

Modelling Five Decades of Major Grain-Legume Dynamics in Odisha, Eastern India: An Integrated Non-Parametric Trend Framework



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Abstract

Grain legumes contribute to food and nutritional security and help maintain soil fertility in rainfed farming systems. This study evaluates long-term changes in the area, production, and yield of seven major grain legumes in Odisha. Time-series data covering the period from 1970-71 to 2019-20 are used. The study period is divided into two subperiods Period I (1970-71 to 1991-92) and Period II (1992-93 to 2019-20) along with the overall period (1970-71 to 2019-20) to examine variations in trend patterns. Several non-parametric methods, namely the Mann-Kendall and Modified Mann-Kendall tests, Sen's slope estimator, Innovative Trend Analysis, Kendall's tau, and Spearman's rank correlation, are employed. During Period I, most pulse crops experienced simultaneous increases in both area and production. In Period II, however, the trends became more uneven with different crops exhibiting divergent growth patterns. Field pea and cowpea performed most consistently showing improvements in area, production, and yield. In the case of pigeon pea, the increase in production was mainly driven by improved productivity rather than an expansion in cultivated area. The long-run trend for horse gram showed a significant decline in the area under cultivation. Black gram and green gram exhibited positive trends in area and production. However, their yield trends were negative and became statistically insignificant after correction for serial correlation. The findings suggest the need for crop-specific policy interventions focusing on productivity enhancement, area stabilisation, and climate-resilient strategies for pulse cultivation.

Keywords: Grain legumes; Pulses; Mann-Kendall test; Modified Mann-Kendall test; Sen's slope; Innovative Trend Analysis; Spearman's rho Odisha; eastern India.

1. Introduction

Grain legumes are important for food and nutritional security in India because they provide an affordable source of plant protein, dietary fibre and essential micronutrients. Legumes also contribute to sustainable farming systems through biological nitrogen fixation and the improvement of soil fertility (Singh & Virk, 2020); (Basak et al., 2023). In this study, the term grain legumes refer to the major pulse crops cultivated in Odisha, namely pigeon pea, black gram, green gram, field pea, cowpea, horse gram and Bengal gram. By contrast, total pulses denote the aggregate category reported in the official statistical source. In Odisha, pulses are cultivated across all districts and are particularly important during the rabi season. Examining their long-term performance is thus relevant not only for understanding changes in the state's pulse sector but also for agricultural planning

and policy formulation (Dash & Prusty, 2020). India has faced long-term problems in pulse production. (Joshi & Saxena, 2002) reported that the per capita availability of pulses in India declined sharply from about 60g/day in 1950 to approximately 26g/day by 2000-01. Imports subsequently increased to fill the gap between domestic demand and supply. Pulse production and productivity remained almost stagnant for several years, while per-capita pulse consumption declined over time. Pulse sector in India under pressure due to demand growth and supply constraint (Murugananthi et al., 2024). Pulses are mostly cultivated under rainfed conditions. The pulses production can be volatile due to higher climatic risk. The yields can be unstable and farmers face higher climate risk. Farmers may also shift land away from pulses when other crops provide more stable returns

and better market support. pulses often have higher yield and price risk than other crops, which reduces farmers' willingness to expand pulse area. Another important reason is the gap between recommended practices and what farmers actually adopt. In particular, adoption is weak in nutrient management and plant protection, which can reduce yields and increase instability (Nain et al., 2015). This suggests that improving extension support and adoption of better practices can help raise pulse productivity.

Policy and incentives also affect pulse production. This is evident from studies that pulses have usually received less government support than other major crops like cereals. Biased incentives in favour of cereals can discourage pulse cultivation. It is essential to establish an impartial agricultural policy that will improve the marketing and procurement of pulses (Reddy et al., 2024); (Joshi & Saxena, 2002). Odisha is an appropriate state as crop performance is significantly influenced by climate variability, irrigation, and the adoption of technology. (Senapati & Goyari, 2020) asserts that precipitation and temperature fluctuations influence crop yield, potentially resulting in yield instability in Odisha. Against this background, the study aims to examine the direction, statistical significance, and magnitude of trends in the area, production, and yield of major grain legumes in Odisha. It further compares crop performance across two policy-informed sub-period and evaluates whether production changes are more closely associated with acreage expansion or yield improvement.

2. Review of literature.

Grain legumes, commonly referred to as pulses in Indian agricultural literature, are widely recognized for their contribution to nutritional security and sustainable agriculture. From a food perspective, pulses contribute high-quality plant protein, dietary fiber, and important micronutrients, and they are especially valuable in cereal-based diets (Ofuya & Akhidue, 2005); (N. Singh, 2017). From a production perspective, pulses support soil health through biological nitrogen fixation and improve sustainability when included in crop rotations (Reddy et al., 2023). Pulses benefit both agriculture and human nutrition, increasing their production has become an important policy objective in India (Ali & Gupta, 2012); (Pathak et al., 2017). Despite their importance to agriculture and nutrition, India has struggled to produce the required quantity of pulses for many years. Their per-capita availability has declined because domestic production has not kept pace with growing demand. Low crop yields and insufficient incentives for farmers are among the major reasons for this shortage (Joshi & Saxena, 2002). Subsequent studies also highlighted periods of stagnant production, continued reliance on imports, and the structural disadvantages faced by pulses relative to cereal crops (Ali & Gupta, 2012) also found that pulse production did not increase significantly during certain periods.

As a result, India continued to depend on imports to meet domestic demand. Pulses also received less advantages than cereal crop such as rice and wheat, in terms of price support, government procurement, improved technology and access to quality input. (Reddy, 2009) discussed the factors responsible for the slow adoption of technology and the low profitability of pulse cultivation. The study suggested that increasing pulse production requires technological improvements, particularly the development and adoption of short-duration and disease-resistant varieties. It also emphasised the expansion of the area under rabi pulses, improved crop management practices and application of micronutrients. The studies also explain weak pulse productivity through technology, seed, and adoption gaps. (Nain et al., 2015) demonstrated that large adoption gaps exist in key recommended practices, particularly nutrient management and plant protection, implying substantial yield gaps between potential and farmers' fields. (Chauhan et al., 2016) strengthened this argument by focusing on seed and variety replacement. They emphasised that improving seed replacement rates and strengthening seed systems are central for raising productivity, especially since a large proportion of pulses are grown under rainfed conditions. The studies also highlight similar bottlenecks limited availability of quality seed, weak dissemination of improved varieties, biotic and abiotic stresses, and lower investment in management practices while proposing extension and technology pathways to raise yields (Kumar Singh et al., 2015); (Shukla & Mishra, 2020); (Pathak et al., 2017) Taken together, this evidence suggests that productivity growth in pulses is closely linked to adoption and delivery systems, not only to biological potential. Policy support and economic incentives appear to be important influences on the performance of pulses. (Srivastava et al., 2010) argued that pulses frequently lose cultivated area to cereals and other crops because of differences in profitability and policy incentives, resulting in unfavourable patterns of crop-area substitution. Pulses not only meet the nutritional needs of the population but also provide non-market benefits, such as biological nitrogen fixation and improved soil fertility. Agricultural policy should therefore recognise the broader importance of pulse cultivation and encourage farmers to engage in pulse production through suitable incentives. Policy measures may have a considerable influence on farmers' production decisions. Even when improved technologies are available, farmers may hesitate to adopt them or expand pulse cultivation if markets remain unstable and reliable procurement arrangements and credible incentives are absent (Reddy et al., 2024); (Reddy et al., 2023). Projection-based studies further underline why pulses research continues to focus on supply constraints. (Jadhav et al., 2018) projected future supply-demand gaps for major pulses and warned that shortages may persist without sustained production growth. (Murugananthi

et al., 2024) similarly projected demand and supply for major pulses and highlighted pulse-wise gaps, reinforcing the view that productivity improvements must be continuous to meet future requirements. Forecasting-oriented research using time-series and hybrid models also indicates that future production paths differ across states and depend heavily on historical dynamics (Mishra et al., 2023). These studies support the need for careful estimation of long-run trends, because projections become more reliable when trend behaviour and period-specific shifts are properly understood. The production and productivity of pulses in Odisha vary considerably across districts and over time. (Dash & Prusty, 2020) reported substantial production gaps and differences in the growth rates of area and yield of rabi pulses across the districts of Odisha.

