.734284 (0.58541) [2.96253]	-0.021668 (0.22914) [-0.09456]	5008.657 (3811.09) [1.31423]
D(TR(-1))	-0.035734 (0.02411) [-1.48214]	-0.00023 (0.00324) [-0.07095]	-0.000216 (5.2E-05) [-4.15176]	-1.16E-05 (2.0E-05) [-0.56895]	-0.131119 (0.33811) [-0.38780]
D(TR(-2))	-0.048565 (0.01831) [-2.65241]	0.001171 (0.00246) [0.47551]	-0.000293 (3.9E-05) [-7.41907]	-4.93E-06 (1.5E-05) [-0.31940]	-0.078355 (0.25678) [-0.30515]

Table 8. Model summary

R-squared	0.582580	0.235424	0.879022	0.452542	0.446665
Adj. R-squared	0.304300	-0.274294	0.798370	0.087569	0.077774
Sum sq. resids	57893446	1047049.	268.6539	41.16130	1.14E+10
S.E. equation	1964.577	264.2030	4.232052	1.656528	27551.36
F-statistic	2.093503	0.461871	10.89895	1.239934	1.210833
Log likelihood	-226.9006	-174.7365	-67.25166	-42.86463	-295.5608
Akaike AIC	18.30005	14.28742	6.019358	4.143433	23.58160
Schwarz SC	18.83232	14.81969	6.551630	4.675704	24.11387
Mean dependent	496.4231	118.0769	3.253846	0.523077	6664.231
S.D. dependent	2355.364	234.0470	9.424828	1.734199	28689.59

Table 7 above displays vector error correction model coefficients based on two lag duration and Error Correction Term. The study's model suggests a short-run link since ECM is negative and substantial. 45 percent of short-run disequilibrium is corrected in a years.

Table 8 above summarises the models. The model's P-Value is.0000. Over 59% of the endogenous variable variance is explained by external factors, indicating a good model. Examine data difficulties. Diagnostic tests shouldn't be in-depth.

5. CONCLUSION

Compound growth rate and trend analysis suggest wheat cultivation has increased. Each hectare produced more wheat in Uttar Pradesh from 1990–1991 to 2019-20. Mechanization helps Uttar Pradesh grow more wheat, this study revealed that Johansen cointegration and vector error correction analysed irrigation, fertilizer, crop intensity, and transportation affect wheat productivity. Fertilizer does affect that wheat grows, concludes the research. which affects wheat yield. Farmers does apply fertilizers properly then wheat output is high, and development targets must be reached, domestic growth mobilisation (i.e., boosting production effort). The study was also examined the trend of wheat production and productivity in Uttar Pradesh's. All model variables are stable.

6. RECOMMENDATIONS

The Following study recomandations were made:

a) Government should subsidize provide is transportation.
b) Government and stakeholder should advise commercial banks to give low-interest long-term loans to farmers because many impoverished farmers can't afford crop mechanization.
c) Government and other i.e, NGO advertising should be increased to raise knowledge about improved agricultural machinery.
d) Government and other i.e, NGO should educate farmers. Farmers can employ technology if they're trained and educated. They should also be told how much fertilizer to use so it yields more.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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