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Growth and Fluctuations of Yields of Pulses in India and its Major States: 1970-71 to 2019-20

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Abstract **Original Research Article**

The agricultural sector plays a pivotal role in sustaining economic growth in developing nations such as India. Stable and consistent yields of major crops are essential not only for ensuring food security but also for maintaining overall economic resilience. The present study examines the growth trends and yield fluctuations of Pulses in India and its major States during the period 1970-71 to 2019-20. Growth performance is evaluated using the Exponential Annual Growth Rate (EAGR) while variability in yields is analysed through several fluctuation measures, including the RSS-based index, the Cuddy Della Valle Index, Coppock's Fluctuation Index, and a Modified Coppock's Index, each capturing distinct dimensions of yield instability. The empirical findings reveal statistically significant improvement in the yield of pulses in India and all major States of India except two major States Orissa and Uttar Pradesh. The growth rate of India and all major State of India except Orissa are positive, only the State Orissa the growth rate is negative.

Keywords: Pulses Yield; Growth Trend; Instability Analysis; Polynomial Modelling; India
JEL Classifications: Q11, Q18, C22.

INTRODUCTION

Agriculture plays a crucial role in India's economy, with nearly 70 percent of the population relying on it either directly or indirectly for their livelihood. Therefore, the development of agriculture is fundamental to the overall progress of the nation and its individual states. Since Indian agriculture is largely dependent on rainfall, the country has made consistent efforts to boost production through the use of science and technology. However, agricultural output often experiences fluctuations due to market cycles, periodic patterns, and unexpected shocks such as natural disasters or wars. These variations and growth patterns in agricultural production can be analysed using autoregressive models of suitable orders. The yield and total production of food grains are vital indicators of a nation's ability to ensure food security for its population. In a densely populated country like India, understanding the growth patterns of food grains under various policy frameworks is essential for effective decision-making. This study focuses on examining the yield trends of Pulses in India and its major States during the period from 1970-71 to 2019-20

Pulses serve as a vital source of protein for the vegetarian population and can be cultivated across a wide range of climatic conditions. They offer good economic returns to farmers while also promoting agricultural and environmental sustainability. India stands as the world's leading producer of pulses, contributing nearly 25 percent to the global output (Anjum and Madhulika, 2018). At present, pulses are cultivated on approximately 25.26 million hectares, yielding about 16.47 million tonnes annually, with an average productivity of 625 kilograms per hectare (Nasim Ahmad et al., 2018).

LITERATURE REVIEW

The agricultural sector remains the backbone of India's economy, contributing not only to employment and rural livelihood but also to food and nutritional security. Within this sector, pulses occupy a unique position as a major source of plant-based protein for the largely vegetarian population. Despite India being the world's largest producer of pulses—accounting for nearly one-quarter of global output—the sector has long been characterized by yield instability, regional disparities, and technological gaps (Anjum & Madhulika, 2018; Ali & Gupta, 2012). Understanding these fluctuations is vital for achieving food security and sustainable agricultural growth.

Early analyses of Indian agriculture emphasized the post-Green-Revolution bias toward cereals such as rice and wheat, which led to stagnation in pulse production (Bhalla & Singh, 2009). Chand, Prasanna, and Singh (2011) observed that limited public investment in irrigation, extension, and research left pulses concentrated in rain-fed and marginal lands. More recent empirical work confirms that while cereal yields grew steadily, pulses lagged because of inadequate technological diffusion and market infrastructure (Kumar and Mittal 2006; Agarwal, 2017; Kulshrestha, & Agrawal, 2019). Consequently, India continues to rely on imports to fill its domestic supply gap (FAO, 2020).

The analysis of agricultural growth and variability has evolved from simple trend estimations to sophisticated econometric modeling. Exponential and log-linear growth functions have traditionally been employed to estimate long-term productivity trends (Nerlove, 1979). However, contemporary studies argue that such linear models fail to capture cyclical and structural breaks inherent in agricultural data (Dolai & Mondal, 2023a). Dolai and Mondal (2023a) identify six structural shifts in Indian agriculture, with strong Green Revolution growth. Dolai and Mondal (2023b) show long-run cointegration between agricultural GDP and key inputs. Dolai and Mondal (2025) find irrigation and fertilizer most influential. Mondal and Dolai (2024) show break-adjusted models improve trend accuracy. To address this limitation, researchers including Pradhan and Mondal (2023, 2024) and Dolai and Mondal (2023) incorporated time-series diagnostics—such as unit-root testing, structural break identification, and trend decomposition—to examine fluctuations in India's GDP, agricultural GDP, and sectoral growth over 1970-71 to 2019-20. Their findings reveal recurring endogenous breaks linked to policy reforms, weather shocks, and technological shifts—an approach highly relevant to studying yield volatility in pulses.

Quantifying instability has also drawn considerable methodological attention. The coefficient of variation (CV) remains a simple yet limited measure of variability. Cuddy and Della Valle (1978) proposed the CDI to adjust for trend effects, while Coppock (1962) introduced a fluctuation index capturing inter-annual variation. Mondal and Mondal Saha (2008) later refined Coppock's index to achieve comparability across datasets. These frameworks have been widely applied in recent studies of India's macroeconomic and agricultural sectors (Pradhan & Mondal, 2023; Dolai & Mondal, 2024), confirming their robustness in long-period analyses such as the present pulse-yield study.

State-level research reveals significant spatial heterogeneity in pulse performance. Kannan and Sundaram (2011) and Birthal et al. (2020) found that central Indian states such as Madhya Pradesh and Maharashtra recorded higher growth due to technology diffusion and targeted interventions like the National Food Security Mission (NFSM). In contrast, eastern states including Odisha and Bihar continued to show negative or statistically insignificant trends. Dutta, Pradhan, and Mondal (2025) extended this perspective by jointly analyzing rice, wheat, pulses, and oilseeds across West Bengal and Odisha, confirming that pulses exhibit the greatest inter-annual yield variability, with cyclical fluctuations of roughly five to six years—closely matching the findings of the present study.

Parallel evidence from macroeconomic analyses strengthens the theoretical link between agricultural volatility and national economic cycles. Pradhan and Mondal (2023, 2024) demonstrated that fluctuations in India's GDP and manufacturing output closely mirror those in the agricultural sector, suggesting that instability in primary production propagates through the broader economy. Their econometric framework, combining exponential growth estimation with autoregressive modeling, provides a methodological template for examining yield dynamics within sub-sectors such as pulses. Similarly, Dolai and Mondal (2023) highlighted the necessity of incorporating break trends when assessing long-run agricultural performance, arguing that ignoring structural changes leads to mis-estimated growth trajectories.

The technological dimension also features prominently in literature. Studies by Joshi and Saxena (2002), Kumar et al. (2023), and Banerjee and Kuri (2014) underline that yield stability in pulses improves markedly with the adoption of short-duration and drought-tolerant varieties, expansion of irrigation, and integrated pest management. Institutional initiatives such as the Technology Mission on Pulses (2007) and NFSM have been credited with increasing productivity, though the benefits remain unevenly distributed across regions (Chand & Raju, 2009). Pradhan and Mondal (2024) further argue that growth in agricultural output follows a non-linear path characterized by acceleration and deceleration phases, reinforcing the suitability of polynomial specifications—quadratic or higher-order—in modeling yield growth. This methodological alignment supports the present study's use of polynomial trend functions to identify inflection points and cyclical turning phases in pulse yields.

Recent interdisciplinary work links agricultural productivity to environmental and macroeconomic shocks. Dolai and Mondal (2023) and Pradhan and Mondal (2024) noted that openness indices, crude-oil price movements, and manufacturing dynamics exert feedback effects on agricultural GDP. These linkages imply that fluctuations in pulse yield cannot be viewed in isolation but are embedded within the broader macro-structural dynamics of India's economy. In this context, examining long-term yield series from 1970-71 to 2019-

20 provides insights not only into agricultural sustainability but also into the resilience of rural livelihoods against systemic shocks.

Overall, the literature presents a clear pattern: agricultural growth in India exhibits both structural progress and persistent volatility. Pulses remain the most vulnerable segment due to climatic sensitivity, policy neglect, and regional disparity. However, recent econometric studies by Dutta, Pradhan, Mondal, and Dolai collectively demonstrate that methodological advances—particularly in fluctuation measurement and trend-break modeling—enable a deeper understanding of cyclical behavior and state-wise divergence. The present study builds upon this integrated tradition by applying exponential and polynomial growth models alongside RSS-, CDI-, and Coppock-based instability indices to evaluate yield performance across India's major states. Through this lens, it contributes to a growing body of work emphasizing that achieving stability in pulses is essential for both food-security objectives and macroeconomic resilience.

DATA SOURCES AND METHODOLOGY

Data Sources

In this research, secondary data have been utilized, primarily sourced from the *Handbook of Statistics on the Indian Economy* published by the Reserve Bank of India (RBI). Data on yield for major States is collected Directorate of Economic and Statistics Department of Agriculture and Farmers Welfare Ministry of Agriculture and Farmers Welfare Government of India and ICAR-Indian Institute of Pulses Research.