Research on other crops in Odisha shows that production may increase because of higher yields, even when the cultivated area does not expand. Thus, area, production, and productivity should be examined together to determine whether output growth results from area expansion, yield improvement, or a combination of both (Sripriya & Dash, 2021). Despite low or statistically insignificant growth in yield, rabi green gram recorded high growth rates in both cultivated area and production in Odisha. The level of instability in green gram production also varied significantly across the districts of the state (Pradhan & Dash, 2024). Climate also plays a crucial role in crop performance. Crop yields are sensitive to variations in rainfall and temperature, which may contribute to production instability. This sensitivity highlights the importance of examining long-term trends in area, production, and yield (Senapati & Goyari, 2020). Existing studies provide valuable insights into the growth, instability, technological adoption, and district-level variation of pulse crops in Odisha. However, three important research gaps remain. First, relatively few studies

have examined the trends of area, production, and yield together over a five-decade period for the major pulse crops cultivated in the state. Second, conventional measures of growth and instability may not always provide robust statistical inference when agricultural time-series data are affected by outliers or serial dependence. Third, limited attention has been given to comparing crop-specific trends across clearly defined pre- and post-economic reform periods using a consistent set of complementary non-parametric techniques. The present study seeks to address these gaps by applying the Mann–Kendall test, the Modified Mann–Kendall test, Sen's slope estimator, Innovative Trend Analysis, Kendall's tau, and Spearman's rank correlation. These methods provide a more comprehensive and reliable assessment of long-term changes in the area, production, and yield of major grain legumes in Odisha.

3. Materials and Methods.

3.1 Data source and study coverage.

The study is based on annual secondary data on the area, production and yield of major grain legumes cultivated in Odisha. The data source is Five Decades of Odisha Agriculture Statistics, published by the Department of Agriculture and Farmers' Empowerment, Government of Odisha. The official publication provides long-term crop-wise information on agricultural area, production and yield for the state. Area is expressed in thousand hectares, production in thousand metric tonnes and yield in kilograms per hectare. The analysis covers seven major grain legumes, pigeon pea, black gram, green gram, field pea, cowpea, horse gram and Bengal gram, and total pulses (The official aggregate category reported in the statistical Source). In this study, the term grain legumes refer to these pulse crops, while the expression total pulses are retained wherever it represents the aggregate category reported in the official statistical source.

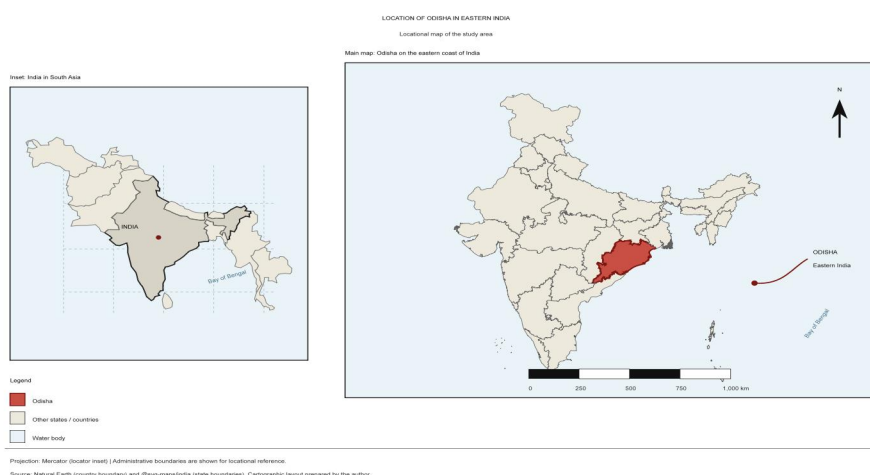


Figure-1 Geographical location of Odisha on the eastern coast of India.

Note: The map is not drawn to scale and is intended only for locational representation. The boundaries shown are indicative.

3.2 Periodization of the study

To examine whether the direction and magnitude of grain-legume trends changed over time, the overall period was divided into two sub-periods: Period I: 1970–71 to 1991–92 (Pre-Reform and Transitional Phase), comprising 22 annual observations; Period II: 1992–93 to 2019–20 (Post-Reform and Pulse-Development Phase), comprising 28 annual observations; overall period: 1970–71 to 2019–20 (long run study period), comprising 50 annual observations. The periodization was informed by developments in the technological and broader economic-policy environment of the early 1990s. Pulses were brought under the Technology Mission on Oilseeds and Pulses in 1990 (Directorate of Oilseeds Development, 2024). The mission-oriented approach placed greater emphasis on improved production technology, timely input delivery, extension, remunerative prices, marketing infrastructure and post-harvest management. Broader economic-policy reforms were initiated in July 1991 (Manmohan Singh, 1991). In the present analysis, 1990–91 and 1991–92 are treated as transitional years, and Period II begins from 1992–93 to represent the subsequent phase in which mission-oriented and other pulse-development interventions became progressively more established. The periodisation is therefore policy informed, but it is not presented as a statistically estimated structural-break year.

3.3 Analytical framework.

The analytical approach is based on non-parametric assessment of trend behavior in area, production and yield of major grain legume included in the study. The study is organized first by period, then by pulse-wise comparison, followed by an inter-period synthesis, and a discussion of possible contributing factors. The explanations draw on the natural calamity indicators, especially rainfall deviation, drought frequency, flood frequency and cyclone incidence, as well as the seasonal pattern of pulse cultivation in Odisha. Kharif pulses are naturally more exposed to monsoon instability, while Rabi pulses depend more on residual moisture, post-monsoon conditions and irrigation support.

3.3.1 Rationale for the Combined Non-Parametric Approach.

Agricultural time-series are often influenced by climatic shocks, technological change, policy interventions, extreme observations and serial dependence. Therefore, reliance on a single statistical method may not provide complete information regarding the direction, significance, magnitude and internal behaviour of a trend. The present study used a combination of complementary non-parametric methods to obtain a more comprehensive assessment of changes in the area, production and yield of major grain legumes in Odisha. The Mann–Kendall test is used to identify the direction and statistical significance of a monotonic trend, while the Modified

Mann–Kendall test provides a corrected assessment of significance when serial correlation is present. Sen's slope estimator measures the median annual rate of change and is relatively less affected by extreme observations. Innovative Trend Analysis provides complementary graphical and numerical evidence regarding the direction and magnitude of trend behaviour that may not be fully captured by conventional monotonic trend tests. Kendall's tau and Spearman's rho are used as supporting rank based correlation measures to assess the direction and strength of the association between time and each agricultural variable. Thus, these methods are used in a complementary manner rather than as competing models. Agreement among the Modified Mann–Kendall statistic, Sen's slope, ITA slope, Kendall's tau and Spearman's rho is treated as evidence of a consistent trend, whereas differences among the results are interpreted cautiously as possible indications of serial correlation, non-linearity or structural change (Mann, 1945); (Kendall, 1938); (Spearman, 1904); (Hamed & Rao, 1998); (Sen, 2012); (Sen, 1968).