Growth

In this study, the yield trends of Pulses in India and its major States are examined through the application of the Exponential Annual Growth Rate (EAGR). To capture the underlying temporal growth dynamics of the yield data, a semi-logarithmic linear trend regression model is employed. The model is represented as:

$$\ln Y_t = a + bt + e_t$$

Here, b denotes the constant exponential growth coefficient, ln represents the natural logarithm, Y□ is the dependent variable indicating yield, t signifies the time variable, and e□ corresponds to the stochastic or random error component. In the basic log-linear growth model, b represents the constant growth rate, i.e., the slope of $\frac{d\ln(Y_t)}{dt}$. When growth is not constant but changes over time, a log-quadratic specification may be used:

$$\ln(Y_t) = a + bt + ct^2.$$

Here, the instantaneous growth rate becomes $\frac{d\ln(Y_t)}{dt} = b + 2ct$, making it time-dependent. A positive b indicates initial growth, while the sign of c determines whether the rate is accelerating (c > 0) or decelerating (c < 0). The growth path of $\ln(Y_t)$ is convex when both b and c are positive, and concave when b > 0 and c < 0 The turning point, representing either a maximum or minimum, occurs at $t = -\frac{b}{2c}$. If the growth rate exhibits more complex behaviour, a log-cubic form may be adopted: $\ln(Y_t) = a + bt + ct^2 + dt^3$

Where the growth rate becomes $\frac{d\ln(Y_t)}{dt} = b + 2ct + 3dt^2$. In this case, the parameters c and d jointly determine the curvature and phase of growth whether it is accelerating, decelerating, or alternating between the two. The inflection point, where the curvature changes, is found at $t = -\frac{c}{3d}$. If a fourth-degree (or higher) polynomial fits even better, we can have more than one inflection point meaning the curve can change direction (convex to concave and back) multiple times. Higher-degree polynomials help to explain long-term cycles or fluctuations in economic growth often caused by policy changes. These cycles are usually smooth and long-term, not short-term business cycles or irregular year-to-year changes.

Fluctuation

The oscillatory behavior inherent within a time-series variable may be quantitatively assessed through a range of statistical metrics such as the Coefficient of Variation (CV), Dispersion, the Cuddy Della Valle Index (CDI), or the Coppock Fluctuation Index, among others. Conceptually, fluctuation embodies the mean deviation of empirical observations from an appropriately specified deterministic component or trend function.

An RSS-based metric of fluctuation encapsulates the relative mean deviation of the logarithmically transformed variable from its fitted trajectory, and is formally expressed as:

$$F_{RSS} = \frac{\sqrt{\frac{1}{T}\sum e_t^2}}{\ln \bar{Y}_t}$$

Where e_t denotes the residual deviations between the actual observations and the corresponding estimated values derived from the model. The numerator thus represents the root mean square of the residuals (i.e., the square root of the average residual sum of squares), while the denominator captures the mean of the logarithmic transformation of the variable. Typically, this measure is articulated in percentage terms. Conceptually, it parallels the coefficient of variation, though here the dispersion of the residuals is normalized by the mean of $\ln Y_t$ rather than the mean of the residuals themselves.

In a similar vein, the Cuddy Della Valle Index (CDI) provides an alternative measure by first detrending the original series, thereby isolating the stochastic or irregular component of variability. Cuddy and Della Valle (1978), along with Della Valle (1979), define the index as:

$$\mathrm{CDI} = \mathrm{CV}(\ln\, \mathrm{Y_t})\sqrt{1-\bar{\mathrm{R}}^2}$$

Here $\mathrm{CV}(\ln \mathrm{Y_t})$ quantifies the total variation within the logarithmic transformation of the series, a fraction of which is ascribed to deterministic trend effects as captured by the coefficient of determination ($\bar{R}^2$). The residual portion, representing $1-\bar{R}^2$, embodies the true magnitude of fluctuation after accounting for trend-induced variability.

Coppock Fluctuation Index

To quantify inter-annual variability, the Coppock Fluctuation Index (Coppock, 1962) is employed, which is mathematically represented as:

$$F_{Coppock} = \exp\,[S.D.(\ln\,(\frac{Y_{t+1}}{Y_t}))]$$

In a scenario where the time-series variable Y_t exhibits uniform or constant growth, the successive ratio $\frac{Y_{t+1}}{Y_t}$ or equivalently, the difference between $\ln(Y_{t+1})$ and $\ln(Y_t)$ remains invariant over time. Consequently, the standard deviation of these logarithmic differences converges to zero, implying that the antilogarithm of the standard deviation assumes a value of unity (Ray, 1983).

The variation in Coppock's fluctuation index between these two series thus provides valuable insight into the average periodicity or cycle length embedded within the data. To facilitate comparability between the RSS-based and Coppock-based measures, the latter can be standardized by rationalizing the standard deviation term, $\mathrm{SD}[\ln\,(\mathrm{Y_{t+1}}/\mathrm{Y_t})]$, with respect to twice the mean of the logarithmic variable, $2(\ln \bar{\mathrm{Y}}_t)$. The adjusted Coppock index is therefore defined as:

$$\mathrm{F'_{Coppock}} = \frac{\mathrm{SD}[\ln\,(\mathrm{Y_{t+1}}/\mathrm{Y_t})]}{2(\ln \bar{\mathrm{Y}}_t)}$$

Under this formulation, $\mathrm{F_{RSS}}$ and $\mathrm{F'_{Coppock}}$ become commensurable, enabling the estimation of the average cycle length inherent in the data as:

$$\text{Average Cycle Length} = 2(\frac{\mathrm{F_{RSS}}}{\mathrm{F'_{Coppock}}})^2$$

A comprehensive theoretical exposition of this adjustment procedure, which addresses the issue of incomparability between the two principal measures of fluctuation, is provided in Mondal and Mondal Saha (2008).

RESULTS AND FINDINGS

Growth of ln (Yield of Pulses) in India during the period 1970-71 to 2019-20

Hair we shall try to examine the nature of growth in ln (Yield of Pulses) in India during the period of 1970-71 to 2019-20 and we shall give some hints about the nature and extent of fluctuations around the growth path.

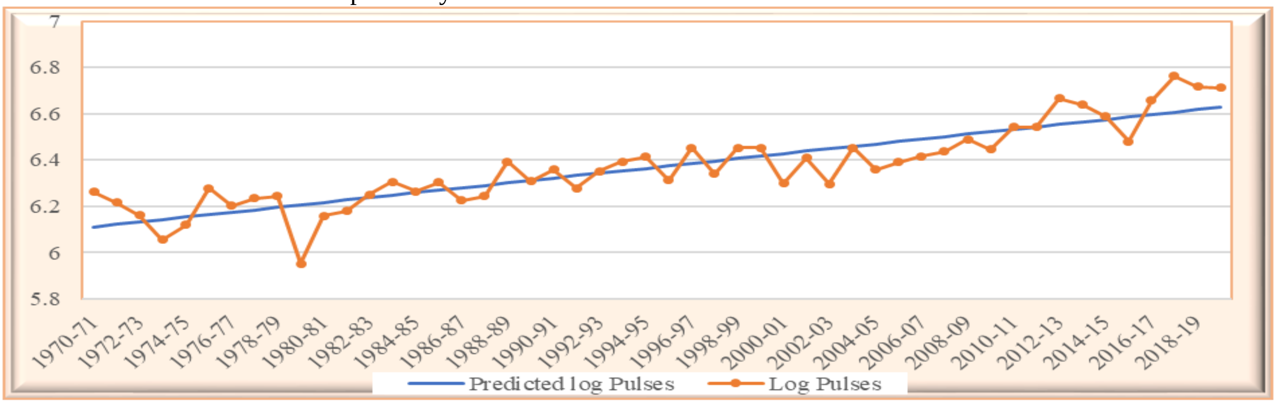

Diagram 1 Ln (Yield of Pulses) in India for the period 1970-71 to 2019-20 and its linear trend

Source: Author's own calculation

The approximate linear trend for ln (Yield of Pulses) in India during the period of 1970-71 to 2019-20 is shown by the solid straight line in Diagram 1. The regression result of linear trend is shown in Table 1. The growth rate of Yield of Pulses production is estimated by 1.05% per annum, R-square = 0.7816, Adjusted R-square = 0.7770, F-value = 171.7506 with P-value = 3.4E-77 and the amount of fluctuation as indicated by R-square is 21.84% of total variation (as 1-R-square = 0.2184)

Table 1: Ln (Yield of Pulses) regressed on Time(T) for India for the period 1970-71 to 2019-2020

	Coefficients	Standard Error	t Stat	P-value
Intercept	6.1014	0.0235	259.3434	3.4E-77
T	0.0105	0.0008	13.1054	1.8E-17
R Square	**Adjusted R Square**	**Standard Error**	**F**	**Significance F**
0.7816	0.7770	0.0819	171.7506	1.8E-17

Source: Author's own calculation

If we observe the Diagram 1 there are fluctuations present the linear trend (constant growth) path. Thus, if we fit polynomial of order/degree then the estimated equation becomes.