3.3.2 Interpretation the non-parametric statistics.

The analysis evaluates monotonic changes in the area, production, and yield of each crop for Period I, Period II, and the overall period. The Mann–Kendall test identifies the direction and significance of a monotonic trend, while the Hamed–Rao modified Mann–Kendall test adjusts the variance for serial correlation. Sen's slope estimates the median annual magnitude of change. Innovative Trend Analysis provides a complementary graphical and numerical assessment by comparing the ordered observations from the first and second halves of each period. Kendall's tau and Spearman's rho are reported as supporting rank-based measures

(i) Mann-Kendall test

Mann-kendall Trend Test is a rank based non-parametric Procedure used to examine whether a time series exhibits a statistically significant monotonic increasing or decreasing trend. The null hypothesis H_0 states that no monotonic trend exists while the alternative hypothesis H_1 , states that the series contains a increasing or decreasing monotonic trend (Mann, 1945); (Kendall, 1938).

The test statistics (s) of a time series $m_1, m_2, m_3, \dots, m_n$ can be achieved by using the MK test:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sign}(m_j - m_k)$$

Where n denotes the length of the data sets, and m_j and m_k denote the observation at times j and k .

$$\text{Sign}(m_j - m_k) \begin{cases} +1 & \text{if } m_j - m_k > 0 \\ 0 & \text{if } m_j - m_k = 0 \\ -1 & \text{if } m_j - m_k < 0 \end{cases}$$

Positive S values show an increasing or upward trend, and negative values of S indicating a decreasing or downward trend in the time series data.

The variance of test statistics VAR(S) can be achieved by the equation

$$\text{VAR}(S) = \frac{1}{18} \{ n(n-1)(2n+5) - \sum_{i=1}^p \tau_i(\tau_i - 1) (2n+5) \}$$

Here, n is the number of observations, ρ is the number of groups tied observation, and τ_i indicates the extent of the i th ties number.

The estimate S and VAR(S) (Hamed & Rao, 1998) are used to estimate the test statistic z when n is > 10 (Gilbert, 1987):

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{VAR}(S)}} & , \text{if } S > 0 \\ 0 & , \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{VAR}(S)}} & , \text{if } S < 0 \end{cases}$$

A positive (+) and negative (-) value of the Z statistic signifies the directions of trends; the (+) values indicates an increasing trend and (-) values indicate a decreasing trend.

Kendall tau (τ) was reported as a supplementary measure of the direction and strength of the monotonic trend (Kendall, 1938):

$$\tau = \frac{S}{\frac{n(n-1)}{2}}$$

A value of τ Closer to +1 indicates a stronger increasing trend, while a value closer to -1 indicates a stronger decreasing trend.

(ii) Modified Mann-Kendall (Mmk) Test

The conventional Mann Kendall test assumes that observations are independent. However, positive or negative serial correlation can inflate or reduce the variance of Mann Kendall statistics and may consequently produce misleading conclusions about trend significance. Therefore, the variance corrected modified mann-kandall test proposed by (Hamed & Rao, 1998) was applied.

The modified VAR (S) statistics can be estimated for the equation

$$\text{VAR}^*(S) = \left(\frac{n(n-1)(2n+5)}{18} \right) \cdot \left(\frac{n}{n_e^*} \right)$$

Here, the correction factor (n/n_e^*) is adjusted to the auto-correlated data as follows:

$$\left(\frac{n}{n_e^*} \right) = 1 + \left(\frac{2}{n^2 + 3n^2 + 2n} \right) \sum_{f=1}^{n-1} (n-f)(n-f-1) \rho_e(f)$$

pe (f) Signifies the autocorrelation between ranks of observations and can be estimated as

$$\rho_e(f) + 2 \sin\left(\frac{\pi}{6} \rho_e(f)\right)$$

The corrected standardised statistic is then calculated as:

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{\text{VAR}^*(S)}} & , \text{if } S > 0 \\ 0 & , \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{VAR}^*(S)}} & , \text{if } S < 0 \end{cases}$$

The corrected z statistics and its corresponding p value were used to determine whether a trend remained statistically significant after accounting for serial correlation. Where the original mann-kandall result was significant but the corrected modified mann-kandall result was insignificant, the trend was interpreted cautiously because the original significance might have been influenced by serial dependence (Hamed & Rao, 1998)

(iii) Sen's Slope Estimation.

Sens slope estimator was used to estimate the magnitude and direction of the monotonic change in area, production, yield. It is a robust non-parametric estimator because the estimated slope is based on the median of all possible pairwise slopes. Therefore, less affected by extreme observations than an ordinary least-square trend coefficient (Sen, 1968).

The linear trend function may be expressed as:

$$F(t) = Qt + B$$

Where Q is the slope of the trend and B is a intercept.

For a time series containing n observations, the slope between each pair of observations is calculated as:

$$Q_{ij} = \frac{x_k - x_j}{k - j} \quad , \quad \text{Where } j > k$$

Where, x_k and x_j are the observation recorded at times j and k respectively.

The total number of pairwise Slope estimates is:

$$N = \frac{n(n-1)}{2}$$

All N slope estimates are arranged in ascending order. Sens slope estimate, denoted by Q, is the median of these ordered slopes. When N is odd:

$$\hat{Q} = Q \left(\frac{(n-1)}{2} \right)$$

When N is even:

$$\hat{Q} = \frac{1}{2} \left[Q \left(\frac{N}{2} \right) + Q \left(\frac{(n+2)}{2} \right) \right]$$

The estimator is therefore the middle ordered slope when N is odd and the arithmetic mean of the two middle slopes when N is even. This corresponds to the standard computational procedure in which all pairwise slopes are sorted and their median is selected (Sen, 1968). The direction of the trend is interpreted as follows:

$Q > 0$ (Increasing Trend)

$Q < 0$ (Decreasing Trend)

$Q = 0$ (little or no Change)

The magnitude of Q represents the median annual change in the variable under consideration.

Confidence interval of Sen's slope:

A $100(1-\alpha)\%$ constructed from the ordered pairwise slope estimates using the variance of the Mann-Kendall statistic S (Sen, 1968); (Gilbert, 1987). First the confidence coefficient is calculated as

$$C_\alpha = Z_{1-\alpha/2} \sqrt{\text{VAR}(s)}$$

Where $\text{VAR}(s)$ is same as defined above and $Z_{1-\alpha/2}$ is obtained from the standard normal distribution.

For a 95 % confidence interval:

$P = 0.05$, $Z_{1-\alpha/2} = 1.96$

The lower and upper rank positions are calculated as:

$M_1 = (N - C_\alpha)/2$ and $M_2 = (N + C_\alpha)/2$. The lower confidence limit is selected from the ordered slope corresponding to the lower rank, while the upper confidence limit is selected from the ordered slope corresponding to the upper rank.

$Q_{\min} = Q(M_1)$

$Q_{\max} = Q(M_2 + 1)$

When the calculated ranks are not integers, they are rounded or interpolated according to the computational procedure used. Thus, the confidence interval for Sen's slope is:

$$Q_{\min} \leq \hat{Q} \leq Q_{\max}$$

When the confidence interval does not contain zero, the estimated slope is statistically different from zero at the selected confidence level.

(iv) Innovative trend analysis (ITA)

Innovative Trend Analysis, proposed by (Sen, 2012), was applied to identify the direction and graphical behaviour of trends in the area, production and yield of major grain legume included in the study. The method was applied separately to Period I, Period II and the overall study period. Period I, covering 1970-71 to 1991-92, contains 22 observations and was divided into two equal halves: 1970-71 to 1980-81 and 1981-82 to 1991-92, with 11 observations in each half. Period II, covering 1992-93 to 2019-20, contains 28 observations and was divided into 1992-93 to 2005-06 and 2006-07 to 2019-20, with 14 observations in each half. The overall period from 1970-71 to 2019-20 contains 50 observations and was divided into 1970-71 to 1994-95 and 1995-96 to 2019-20, with 25 observations in each half. For each crop and variable, the observations in the first and second halves were arranged independently in ascending order. The ordered values of the first half were plotted on the horizontal axis, while the corresponding ordered values of the second half were plotted on the vertical axis. A 45-degree 1:1 line was used as the no-trend reference line. Points located

above the reference line indicated an increasing trend, points below the line indicated a decreasing trend, and points distributed around the line indicated the absence of a clear trend (Sen, 2012).

ITA trend slope: The ITA slope was calculated as $SITA = 2(Y-X)/N$, where X and Y represent the mean values of the first and second halves, respectively, and N represents the total number of observations. Positive and negative slope values indicate increasing and decreasing trends, respectively. The ordered values are plotted against the 45 degree no trend line: $y=x$ or (1:1).

Normalized ITA trend indicator:

$$B = \frac{1}{n} \sum_{f=1}^{n-1} \frac{10(x_j - x_k)}{\bar{x}}$$

Where B is the normalised ITA indicator. This measure expresses the difference between the two-sub series relative to the mean of the first half.

Thus: $B > 0$ (Positive trend)

$B < 0$ (Negative Trend)

$B \approx 0$ (No substantial relative trend trend)

(v) Spearman's ρ .

Spearman's rank correlation coefficient (Spearman, 1904) was used as an additional measure of the direction and strength of association between time and each area, production and yield series. For data without tied ranks, the coefficient is:

$$\rho = 1 - \frac{6 \sum_{i=1}^n d_i^2}{n(n^2 - 1)}$$

Where d_i is the difference between the rank of time and the rank of the agricultural variable for observation i .

The coefficient ranges between -1 and +1. A positive value indicates that the variable generally increases over time, while a negative value indicates that it generally decreases.

3.3.3 Statistical software

All statistical analyses were performed in R using the RStudio integrated development environment. Appropriate R packages were used to conduct the Mann-Kendall test, Modified Mann Kendall test, Sen's slope estimation, Innovative Trend Analysis and Spearman's rank correlation analysis. The results were organized and interpreted according to their direction, statistical significance and estimated magnitude of change.

4. Results and discussion.

The estimated trends vary considerably across grain legumes, variables and periods. Accordingly, the results are interpreted by considering the direction and significance of the Mk and Mmk statistics together with Kendall's tau, Sen's slope, Spearman's rho and the ITA results. Greater weight is placed on Mmk because it adjusts the variance of the Mk statistic for serial dependence. A trend is described as robust

when its direction is consistent across the principal measures and remains statistically significant after Mmk correction. Where the direction is consistent but Mmk significance is not retained, the evidence is described as a tendency rather than a robust trend. The ITA plots and slopes provide complementary evidence on trend direction and internal behaviour, but their significance classifications should be read only after the reported critical bounds have been verified.

(i) Period I: Broad expansion with crop-specific exceptions (1970-71 to 1991-92).

During Period I (Table-1), most of the major grain legume crops experienced a general increase in cultivation with more land being allocated to these crops across the region. In other words, there was a widespread expansion in their area, indicating a favourable phase for pulse cultivation during that period. Pigeon pea recorded strong positive trends in area, production and yield. The Mmk statistics were significant for all three variables ($z = 4.600, 3.949$ and 3.778 , respectively), while Kendall's tau ranged from 0.584 for yield to 0.904 for area. Sens slope estimate was also positive, indicating annual increase of 6.58 thousand hector in area, 6.05 thousand tons of production and 16.40 kg per hectare in yield. The results from different tests consistently suggest that the early growth in pigeon pea production was supported by both acreage expansion and yield improvement. This indicates that during Period I, black gram experienced overall positive growth. The cultivated area, total production, and yield all increased significantly even after adjusting for serial correlation (Mmk correction) which makes the results more reliable. The positive Sen's slope values further show that this growth was consistent over time, area expanded, production increased, and productivity also improved. In simple terms, black gram performed well in this period due to both expansion of cultivation and gains in efficiency. The relatively smaller yield slope indicates that productivity improved at a slower rate compared to the expansion of cultivated area. However, as area and yield are measured in different units, their relative contributions to overall growth cannot be directly compared. Green gram showed strong increases in area and production (Mmk $Z = 4.737$ and 3.854) but no clear trend in yield. The Mk and Mmk statistics for yield were close to zero, and Sen's slope was slightly

negative (-0.14 kg per hectare per year). This indicates that the increase in green gram production was mainly due to expansion in cultivated area, with no consistent improvement in productivity over time. Field pea exhibited a different trend pattern. Its production declined significantly (Mmk $Z = -2.425$, Sen's slope = -0.34 thousand tonnes per year), while yield showed no significant trend. The area under field pea also appears to have declined. The combined results indicate contraction in field-pea cultivation and output during period I rather than broad-based improvement. Cowpea exhibited mixed pattern during the same period. Area and production did not show statistically robust trends, whereas yield increased significantly (Mmk $z = 3.526$; Sen's slope = 10.17 kg per hectare per year). This suggests that productivity improved even though the crop did not expand consistently in area or output. Horse gram and Bengal gram showed significant positive trends in area, production, and yield. Total pulses also increased strongly across all three variables, indicating that the overall pulse sector expanded during Period I, despite the weaker performance of field pea and the mixed results observed for cowpea.

The Innovative Trend Analysis (ITA) (Table-2) further supports the findings obtained from the Mk/Mmk and Sen's slope estimations (Table-1). The graphical distribution reveals that most major grain legumes including pigeon pea, black gram, green gram, horse gram, and Bengal gram are positioned above the 1:1 equality line indicating a consistent upward shift in area, production, and yield during Period-I (Figure-1). This confirms that pulse cultivation expansion was not only statistically significant but also structurally stable over time. Among individual crops, pigeon pea and black gram exhibit the strongest upward deviation reflecting sustained growth driven by both acreage expansion and productivity gains. Green gram and horse gram also demonstrate positive shifts although yield improvements remain comparatively moderate. In contrast, field pea shows a weak or downward clustering pattern confirming contraction in cultivation and production. Cowpea a mixed distribution, with relatively stronger movement in yield but weak trends in area and production. Overall, ITA results validate that Period I was predominantly an expansion driven phase in Odisha's pulse economy with crop-specific variations in productivity performance.

Table 1. Non-parametric trend estimates for the area, production and yield of major grain legumes during Period I (1970-71 to 1991-92).

Crop	Variable	Mk (z statistics)	Mmk (corrected z statistics)	MK tau	Sen's Slope	Spears man Rho test
Pigeon pea	Area	5.865***	4.600***	0.904	6.58	0.968***
	Production	5.188***	3.949***	0.800	6.05	0.923***
	Yield	3.778***	3.778***	0.584	16.40	0.794***
Black	Area	5.583***	3.891***	0.861	20.88	0.957***
	Production	5.4704***	5.3248***	0.844	12.46	0.953***

<i>gram</i>	Yield	2.792***	2.792***	0.432	4.55	0.620***
<i>Green gram</i>	Area	4.737***	4.737***	0.731	19.97	0.868***
	Production	3.158***	3.854***	0.489	9.49	0.698***
	Yield	-0.056	-0.069	- 0.012	-0.14	0.018
<i>Field pea</i>	Area	-2.312**	-2.835***	- 0.359	-0.53	-0.566***
	Production	-2.425**	-2.425**	- 0.376	-0.34	-0.509**
	Yield	0.225	0.288	0.038	0.81	0.045
<i>Cow pea</i>	Area	-0.338	-0.224	- 0.056	-0.07	-0.260
	Production	0.789	0.612	0.125	0.09	0.097
	Yield	3.526***	3.526***	0.545	10.17	0.700***
<i>Horse Gram</i>	Area	5.132***	5.132***	0.792	12.09	0.925***
	Production	4.793***	4.793***	0.740	6.55	0.897***
	Yield	2.510**	2.510**	0.389	2.58	0.555***
<i>Bengal gram</i>	Area	3.582***	3.386***	0.554	1.15	0.694***
	Production	4.116***	4.116***	0.636	1.04	0.780***
	Yield	3.386***	3.386***	0.523	9.50	0.736***
<i>Total pulses</i>	Area	5.696***	5.695***	0.878	67.08	0.959***
	Production	5.019***	6.106***	0.774	40	0.928***
	Yield	2.086**	2.556**	0.324	3.66	0.478**

Note: A = area; P = production; Y = yield. Level of significance $p < 0.10$, $p < 0.05$, and $p < 0.01$. Mk=Mann-Kendall; Mmk=Modified Mann-Kendall.