Table 2: Polynomial of Ln (Yield of Pulses) in India and their quadratic linear trend during the period 1970-71 to 2019-20

	Coefficients	Degree	Liner	Quadratic	Cubic	Degree Four	Degree Five
Intercept (a)	6.1719	**R Square**	0.7816	0.8115	0.8167	0.8370	0.8491
T (b)	0.0024	**Adjusted R Square**	0.7770	0.8035	0.8048	0.8225	0.8319
T^2 (c)	0.0002	**F**	171.75	101.18	68.33	57.75	49.50
		Significance F	1.8E-17	9.3E-18	5.6E-17	3.8E-17	5.7E-17

Source: Author's own calculation

If we observe the Table 2 for linear adjusted R square is 0.7770 and significance F is 1.8E-17 and for quadratic the adjusted R square is 0.8035, which is little increases the linear and significance F is 9.3E-18, which is also more significance then linear. For cubic or polynomial of order/degree three the adjusted R square is 0.8048 and significance F is 5.6E-17. The adjusted R square is little increase then quadratic and significance F is less significance than quadratic. Now if we go polynomial of order/degree four the adjusted R square is 0.8225 and significance F is 3.8E-17. The adjusted R square is little increases than cubic and significance F is more significance than cubic but less significance than quadratic. If we go polynomial of order/degree five, the adjusted R square is 0.8319 and significance F is 5.7E-17. The adjusted R square is little increase then polynomial of order/degree four but significance F is less significance than polynomial of degree four. So, we conclude hair quadratic is batter fit (as indicated green shaded) of polynomial of ln (Yield of Pulses) in India during the period 1970-71 to 2019-20.

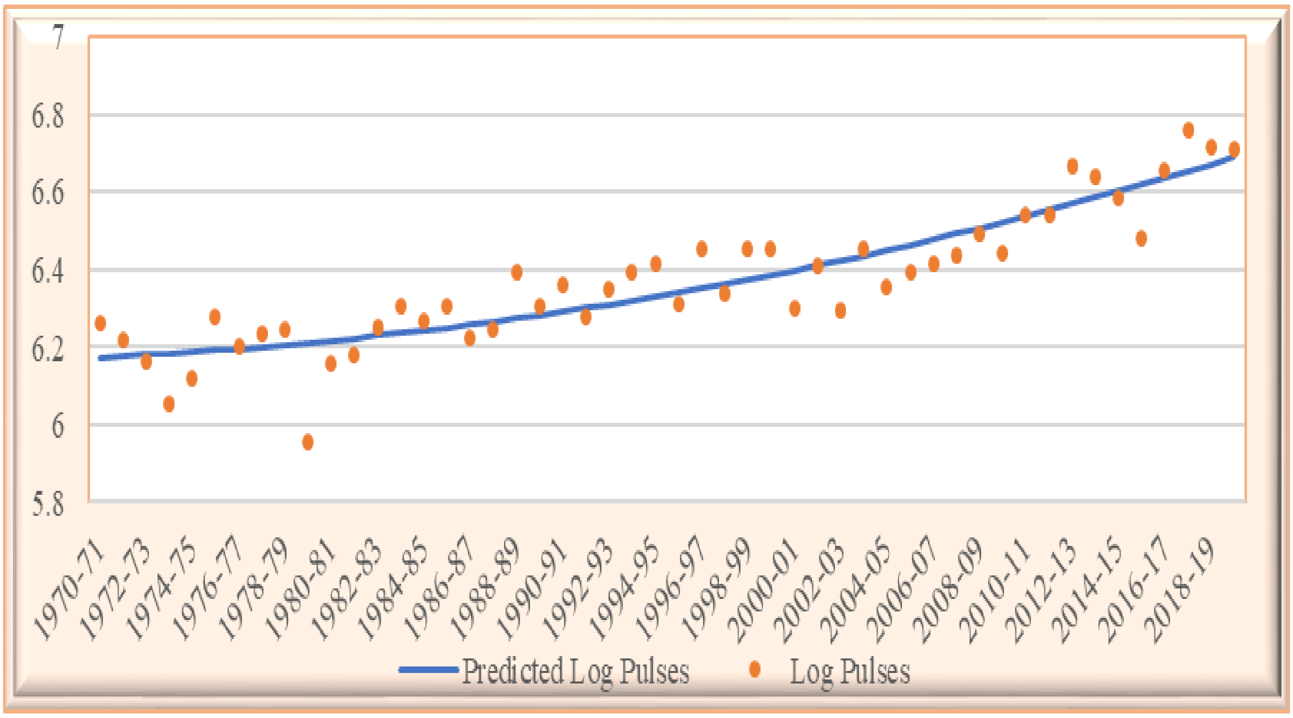

Diagram 2: Data point of ln (Yield of Pulses) in India and their quadratic linear trend during the period 1970-71 to 2019-20

Source: Author's own calculation

Hair the coefficient of b and c are 0.0024 and 0.0002, both the coefficient b and c are positive. So, we have positive growth with accelerating in Diagram 2. The ln (Yield of Pulses) in India extended period becomes U-shaped or strictly convex with a minimum point and this minimum point is (-b/2c) = -7.4524. So, in the year 1963-64 the growth rate becomes zero. After the year 1963-64 the growth rate continuously increasing.

Fluctuations in ln (Yield of Pulses) in India during the period 1970-71 to 2019-20

The residual after the trend in ln (Yield of Pulses) in India during the period 1970-71 to 2019-20 is presented in Diagram 3. The date points show not only fluctuate year-to-year but also some other types of fluctuation that is cyclical fluctuation, seasonal fluctuation etc.

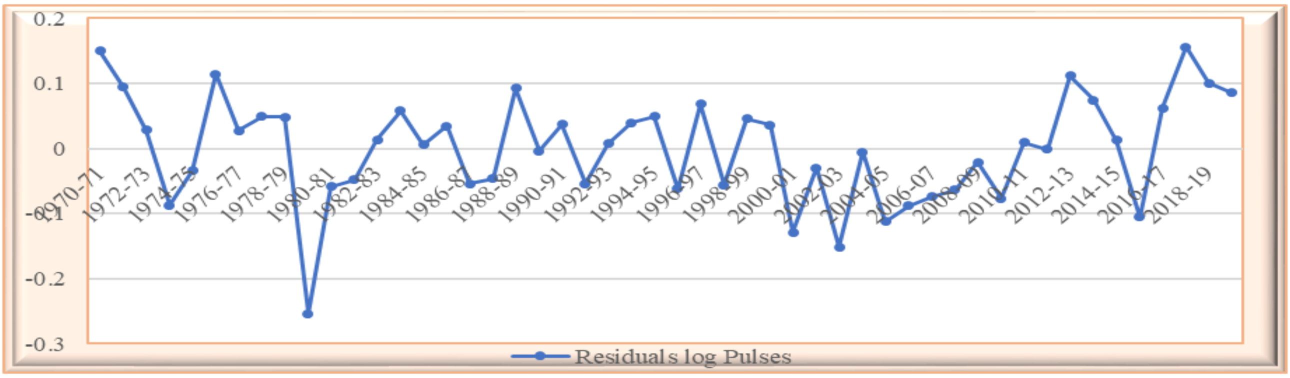

Diagram 3: Fluctuation in ln (Yield of Pulses) in India during the period 1970-71 to 2019-20
Source: Author's own calculation

Table 3: Ln (Yield of Pulses) regressed on Time(T) and their fluctuations in India during the period 1970-71 to 2019-20

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Intercept	6.1014	0.0235	259.3434	3.4E-77
T	0.0105	0.0008	13.1054	1.8E-17
R Square	**Adjusted R Square**	**Standard Error**	**F**	**Significance F**
0.7816	0.7770	0.0819	171.7506	1.8E-17
$\mathbf{F_{Coppock}}$	1.1026		**CDVI**	0.0127
$\mathbf{F'_{Coppock}}$	0.0077		$\mathbf{F_{RSS}}$	0.0126
Average length of cycles				5.41

Source: Author's own calculation

In Diagram 3 and Table 3 shows the result of fluctuations in ln (Yield of Pulses) in India during the period 1970-71 to 2019-20. The number of fluctuations indicated by R-square in 21.84% of total variation (as 1-R-square = 0.2184). Another method of average overall fluctuations is F_{RSS}, which if found to be 0.0126. Diagram 3 shows that year-to-year fluctuations of ln (Yield of Pulses) in India during the period 1970-71 to 2019-20. The year-to-year measure of fluctuation is given by Coppock (1962), which is found to be 1.1026. RSS-based and Coppock-based measure are not directly comparable because $F_{Coppock}$ is not unit free then we need to consider the adjusted Coppock measure of fluctuations ($F'_{Coppock}$) that is 0.0077. Which is 61.11% of total fluctuation and rest of 38.88% is due to cyclical fluctuation and irregular fluctuation. To find out the approximate average length of full cycle, we use $2(F_{RSS}/F'_{Coopock})^2$. Which is found to be 5.41 years.

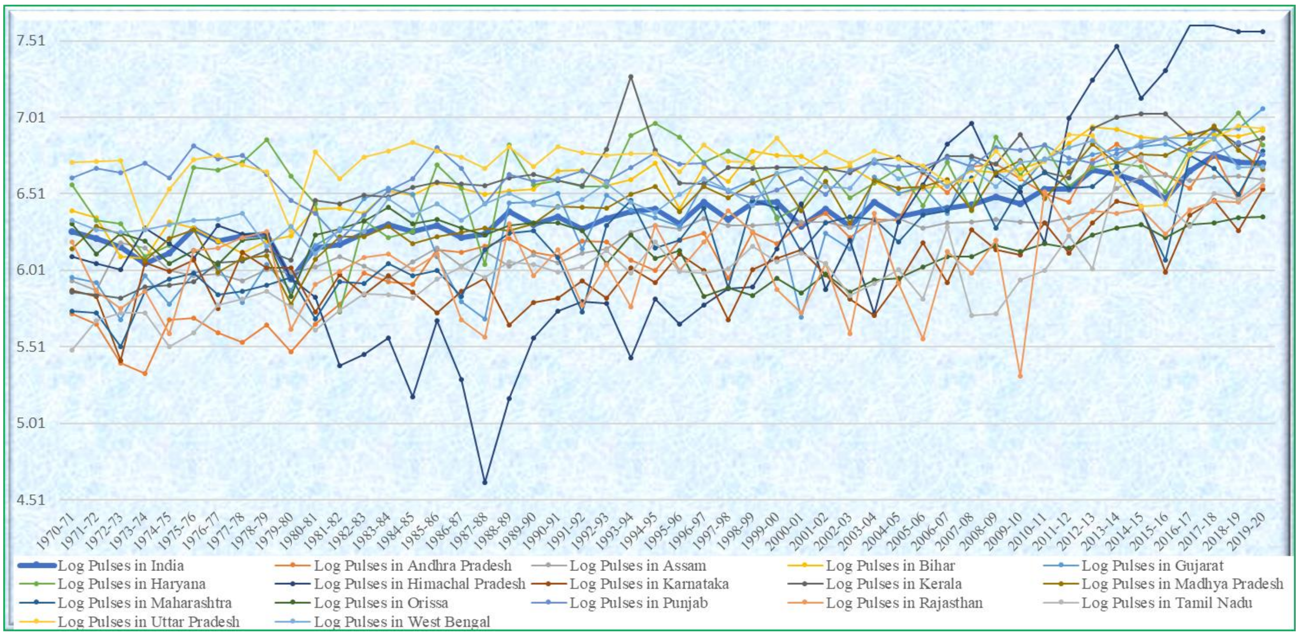

Diagram 4: Ln (Yield of Pulses) in India and its major States during the period 1970-71 to 2019-20
Source: Author's own calculation

Table 4: Ln (Yield of Pulses) regressed on Time(T) for India and its major States for the period 1970-71 to 2019-2020

		Coefficients	Standard Error	t Stat	P-value	R Square	Adjusted R Square	Standard Error	F	Significance F
India	**Intercept**	6.1014	0.0235	259.3434	3.43E-77	0.7816	0.7770	0.0819	171.7506	1.79E-17
	T	0.0105	0.0008	13.1054	1.79E-17					
Andhra Pradesh	**Intercept**	5.5073	0.0416	132.4129	3.37E-63	0.8758	0.8732	0.1448	338.5397	2.21E-23
	T	0.0261	0.0014	18.3994	2.21E-23					
Assam	**Intercept**	5.9025	0.0236	250.5027	1.81E-76	0.8450	0.8418	0.0821	261.7580	4.56E-21
	T	0.0130	0.0008	16.1789	4.56E-21					
Bihar	**Intercept**	6.2207	0.0315	197.5372	1.60E-71	0.7782	0.7736	0.1097	168.4106	2.60E-17
	T	0.0139	0.0011	12.9773	2.60E-17					
Gujarat	**Intercept**	5.8507	0.0630	92.8108	8.08E-56	0.6489	0.6415	0.2195	88.6958	1.74E-12
	T	0.0203	0.0022	9.4178	1.74E-12					
Haryana	**Intercept**	6.3802	0.0661	96.4720	1.27E-56	0.2078	0.1913	0.2303	12.5882	8.79E-04
	T	0.0080	0.0023	3.5480	8.79E-04					
Himachal Pradesh	**Intercept**	5.3601	0.1527	35.1100	6.89E-36	0.4556	0.4442	0.5317	40.1665	7.63E-08
	T	0.0330	0.0052	6.3377	7.63E-08					
Karnataka	**Intercept**	5.7528	0.0514	111.8974	1.06E-59	0.4142	0.4020	0.1790	33.9407	4.62E-07
	T	0.0102	0.0018	5.8259	4.62E-07					
Kerala	**Intercept**	6.0571	0.0548	110.4353	1.99E-59	0.7040	0.6978	0.1910	114.1653	2.77E-14
	T	0.0200	0.0019	10.6848	2.77E-14					
Madhya Pradesh	**Intercept**	6.0414	0.0338	178.6405	1.99E-69	0.7839	0.7794	0.1178	174.1500	1.38E-17
	T	0.0152	0.0012	13.1966	1.38E-17					
Maharashtra	**Intercept**	5.7257	0.0473	120.9616	2.56E-61	0.7325	0.7269	0.1648	131.4153	2.40E-15
	T	0.0185	0.0016	11.4637	2.40E-15					
Orissa	**Intercept**	6.1704	0.0467	132.0465	3.85E-63	0.0012	-0.0196	0.1627	0.0581	8.11E-01
	T	-0.0004	0.0016	-0.2410	8.11E-01					
Punjab	**Intercept**	6.5511	0.0352	186.1667	2.75E-70	0.2126	0.1962	0.1226	12.9618	7.51E-04
	T	0.0043	0.0012	3.6002	7.51E-04					
Rajasthan	**Intercept**	5.8687	0.0781	75.1394	1.91E-51	0.1509	0.1333	0.2720	8.5336	5.30E-03
	T	0.0078	0.0027	2.9212	5.30E-03					
Tamil Nadu	**Intercept**	5.6251	0.0533	105.5218	1.76E-58	0.5766	0.5678	0.1857	65.3624	1.64E-10
	T	0.0147	0.0018	8.0847	1.64E-10					
Uttar Pradesh	**Intercept**	6.6611	0.0400	166.3608	6.04E-68	0.0493	0.0295	0.1394	2.4872	1.21E-01
	T	0.0022	0.0014	1.5771	1.21E-01					
West Bengal	**Intercept**	6.2026	0.0244	253.7519	9.76E-77	0.8224	0.8187	0.0851	222.2816	1.22E-19
	T	0.0124	0.0008	14.9091	1.22E-19					

Source: Author's own calculation

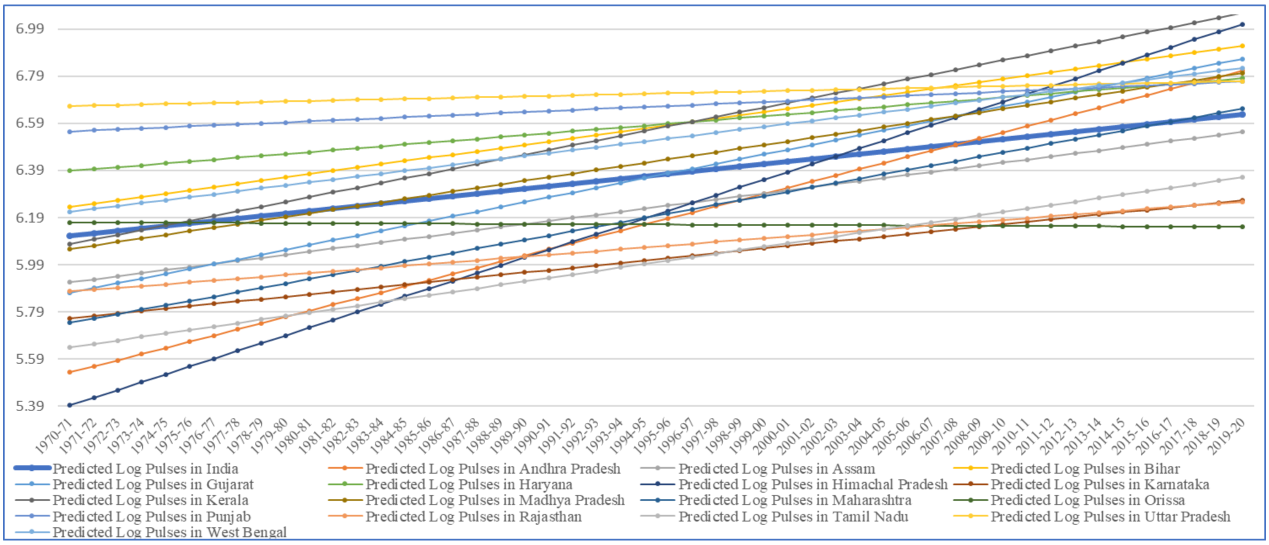

Diagram 5 Predicted Log Pulses in India and its major States during the period 1970-71 to 2019-20