Source: Author's calculations based on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).

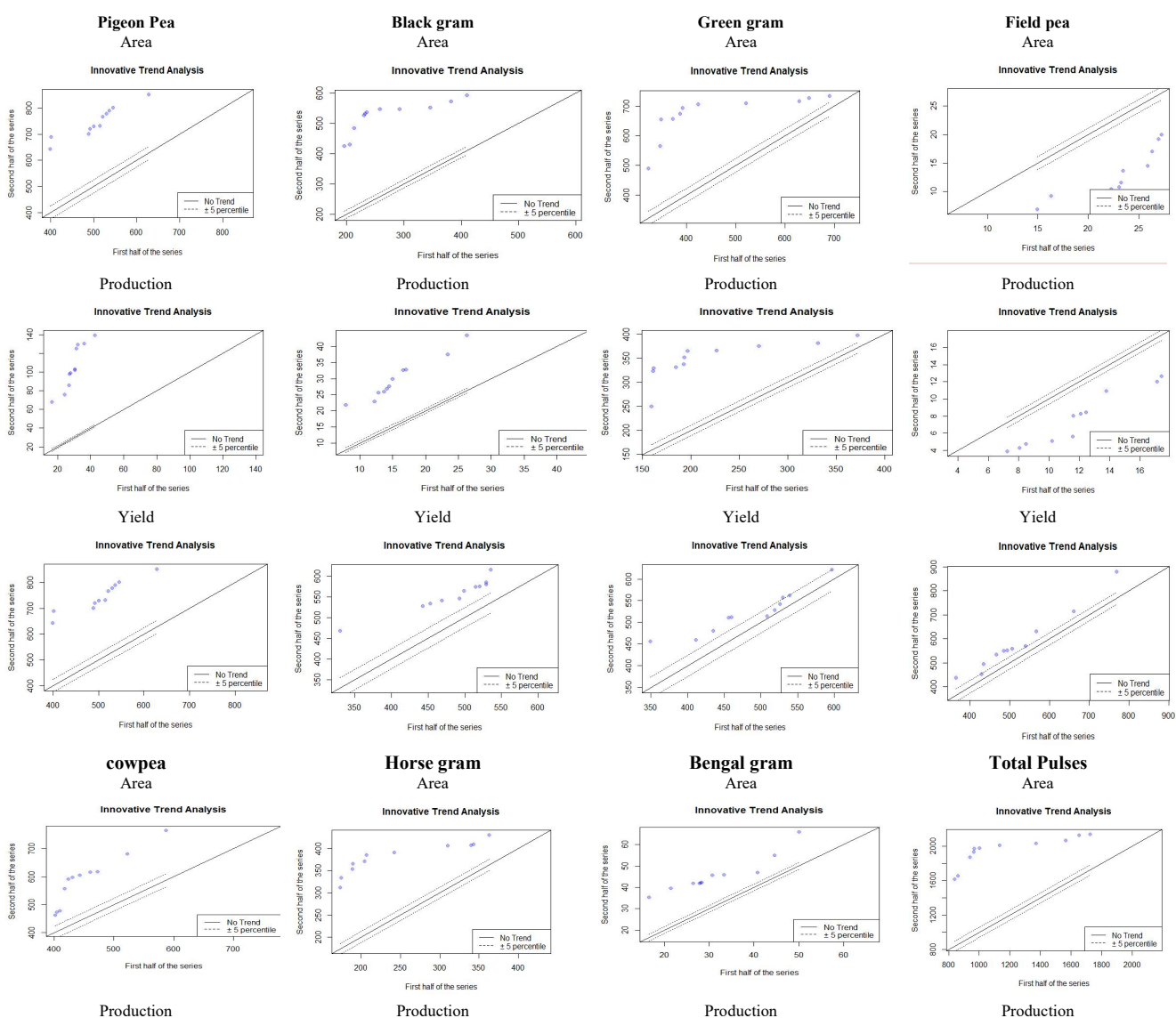
Table 2. Innovative Trend Analysis results for the area, production and yield of major grain legumes during Period I (1970-71 to 1991-92)

Crop	Variable	Trend slope	Trend indicator	95% Critical limit [lower limit, Upper limit]	Trend result
Pigeon pea	Area	7.3792	13.8142	[-0.8355, 0.8355]	Increase (S)
	Production	6.8657	25.4870	[-0.6522, 0.6522]	Increase (S)
	Yield	21.9174	4.7732	[-1.7700, 1.7700]	Increase (S)
Black gram	Area	22.7395	9.1751	[-3.4241, 3.4241]	Increase (S)
	Production	14.4998	12.1861	[-1.7892, 1.7892]	Increase (S)
	Yield	6.5785	1.4976	[-0.6611, 0.6611]	Increase (S)
Green gram	Area	18.6190	4.4355	[-4.3440, 4.3440]	Increase (S)
	Production	11.2992	5.5833	[-2.2508, 2.2508]	Increase (S)
	Yield	3.4380	0.7805	[-0.7764, 0.7764]	Increase (S)
Field pea	Area	-0.8874	-4.2903	[-0.1145, 0.1145]	Decrease (S)
	Production	-0.3812	-3.5471	[-0.0406, 0.0406]	Decrease (S)
	Yield	5.4876	1.1614	[-0.7485, 0.7485]	Increase (S)
Cowpea	Area	-0.5055	-2.9328	[-0.0734, 0.0734]	Decrease (S)
	Production	-0.0535	-0.6876	[-0.0637, 0.0637]	Decrease (NS)
	Yield	12.1736	2.9596	[-1.5271, 1.5271]	Increase (S)
Horse gram	Area	11.8294	5.2293	[-1.5656, 1.5656]	Increase (S)

	Production	7.0325	7.1734	[-1.0838, 1.0838]	Increase (S)
	Yield	4.4545	1.1176	[-0.5934, 0.5934]	Increase (S)
Bengal gram	Area	1.2771	4.4377	[-0.1516, 0.1516]	Increase (S)
	Production	1.2748	8.9028	[-0.0822, 0.0822]	Increase (S)
	Yield	13.6033	2.9987	[-1.3550, 1.3550]	Increase (S)
	Area	69.4649	6.4562	[-10.8677, 10.867]	Increase (S)
Total pulses	Production	45.2331	8.9435	[-6.7972, 6.7972]	Increase (S)
	Yield	6.2645	1.4569	[-0.3554, 0.3554]	Increase (S)

Note: S = statistically significant at the 5% level; NS = not significant. Significance is classified by comparing the trend slope with the reported 95% confidence limits. Positive and negative slopes denote increasing and decreasing trends, respectively.

Source: Author's calculations based on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).