Source: Author's own calculation

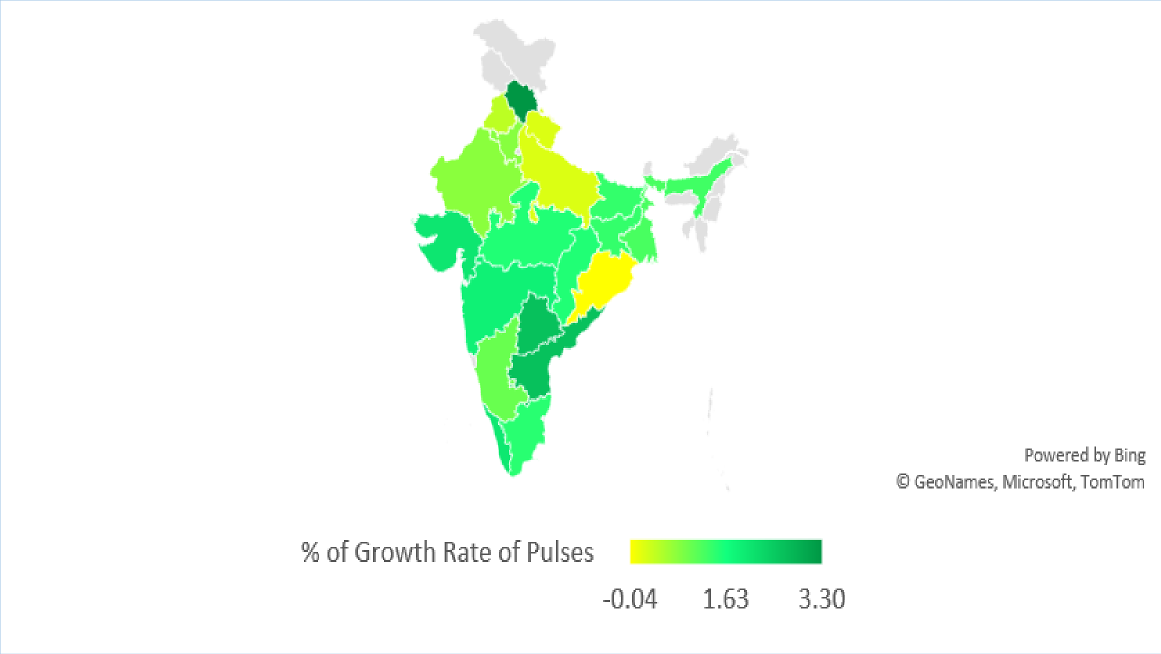

Diagram 6 Growth rate (%) of yield of Pulses of major States in India during the period 1970-71 to 2019-20
Source: Author's own calculation

Diagram 4 shows that there exists an approximate linear trend in the log values of yield of Pulses in India and its major States during the period 1970-71 to 2019-20. Here the blue bold line indicates the yield of Pulses in India during the period 1970-71 to 2019-20. And other lines indicate the major States of India.

The growth rate of yield of Pulses production in India and its major States shows the Table 4 and also shows the R-square, Adjusted R-square, F-value with P-value. The growth rate of yield of Pulses in India is positive and highly significance. The growth rate of yield of Pulses in India is 1.05%. The growth rate of yield of Pulses in Orisa is negative and insignificance (as indicated yellow shaded). The growth rate of yield of Pulses in Uttar Pradesh is positive but insignificance. The growth rate of yield of Pulses of all other major States in India is positive and highly significance.

Diagram 5 shows predicated log Pulses in India and its major States during the period 1970-71 to 2019-20. If we see the Diagram 5 blue bold line is the predicated log Pulses in India and the other lines are major States in India the growth rate of India is 1.05%. If we compare major States with India some States are converge, some States are diverged, some States are initial period below from India after than above form India and some States are above form India after than below from India. Assam, Haryana, Punjab, Tamil Nady and Uttar Pradesh are converged from India but Assam and Tamil Nadu are below from India and Haryana, Punjab and Uttar Pradesh are above from India. The growth rate of Assam, Haryana, Punjab, Tamil Nady and Uttar Pradesh are 1.30%, 0.80%, 0.43%, 1.47% and 0.22%. Bihar, Karnataka, Rajasthan and West Bengal are diverged from India but Karnataka and Rajasthan are below from India and Bihar and West Bengal are above from India. The growth rate of Bihar, Karnataka, Rajasthan and West Bengal are 1.39%, 1.02%, 0.78% and 1.24%. In initial period Andhra Pradesh, Gujarat, Himachal Pradesh, Kerala, Madhya Pradesh and Maharashtra are below from India after than above from India. In the year 2008 Andhra Pradesh was above from India, 1995 Gujarat was above from India, 2002 Himachal Pradesh was above from India, 1974 Kerala was above from India, 1982 Madhya Pradesh was above from India and 2016 Maharashtra was above from India. The growth rate of Andhra Pradesh, Gujarat, Himachal Pradesh, Kerala, Madhya Pradesh and Maharashtra are 2.16%, 2.03%, 3.30%, 2.00%, 1.52% and 1.85%. Only one States Orissa in initial period above from India after than below from India. In the year 1976 Orissa was below from India. The growth rate of Orissa is -0.04%.

Diagram 6 shows that percentage of growth rate of yield of Pulses of major States in India during the period 1970-71 to 2019-20. In Diagram 6 deep green colour is the highest growth rate and light green is the lowest growth rate and yellow colour is the negative growth rate. Here the highest growth rate is Himachal Pradesh that is 3.30% and lowest growth rate is Uttar Pradesh that is 0.22% and negative growth rate is Orissa that is -0.04%.

If we observe the Diagram 4 there are fluctuations present, the linear trend (constant growth) path. Thus, if we fit polynomial of order/degree then the estimated equation becomes.

Table 5: Polynomial of Ln(yield of Pulses) of major States in India during the period 1970-71 to 2019-20

Major States of India		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
Andhra Pradesh	R Square	0.8758	0.8803	0.8806	0.8807	0.9036	0.9188	0.9266
	Adjusted R Square	0.8732	0.8752	0.8728	0.8701	0.8926	0.9074	0.9144
	F	338.54	172.8	113.1	83.08	82.48	81.05	75.73
	Significance F	2.21E-23	2.17E-22	3.05E-21	3.46E-20	3.26E-21	8.17E-22	9.39E-22
	Intercept(a)				T(b)			
	5.5073				0.0261			
Assam		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
	R Square	0.845	0.8713	0.8713	0.885	0.8876	0.9203	0.9253
	Adjusted R Square	0.8418	0.8658	0.8629	0.8748	0.8748	0.9092	0.9128
	F	261.76	159.06	103.83	86.6	69.5	82.78	74.27
	Significance F	4.56E-21	1.19E-21	1.70E-20	1.53E-20	9.29E-20	5.39E-22	1.37E-21
	Intercept(a)	T(b)			T^2(c)		(-b/2c)	-11.11
	5.981	0.0039			0.0002		1959-60	0
Bihar		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
	R Square	0.7782	0.7827	0.7913	0.8223	0.8739	0.8745	0.8796
	Adjusted R Square	0.7736	0.7735	0.7777	0.8065	0.8595	0.8569	0.8595
	F	168.41	84.67	58.13	52.06	60.97	49.92	43.82
	Significance F	2.60E-17	2.62E-16	1.10E-15	2.55E-16	1.15E-18	8.62E-18	2.71E-17
	Intercept(a)	T(b)			T^2(c)	T^3(d)	T^4(e)	T^5(f)
	6.5007	-0.1407			0.0196	-0.0009	1.92E-05	-1.40E-07
	Year of Point of inflection	1981-82			1997-98		2012-13	
	Growth rate	4.08			-0.44		3.01	
Gujarat		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
	R Square	0.6489	0.6527	0.678	0.6782	0.691	0.6941	0.6943
	Adjusted R Square	0.6415	0.6379	0.657	0.6496	0.6559	0.6515	0.6433
	F	88.7	44.17	32.29	23.71	19.68	16.26	13.63
	Significance F	1.74E-12	1.61E-11	2.19E-11	1.36E-10	2.99E-10	1.15E-09	4.87E-09
	Intercept(a)				T(b)			
	5.8507				0.0203			
Haryana		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
	R Square	0.2078	0.2078	0.2121	0.2473	0.2519	0.2799	0.2802
	Adjusted R Square	0.1913	0.1741	0.1608	0.1804	0.1669	0.1795	0.1603
	F	12.5882	6.1639	4.1287	3.6957	2.963	2.786	2.3359
	Significance F	0.0009	0.0042	0.0113	0.011	0.0217	0.0223	0.0415
	Intercept(a)				T(b)			
	6.3802				0.008			
Himachal Pradesh		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
	R Square	0.4556	0.83	0.8394	0.85	0.8666	0.8808	0.884
	Adjusted R Square	0.4442	0.8228	0.8289	0.8366	0.8515	0.8642	0.8646
	F	40.17	114.75	80.11	63.74	57.18	52.98	45.71
	Significance F	7.63E-08	8.22E-19	2.75E-18	5.85E-18	3.88E-18	2.84E-18	1.26E-17
	Intercept(a)	T(b)			T^2(c)		(-b/2c)	18.39
	6.3859	-0.0853			0.0023		1987-88	0
Karnataka		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
	R Square	0.4142	0.5393	0.5513	0.5671	0.5716	0.5753	0.5755
	Adjusted R Square	0.402	0.5197	0.522	0.5286	0.523	0.5161	0.5047
	F	33.94	27.51	18.84	14.74	11.74	9.71	8.13
	Significance F	4.62E-07	1.23E-08	4.10E-08	9.07E-08	3.04E-07	9.42E-07	3.11E-06
	Intercept(a)	T(b)			T^2(c)		(-b/2c)	13.76
	5.9453	-0.012			0.0004		1983-84	0
Kerala		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
	R Square	0.704	0.8194	0.8577	0.8603	0.8936	0.8941	0.8952
	Adjusted R Square	0.6978	0.8117	0.8484	0.8478	0.8815	0.8793	0.8778
	F	114.17	106.63	92.41	69.26	73.88	60.51	51.27
	Significance F	2.77E-14	3.41E-18	1.71E-19	1.20E-18	2.83E-20	2.31E-19	1.52E-18
	Intercept(a)		T(b)		T^2(c)	T^3(d)	T^4(e)	T^5(f)
	5.924		-0.0712		0.0183	-0.001	2.22E-05	-1.70E-07