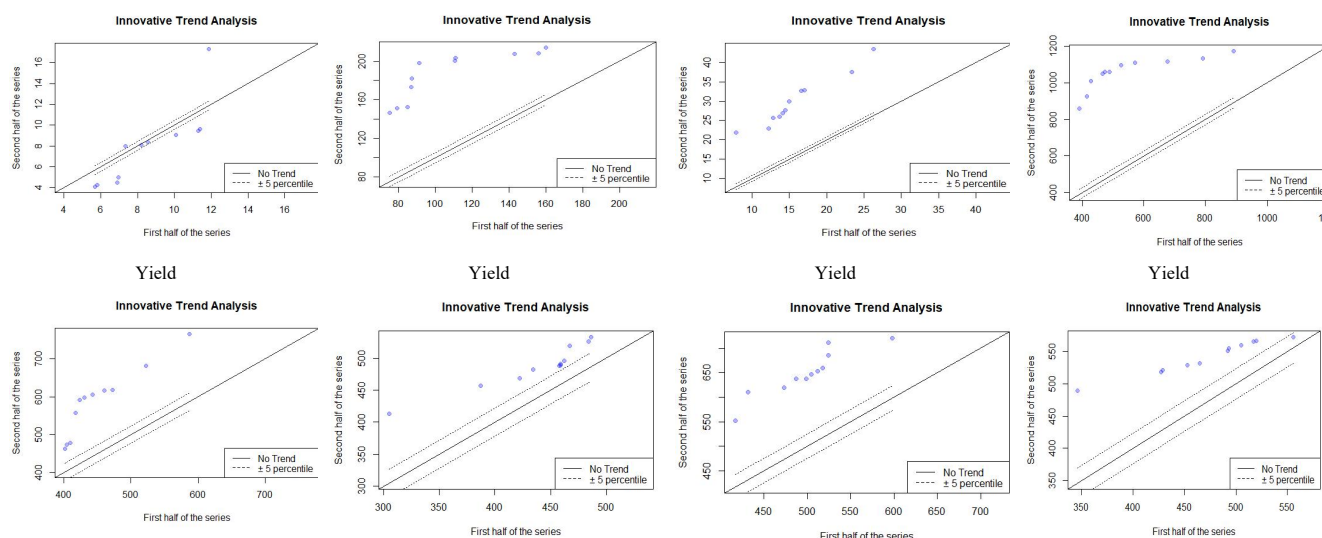


Figure 1: Innovative Trend Analysis plots for the area, production and yield of major grain legumes during Period I (1970-71 to 1991-92).

Note: The 45-degree line 1:1 the no-trend condition. Points above the line indicate an increasing trend, points below the line indicate a decreasing trend, and points distributed close to the line suggest no clear trend. The dashed lines represent the significance or confidence limits shown in the ITA plots.

Source: Author's calculations and graphical presentation based on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).

(ii) Period II: differentiated crop performance (1992-93 to 2019-20).

Period II (Table-3) showed greater variation in the performance of individual grain legumes. Pigeon pea area did not show any significant trend (Mmk $Z = -1.047$, Sen's slope = -0.34 thousand hectares per year) while production and yield increased significantly (Mmk $Z = 2.066$ and 3.413). This suggests that the rise in production was mainly due to improvements in yield rather than expansion in cultivated area. The positive yield slope of 15.73 kg per hectare per year along with stable area and increasing production indicates that production growth was mainly driven by improvements in productivity. However, this should not be interpreted as a formal decomposition of production change. Black gram area remained largely stable, while production showed a significant positive trend (Mmk $Z = 2.546$). Yield was positive under the conventional Mk test but became non-significant after Mmk correction ($Z = 1.052$). This indicates that, although black gram production increased in the period II, the improvement in yield is not statistically robust after adjusting for serial correlation. Green gram showed stronger performance in area and production, both of which remained significant after Mmk correction ($Z = 3.587$

and 2.291). The yield trend was positive but not significant under the Mmk test ($Z = 1.554$), indicating only a tendency toward improvement rather than a strong and reliable increase in productivity. Field pea and cowpea performed strongly in Period II. For both crops, area, production, and yield increased significantly under both Mk and Mmk tests, with positive rank correlations and Sen's slope estimates. Field pea showed strong Mmk Z -statistics, ranging from 4.977 for production to 5.343 for yield, while cowpea values ranged from 2.892 for area to 3.644 for production. The consistent results across variables and methods suggest that the improvement in the period II was broad-based, rather than limited to a single dimension. Horsegram showed the clearest decline. The cultivated area decreased significantly (Mmk $Z = -3.607$, Sen's slope = -5.37 thousand hectares per year). Production showed a negative trend under the Mk test but became non-significant after Mmk correction ($Z = -1.461$), and yield did not exhibit any significant trend. The most reliable conclusion is a clear decline in horse gram area, along with a tendency for production to decrease, rather than a statistically confirmed decline in all three variables. Bengal gram showed significant increases in production and yield after Mmk correction ($Z = 2.546$ and 3.726), while the positive trend in area was not statistically significant ($Z = 1.533$). This suggests that the rise in production was mainly driven by improvements in yield rather than expansion in cultivated area. Thus, the policy efforts should focus more on enhancing productivity through improved seeds, better agronomic practices and efficient input use rather than relying on further expansion of area. Total pulses exhibited a positive tendency during Period II. However, the statistical evidence was weaker than in Period I and indicated considerable heterogeneity in crop-specific trends.

Period II can be characterized as a phase of

productivity improvement and selective crop expansion where pulses were driven more by yield enhancement and crop-specific performance rather than uniform expansion across all pulse crops (Table - 4). The ITA results broadly support the findings, indicating widespread improvement in area, production, and yield across most pulses but its magnitude is different. Pigeon pea showed a decline in area but significant increases in production and yield. It suggests productivity led growth rather than expansion in cultivated land. Black gram and green gram show significant improvements in all three variables with ITA confirming a consistent upward movement particularly strong for area and production.

Field pea and cowpea emerged as the most robust performers in this period showing significant positive trends across area, production, and yield in both ITA and statistical tests indicating broad based structural improvement in these crops. In contrast, horse gram showed a clear structural weakness with a significant decline in area and production. Bengal gram also exhibited significant gains in production and yield while area expansion remained comparatively modest indicating yield-driven growth. For total pulses, the ITA results indicate an overall positive but less uniform trend reflecting considerable inter crop variation.

Table 3. Non-parametric trend estimates for the area, production and yield of major grain legumes during Period II (1992-93 to 2019-20)

Crop	variable	Mk (z statistics)	Mmk (corrected z statistics)	Mk tau	Sen's Slope	Spears man Rho test
Pigeon pea	Area	-1.047	-1.047	-0.142	-0.34	-0.272
	Production	2.706***	2.066**	0.365	2.16	0.381**
	Yield	4.563***	3.413***	0.613	15.73	0.802***
Black gram	Area	0.000	0.000	0.000	-0.00	0.017
	Production	3.417***	2.546**	0.460	0.55	0.681***
	Yield	1.759*	1.052	0.238	3.61	0.170
Green gram	Area	4.168***	3.587***	0.560	12.04	0.732***
	Production	3.338***	2.291**	0.449	9.36	0.537***
	Yield	2.29**	1.554	0.309	4.42	0.272
Field pea	Area	5.037***	7.784***	0.677	0.67	0.851***
	Production	5.393***	4.977***	0.724	0.68	0.885***
	Yield	5.674***	5.343***	0.765	8.92	0.904***
Cow pea	Area	4.840***	2.892***	0.650	1.74	0.775***
	Production	4.958***	3.644***	0.666	1.39	0.812***
	Yield	4.979***	3.502***	0.670	9.41	0.832***
Horse Gram	Area	-5.591***	-3.607***	-0.751	-5.37	-0.502***
	Production	-2.509**	-1.461	-0.338	-1.12	-0.502***
	Yield	1.561	0.893	0.212	3	0.151
Bengle gram	Area	2.153**	1.533	0.291	0.37	0.380**
	Production	3.417***	2.546**	0.460	0.55	0.681***
	Yield	5.297***	3.726***	0.714	9	0.874***
Total pulses	Area	1.363	0.978	0.185	12.72	0.182
	Production	2.153**	1.545	0.291	17.76	0.227
	Yield	2.372**	1.525	0.320	5.60	0.291

Note: A = area; P = production; Y = yield. Level of significance $p < 0.10$, $p < 0.05$, and $p < 0.01$. Mk=Mann-Kendall; Mmk=Modified Mann-Kendall.

Source: Author's calculations on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).

Table 4. Innovative Trend Analysis results for the area, production and yield of major grain legumes during Period II (1992-93 to 2019-20).