	Year of Point of inflection	**1978-79**			**1997-98**		**2011-12**	
	Growth rate	7.06			-0.84		2.95	
Madhya Pradesh		**Liner**	**Quadratic**	**Cubic**	**Degree Four**	**Degree Five**	**Degree Six**	**Degree Seven**
	R Square	0.7839	0.7885	0.7983	0.8244	0.8363	0.8629	0.8629
	Adjusted R Square	0.7794	0.7795	0.7851	0.8087	0.8177	0.8437	0.84
	F	174.15	87.63	60.68	52.8	44.97	45.1	37.76
	Significance F	1.38E-17	1.39E-16	5.04E-16	1.97E-16	3.33E-16	5.60E-17	3.96E-16
	Intercept(a)				**T(b)**			
	6.0414				0.0152			
Maharashtra		**Liner**	**Quadratic**	**Cubic**	**Degree Four**	**Degree Five**	**Degree Six**	**Degree Seven**
	R Square	0.7325	0.7332	0.7333	0.7334	0.735	0.735	0.7444
	Adjusted R Square	0.7269	0.7218	0.7159	0.7097	0.7049	0.698	0.7018
	F	131.42	64.58	42.15	30.95	24.41	19.88	17.47
	Significance F	2.40E-15	3.28E-14	2.99E-13	2.11E-12	1.11E-11	5.87E-11	1.34E-10
	Intercept(a)				**T(b)**			
	5.7257				0.0185			
Orissa		**Liner**	**Quadratic**	**Cubic**	**Degree Four**	**Degree Five**	**Degree Six**	**Degree Seven**
	R Square	0.0012	0.1517	0.4174	0.4185	0.6838	0.7128	0.7606
	Adjusted R Square	-0.0196	0.1156	0.3794	0.3668	0.6479	0.6727	0.7207
	F	0.06	4.2	10.99	8.1	19.03	17.79	19.07
	Significance F	0.8106	0.0209	1.46E-05	5.25E-05	4.89E-10	3.13E-10	3.54E-11
	Intercept(a)	**T(b)**	**T^2(c)**	**T^3 (d)**	**T^4(e)**	**T^5 (f)**	**T^6 (g)**	**T^7 (h)**
	6.3332	-0.043	-0.0088	0.0025	-0.0002	6.60E-06	-1.03E-07	6.11E-10
	Year of Point of inflection			**1971-72**	**1980-81**	**1993-94**	**2007-08**	**2015-16**
	Growth rate			-5.36	3.55	-4.78	4.5	-0.04
Punjab		**Liner**	**Quadratic**	**Cubic**	**Degree Four**	**Degree Five**	**Degree Six**	**Degree Seven**
	R Square	0.2126	0.338	0.3617	0.3617	0.3635	0.4206	0.51
	Adjusted R Square	0.1962	0.3098	0.3201	0.305	0.2912	0.3397	0.4284
	F	12.96	12	8.69	6.38	5.03	5.2	6.25
	Significance F	0.0008	6.17E-05	0.0001	0.0004	0.001	0.0004	4.80E-05
	Intercept(a)	**T(b)**	**T^2(c)**	**T^3 (d)**	**T^4(e)**	**T^5 (f)**	**T^6 (g)**	**T^7 (h)**
	6.2977	0.3246	-0.0777	0.0077	-0.0004	1.00E-05	-1.33E-07	7.08E-10
	Year of Point of inflection			**1976-77**	**1986-87**	**1996-97**	**2007-08**	**2015-16**
	Growth rate			-4.97	2.29	-0.91	2.69	-1.33
Rajasthan		**Liner**	**Quadratic**	**Cubic**	**Degree Four**	**Degree Five**	**Degree Six**	**Degree Seven**
	R Square	0.1509	0.2248	0.2707	0.2763	0.2816	0.2895	0.3115
	Adjusted R Square	0.1333	0.1918	0.2231	0.212	0.2	0.1903	0.1967
	F	8.53	6.81	5.69	4.3	3.45	2.92	2.71
	Significance F	0.0053	0.0025	0.0021	0.005	0.0102	0.0177	0.0205
	Intercept(a)	**T(b)**	**T^2(c)**	**T^3 (d)**	**Point of inflection**		20.15 (1989-90)	
	5.8703	0.0277	-0.0016	2.63E-05	**Growth rate**		-0.43	
Tamil Nadu		**Liner**	**Quadratic**	**Cubic**	**Degree Four**	**Degree Five**	**Degree Six**	**Degree Seven**
	R Square	0.5766	0.5816	0.6847	0.715	0.7294	0.7773	0.7788
	Adjusted R Square	0.5678	0.5638	0.6642	0.6896	0.6986	0.7462	0.7419
	F	65.36	32.66	33.3	28.22	23.71	25.02	21.12
	Significance F	1.64E-10	1.28E-09	1.35E-11	9.29E-12	1.75E-11	1.55E-12	7.16E-12
	Intercept(a)	**T(b)**		**T^2(c)**	**T^3(d)**	**T^4(e)**	**T^5(f)**	**T^6(g)**
	5.3961		0.1586	-0.0297	0.0026	-0.0001	1.94E-06	-1.33E-08
	Year of Point of inflection	**1976-77**		**1985-86**		**1999-00**		**2013-14**
	Growth rate	0.32		3.66		-2.55		8.19
Uttar Pradesh		**Liner**	**Quadratic**	**Cubic**	**Degree Four**	**Degree Five**	**Degree Six**	**Degree Seven**
	R Square	0.0493	0.065	0.1066	0.2212	0.2213	0.2697	0.2728
	Adjusted R Square	0.0295	0.0252	0.0483	0.1519	0.1328	0.1678	0.1516
	F	2.49	1.63	1.83	3.19	2.5	2.65	2.25
	Significance F	0.1213	0.2062	0.155	0.0216	0.0445	0.0283	0.0487
	Intercept(a)	**T(b)**	**T^2(c)**	**T^3 (d)**	**T^4(e)**	**Point of inflection**	13.48 (1982-83)	33.73 (2003-04)
	6.708	-0.0365	0.0044	-0.0002	1.60E-06	**Growth rate**	1.46	-1.2

		Liner	Quadratic	Cubic	Degree Four	Degree Five	Degree Six	Degree Seven
West Bengal	**R Square**	0.8224	0.8267	0.8386	0.8387	0.857	0.8715	0.8722
	Adjusted R Square	0.8187	0.8193	0.8281	0.8244	0.8408	0.8535	0.8509
	F	222.28	112.1	79.69	58.5	52.76	48.59	40.96
	Significance F	1.22E-19	1.29E-18	3.04E-18	2.95E-17	1.76E-17	1.42E-17	9.22E-17
	Intercept(a)				**T(b)**			
	6.2026				0.0124			

Source: Author's own calculation

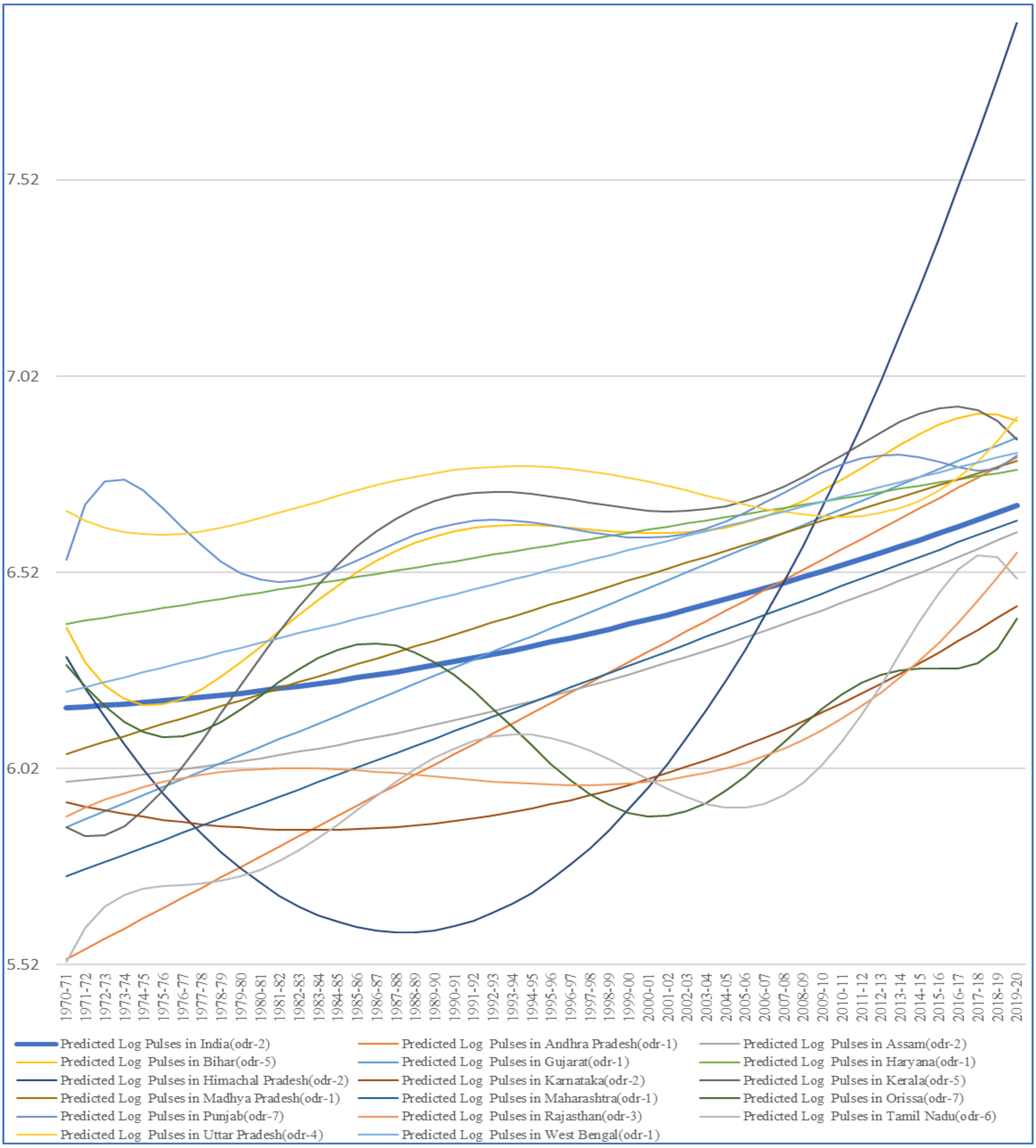

Diagram 7: Polynomial of Ln (yield of Pulses) in India and its major States during the period 1970-71 to 2019-20