Crop	Variable	Trend slope	Trend indicator	95% Critical limit [Lower limit, Upper limit]	Trend result
Pigeon	Area	-0.3810	-0.3742	[-0.1191, 0.1191]	Decrease (S)

pea	Product ion	1.8782	2.7138	[-0.2790, 0.2790]	Increase (S)
	Yield	16.0000	3.3220	[-2.3912, 2.3912]	Increase (S)
Black gram	Area	3.0204	0.8097	[-0.5748, 0.5748]	Increase (S)
	Product ion	0.7532	5.6818	[-0.0724, 0.0724]	Increase (S)
	Yield	2.2398	0.7506	[-0.6772, 0.6772]	Increase (S)
Green gram	Area	13.6207	3.0463	[-0.8604, 0.8604]	Increase (S)
	Product ion	8.3458	4.6076	[-0.9561, 0.9561]	Increase (S)
	Yield	4.0204	1.4203	[-0.8200, 0.8200]	Increase (S)
Field pea	Area	0.7715	5.4191	[-0.0553, 0.0553]	Increase (S)
	Product ion	0.7875	9.4409	[-0.0511, 0.0511]	Increase (S)
	Yield	11.0459	2.6548	[-0.8385, 0.8385]	Increase (S)
Cowpea	Area	1.9988	8.2410	[-0.2097, 0.2097]	Increase (S)
	Product ion	1.7524	12.8950	[-0.1516, 0.1516]	Increase (S)
	Yield	10.9541	2.7326	[-0.9504, 0.9504]	Increase (S)
Horse gram	Area	-5.2332	-2.4068	[-0.3854, 0.3854]	Decrease (S)
	Product ion	-1.9450	-2.2789	[-0.5110, 0.5110]	Decrease (S)
	Yield	1.4898	0.5492	[-0.4901, 0.4901]	Increase (S)
Bengal gram	Area	0.5769	2.6134	[-0.0525, 0.0525]	Increase (S)
	Product ion	0.7532	5.6818	[-0.0724, 0.0724]	Increase (S)
	Yield	10.3929	2.4207	[-1.1802, 1.1802]	Increase (S)
Total pulses	Area	18.9167	1.5205	[-1.8065, 1.8065]	Increase (S)
	Product ion	16.0469	2.9213	[-2.9172, 2.9172]	Increase (S)
	Yield	4.5714	1.4832	[-0.8377, 0.8377]	Increase (S)

Note: S = statistically significant at the 5% level; NS = not significant. Significance is classified by comparing the trend slope with the reported 95% confidence limits. Positive and negative slopes denote increasing and decreasing trends, respectively.

Source: Author's calculations based on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).

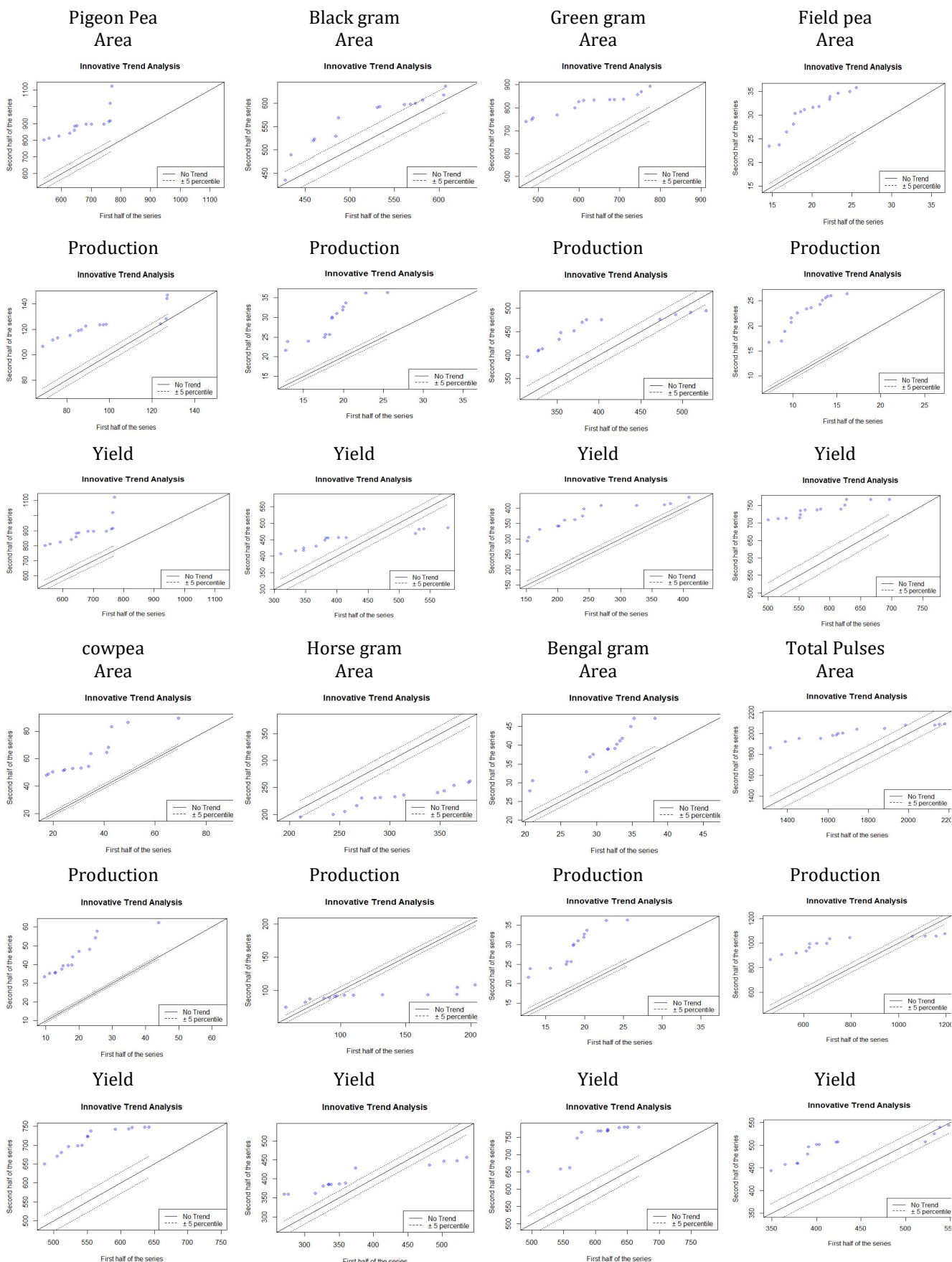


Figure: 2 Innovative Trend Analysis plots for the area, production and yield of major grain legumes during Period II (1992-93 to 2019-20).

Note: The 45-degree line 1:1 the no-trend condition. Points above the line indicate an increasing trend, points below the line indicate a decreasing trend, and points distributed close to the line suggest no clear trend. The dashed lines represent the significance or confidence limits shown in the ITA plots.

Source: Source: Author's calculations and graphical presentation based on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).

(iii) Overall period: persistent gains and long-run vulnerabilities (1970-71 to 2019-20).

Across the full 50-year period (Table-5), pigeon-pea production and yield increased robustly (Mmk $z = 3.640$ and 5.583), whereas the positive area trend did not remain significant after correction ($z = 1.493$). This long-run combination is consistent with productivity playing an important role in sustaining output while acreage growth became less certain. Black-gram area increased significantly (Mmk $z = 2.135$), but its production trend became nonsignificant after correction and yield showed a negative, nonsignificant tendency. Green gram recorded robust increases in area and production (Mmk $z = 3.592$ and 1.976), while its negative yield trend was not Mmk significant. These findings show that long-run acreage and output gains in black gram and green gram were not matched by robust productivity growth. Field pea and cowpea recorded the most internally consistent long-run improvements. For both crops, area, production and yield were positive and remained statistically significant after Mmk correction. Cowpea displayed particularly strong rank-based association with time, while field pea's later gains were sufficient to reverse its early contraction. Bengal-gram production and yield also increased robustly, whereas area remained statistically unchanged. Thus, over the overall study period production growth was driven primarily by yield improvement rather than area expansion. Horse gram was the weakest long-run performer, although the strength of the conclusion differs across methods. Mk indicated negative trends in area, production and yield, but none remained significant after Mmk correction. Sen's slopes were negative for all three variables, and ITA also reported decreasing trends. The combined evidence indicates a persistent downward tendency. At the aggregate level, total-

pulse area increased significantly over the overall period (Mmk $z = 2.145$; Sen's slope = 17.26 thousand ha per year). Production was positive but only marginally significant after Mmk correction ($z = 1.727$), with a small positive Sen's slope of 0.30 thousand tonnes per year. Yield showed no significant monotonic trend. The aggregate results therefore indicate long-run expansion in pulse area without corresponding evidence of uniform productivity improvement. This apparent aggregate stability masks substantial heterogeneity among individual crops.