Source: Author's own calculation

We tried to find a higher order polynomial function up to seven degrees to find out the nature of the growth of yield of Pulses of major States in India. Here different States are optimum in different order/degree. In

Table 5 some States are optimum in linear; those states are Andhra Pradesh, Gujarat, Haryana, Madhya Pradesh, Maharashtra and West Bengal (as indicated green shaded in Table 5). Its means either there is no any fluctuation or there is regular fluctuation of short length.

Some States are optimum in quadratic (order/degree Two). Those States are Assam, Himachal Pradesh and Karnataka (as indicated green shaded in Table 5). In the States Assam both the coefficients b and c are positive so we have positive growth with acceleration. In Diagram 7 the line of Assam extended period becomes U-shaped or strictly convex with a minimum point and this minimum point for Assam is (-b/2c) = -11.11 so, in the year 1959-60 growth rate was zero. After the year 1959-60 the growth rate continuously increasing. In initial period that is 1970-71 the growth rate of yield of Pulses in Assam was 0.43% and the year 2019-20 the growth rate was 2.17%. In States Himachal Pradesh and Karnataka, the coefficient of b is negative and coefficient of c is positive so we have positive growth with acceleration. In figure 7 the line of Himachal Pradesh and Karnataka extended period becomes U-shaped or strictly convex with minimum point and this minimum point for Himachal Pradesh is (-b/2c) = 18.39 that means in the year 1987-88 the growth rate was zero. In initial period that is 1970-71 the growth rate of yield of Pulses in Himachal Pradesh was -8.07 and the last period that is 2019-20 the growth rate was 14.67. The minimum point for Karnataka is (-b/2c) = 13.76 that means in the year 1983-84 the growth rate was zero. In initial period that is 1970-71 the growth rate of yield of Pulses in Karnataka was -1.11 and the last period that is 2019-20 the growth rate was 3.16.

The best fitted polynomial for yield of Pulses is cubic in nature for the only state Rajasthan (as indicated green shaded in Table 5). Here the coefficient b is positive, coefficient c is negative and coefficient d is positive; that means in initial period the growth rate is positive after than the growth rate is decelerate and finally the growth rate is accelerate. In 1st phase the path of yield of Pulses in Rajasthan was concave and 2nd phase convex and have a point of inflection that is t = (-c/3d) = 20.15 in the year 1989-90 where growth rate was -0.43%. In initial year that is 1970-71 the growth rate of yield of Pulses in Rajasthan was 2.46% and the last year that is 2019-20 the growth rate was 6.60%.

The best fitted polynomial for yield of Pulses is degree four in nature for the only state Uttar Pradesh (as indicated green shaded in Table 5). Here the coefficient of b is negative it means growth rate of initial period that is 1970-71 was negative. Here c is positive d is negative and e is positive its means in initial period growth rate is increasing after than growth rate decreasing and finally it is increasing. Here we have two points of inflection 13.48 and 33.73. Year of the inflection point are 1982-83 and 2003-04. The growth rate of year of inflection points is 1.46% and -1.20%.

Two States are optimum in degree Five; those states are Bihar and Kerala (as indicated green shaded in Table 5). Here both the States Bihar and Kerala coefficient of b is negative that means in initial period the growth rate was negative. Coefficient c is positive d is negative e is positive and f is negative so, in initial year growth rate was negative after than increasing next period decreasing after than increasing and finally decreasing. If we see the diagram 7 the path of yield of Pulses in Bihar and Kerala initially concave after than convex after than concave after than convex and finally concave. Here we have three points of inflection, the year of three inflection point in Bihar are 1981-82, 1997-98, and 2012-13 and the growth rate of those years was 4.08%, -0.44% and 3.10%. The year of inflection point in Kerala are 1978-79, 1997-98 and 2011-12. The growth rate of those years was 7.06%, -0.84% and 2.95%.

Only one State Tamil Nadu best fitted polynomial for degree six in nature (as indicated green shaded in Table 5). Here the coefficient of b is positive c is negative d is positive e is negative f is positive and g is negative. If we see the diagram 7 the path of yield of Pulses in Tamil Nadu 1st phase convex 2nd phase concave 3rd phase convex 4th phase concave 5th phase convex and 6th phase concave. Here we have four points of inflection. The year of the inflection point are 1976-77, 1985-86, 1999-00 and 2013-14. The growth rate of year of inflection point was 0.32%, 3.66%, -2.55% and 8.19%. In initial year (1970-71) growth rate was 10.67% and in last year (2019-20) the growth rate was -8.58%.

Two States are optimum in degree seven; those States are Orissa and Punjab (as indicated green shaded in Table 5). In the State Orissa coefficient of b is negative coefficient c is negative coefficient d is positive coefficient e is negative coefficient f is positive coefficient g is negative and coefficient h is positive. If we see the diagram 7 the path of yield of Pulses in Orissa 1st phase concave 2nd phase convex 3rd phase concave 4th phase convex 5th phase concave 6th phase convex. Here we have five points of inflection. The year of the inflection points are 1971-72, 1980-81, 1993-94, 2007-08, 2015-16. The growth rate of the year of inflection points was -5.36%, 3.55%, -4.78%, 4.50% and -0.04%. In State Punjab coefficient of b is positive c is negative d is positive e is negative f is positive g is negative h is positive. If we see the diagram 7 the path of yield of Pulses in Punjab 1st phase convex 2nd phase concave 3rd phase convex 4th phase concave 5th phase convex 6th phase concave and 7th phase convex. Here we have five points of inflection. The year of the inflection points are 1976-77, 1986-87, 1996-97, 2007-08 and 2015-16. The growth rate of year of inflection points was -4.97%, 2.29%, -0.91%, 2.69% and -1.33%.

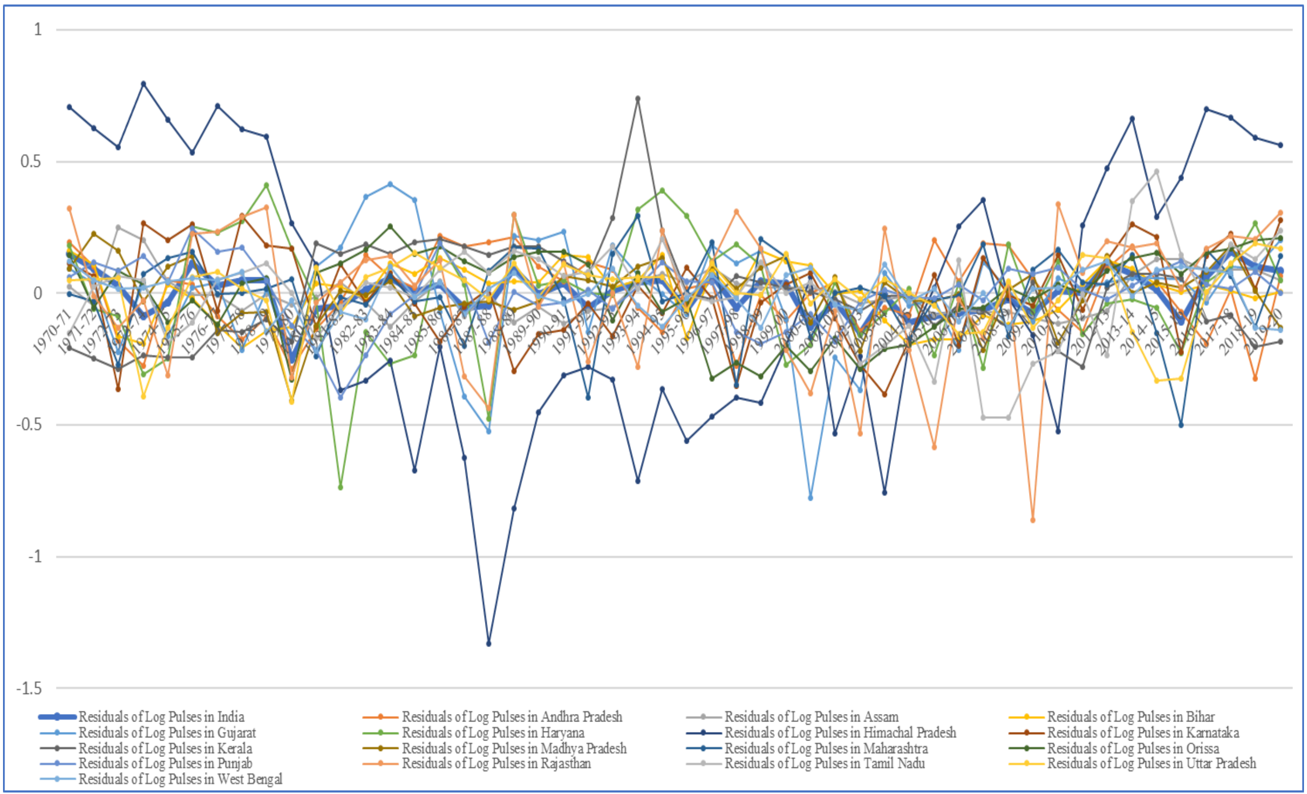

Diagram 8 Fluctuation in ln (Yield of Pulses) in India and its major States during the period 1970-71 to 2019-20
Source: Author's own calculation

Table 6: Fluctuation of yield of Pulses in India and its major States during the period 1970-71 to 2019-20

	$F_{Coppock}$	$F'_{Coppock}$	CDVI	F_{RSS}	1-R Square	Average length of cycles
India	1.1026	0.0077	0.0127	0.0126	0.2184	5.41
Andhra Pradesh	1.1752	0.0131	0.0232	0.0230	0.1242	6.18
Assam	1.0764	0.0059	0.0130	0.0129	0.1550	9.53
Bihar	1.1094	0.0079	0.0165	0.0163	0.2218	8.56
Gujarat	1.2797	0.0194	0.0341	0.0338	0.3511	6.09
Haryana	1.3187	0.0210	0.0346	0.0343	0.7922	5.32
Himachal Pradesh	1.3671	0.0252	0.0849	0.0840	0.5444	22.20
Karnataka	1.2523	0.0187	0.0295	0.0292	0.5858	4.87
Kerala	1.1552	0.0110	0.0288	0.0285	0.2960	13.46
Madhya Pradesh	1.1574	0.0114	0.0181	0.0179	0.2161	4.99
Maharashtra	1.2774	0.0198	0.0263	0.0261	0.2675	3.48
Orissa	1.1342	0.0102	0.0262	0.0259	0.9988	12.83
Punjab	1.1092	0.0078	0.0182	0.0180	0.7874	10.73
Rajasthan	1.4555	0.0309	0.0444	0.0439	0.8491	4.03
Tamil Nadu	1.2065	0.0156	0.0306	0.0303	0.4234	7.51
Uttar Pradesh	1.1803	0.0123	0.0206	0.0203	0.9507	5.43
West Bengal	1.1130	0.0082	0.0129	0.0128	0.1776	4.86

Source: Author's own calculation

Here we shall try to explain overall average fluctuation by using deviation from the mean value. The F_{RSS} measure and the Cuddy and Della Valle's (1978) index both indicate overall average fluctuation. Another method we use to explain the overall average fluctuation is (1-R Square) which indicate the deviation from variance. The year-to-year measure of fluctuation is given by Coppock (1962). The F_{RSS} based and Coppock based measure are not directly comparable because $F_{Coppock}$ is unit free. Mondal and Mondal Saha (2008) have suggested a modified Coppock measure of year-to-year fluctuation, whose method can be directly comparable with the F_{RSS} based measure and also estimated the average length of full cycles. In Diagram 8 and Table 6 shows the result of the fluctuation of yield of Pulses in India and its major States during the period

1970-71 to 2019-20. Here the overall fluctuation in India by using deviation from mean value that is F_{RSS} = 0.0126 and it is little difference from CDVI which is CDVI = 0.0127. Another method of overall average fluctuation is (1-R Square) is found to be in India is 0.2184. The year-to-year fluctuation in India is 0.0077 and average length of full cycles is 5.41 years. The highest F_{RSS} is Himachal Pradesh which is 0.0840 and lowest is West Bengal which is 0.0128. The highest (1-R Square) is Orissa which is 0.9988 and lowest is Andhra Pradesh which is 0.1242. The highest year-to-year fluctuation which is measure by $F'_{Coppock}$ is Rajasthan that is 0.0309 and lowest is Assam that is 0.0059. The highest average length of full cycle is Himachal Pradesh that is 22.20 years.

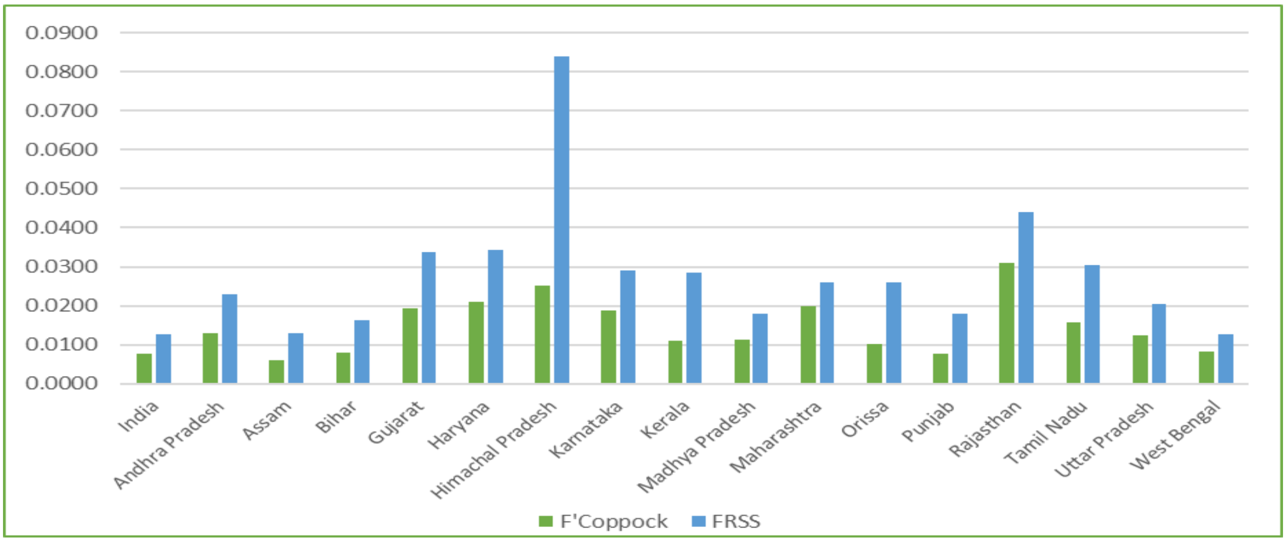

Diagram 9: Comparative analysis of fluctuation of yield of Pulses in India and its major States during the period 1970-71 to 2019-20 using $F'_{Coppock}$ and F_{RSS} method.
Source: Author's own calculation

Table 6 and Diagram 9 shows the comparative analysis of fluctuation of yield of Pulses in India and its major States during the period 1970-71 to 2019-20 by using $F'_{Coppock}$ and F_{RSS}. The highest year-to-year fluctuation ($F'_{Coppock}$) is Rajasthan which is 0.0309 and lowest year-to-year fluctuation is Assam which is 0.0059. The overall average fluctuation is measured by Cuddy and Della Valle index (1978). Here the highest overall fluctuation is Himachal Pradesh which is 0.0840 and lowest is West Bengal which is 0.0128.

CONCLUSION

This study examined the long-term growth behaviour and fluctuations in pulses yield across India and its major producing states over a fifty-year period (1970–71 to 2019–20), employing exponential and polynomial trend models alongside multiple instability indices. The empirical results reveal that, at the national level, pulses yield has experienced a modest but statistically significant upward trend, growing at approximately 1.05 percent per annum. Despite this improvement, the production environment remains characterised by notable variability, as reflected in the Cuddy–Della Valle instability index, Coppock's instability score, and the modified Coppock measure. These indicators collectively point to medium-term cyclical movements and year-to-year volatility that still constrain the stability of pulses production in India.

State-level analysis highlights pronounced heterogeneity. While most states registered statistically significant positive yield growth, the pace of improvement varied substantially. Himachal Pradesh emerged as the best performer, recording the highest annual growth rate, whereas Uttar Pradesh exhibited the lowest positive growth, and Odisha showed a marginal and statistically insignificant decline. Instability patterns were equally diverse: Himachal Pradesh demonstrated the highest overall fluctuation, while West Bengal recorded the lowest instability. Year-to-year volatility was greatest in Rajasthan, indicating its heightened vulnerability to climatic and market shocks. These findings underscore the fact that pulses production trajectories are far from uniform and are shaped by state-specific ecological conditions, technological adoption levels, and input–infrastructure environments. The model diagnostics further reveal that different polynomial forms best fit different states, reflecting the presence of multiple structural shifts, inflection points, and non-linear growth paths over time. Such diversity suggests that national averages can obscure important regional dynamics and reinforces the need for state-tailored interventions in pulses development.

Overall, the study concludes that although India has made gradual progress in improving pulses yield, substantial instability persists across states. Enhancing the resilience and productivity of the pulses sector will require region-specific technological support, expansion of irrigation, effective extension services, and improved market linkages. Policies must also account for cyclical fluctuations when designing procurement, price support, and buffer-stock strategies. Future research integrating climatic variables, input-use patterns, and policy shocks would deepen understanding of the drivers behind yield variability and support more evidence-based policymaking.

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