The ITA results for Period III indicate a phase of growth in production some pulse crops while others face yield challenges. This suggests increasing differences in performance across crops within the pulse sector in Odisha (Table-6). Most pulses exhibited statistically significant trends in at least one dimension (Area, Production and Yield) that the period was characterized by both expansion and structural change within pulse cultivation. Pigeon pea showed consistent improvement across area, production, and yield, supported by positive ITA slopes indicating sustained expansion along with productivity gains. Black gram recorded a significant increase in area, while production remained statistically non-significant and yield showed a significant decline. Green gram shows a similar pattern. Field pea and cowpea both are emerged as the strongest performing pulses in this period. Both exhibited significant positive trends across all three variables with particularly strong ITA indicators for area and production. It reflects robust and sustained structural growth. In contrast, horse gram continued its long-term decline with significant negative trends in area, production, and yield. Bengal gram showed a mixed pattern, with a decline in area but significant increases in production and yield suggesting productivity led growth despite shrinking cultivated area. For total pulses, the ITA results indicate an overall increase in area and production while yield showed a declining trend. It suggests that aggregate growth was primarily due to expansion in area rather than productivity improvement.

Table 5. Non-parametric trend estimates for the area, production and yield of major grain legumes over the overall study period (1970-71 to 2019-20)

Crop	Variable	Mk (z statistics)	Mmk (corrected z statistics)	MK tau	Sen's Slope	Spears man Rho test
Pegion pea	Area	3.563***	1.493	0.348	1.43	0.463***
	Production	5.387***	3.640***	0.526	2.23	0.670***
	Yield	6.106***	5.583***	0.596	8.32	0.788***
Black gram	Area	4.834***	2.135**	0.472	6.23	0.615***
	Production	2.576***	1.436	0.252	2.36	0.331**
	Yield	-1.857*	-1.115	-0.182	-1.61	-0.419***

Green gram	Area	6.273***	3.592***	0.613	8.03	0.766***
	Production	3.446***	1.976**	0.337	2.84	0.456***
	Yield	-2.350**	-1.339	-0.230	-1.61	-0.405***
Field pea	Area	4.249***	1.871*	0.415	0.36	0.549***
	Production	4.968***	2.172**	0.485	0.34	0.643***
	Yield	5.388***	3.879***	0.526	5.95	0.624***
Cow pea	Area	6.658***	3.855***	0.650	1.19	0.816***
	Production	7.244***	3.953***	0.707	0.83	0.871***
	Yield	6.324***	4.382***	0.617	6.50	0.764***
Horse Gram	Area	-2.358**	-1.107	-0.231	-3.09	-0.219
	Production	-1.823*	-0.931	-0.178	-0.69	-0.277
	Yield	-1.782*	-1.139	-0.174	-1.39	-0.427***
Bengle gram	Area	0.777	0.488	0.076	0.07	0.092
	Production	3.145***	2.391**	0.307	0.25	0.425***
	Yield	5.998***	5.001***	0.586	5.38	0.765***
Total pulses	Area	4.215***	2.145**	0.412	17.26	0.520***
	Production	2.994***	1.727*	0.293	9.012	0.338**
	Yield	-0.468	-0.276	-0.046	9.01	-0.139

Note: Level of significance $p < 0.10$, $p < 0.05$, and $p < 0.01$. Mk=Mann-Kendall; Mmk=Modified Mann-Kendall.

Source: Author's calculations based on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).

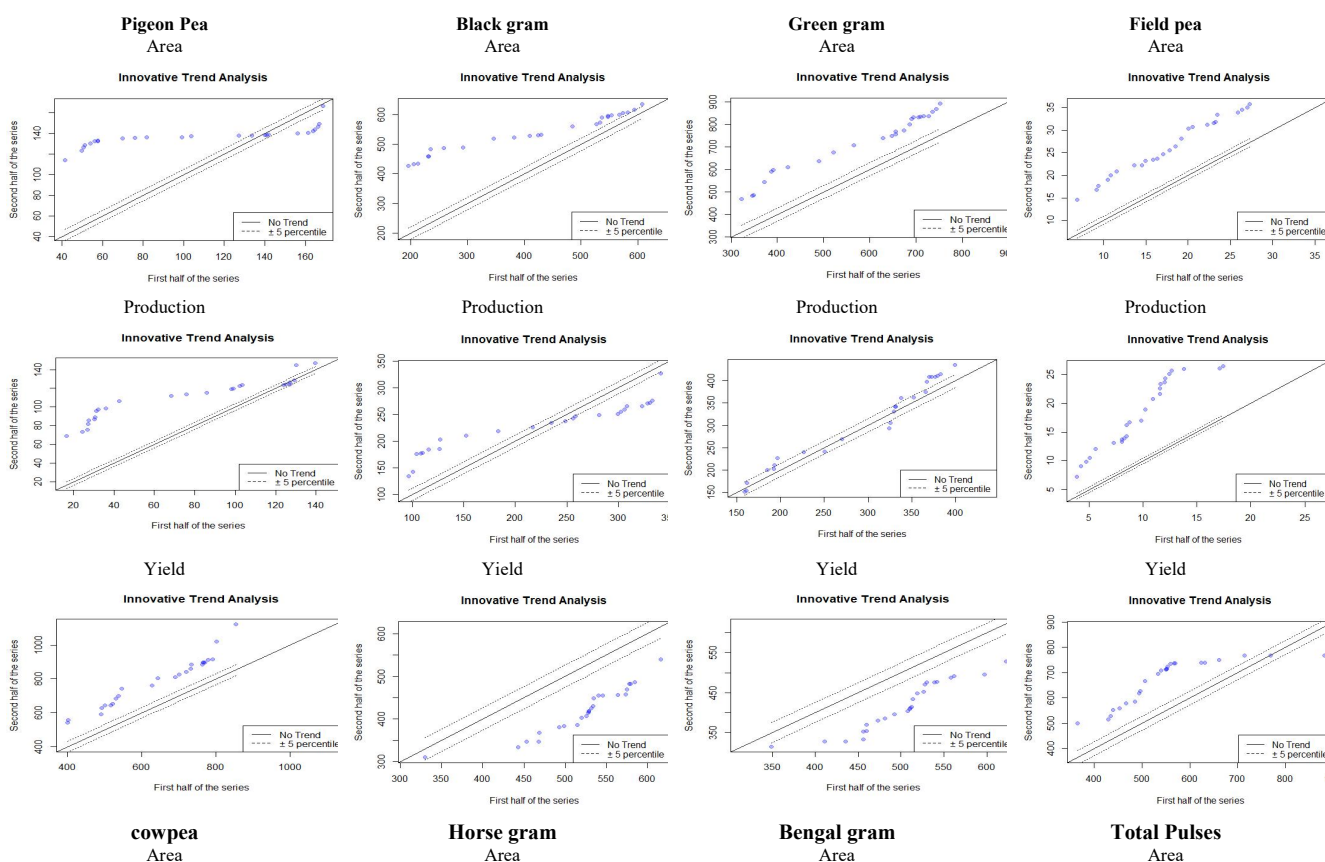
Table 6. Innovative Trend Analysis results for the area, production and yield of major grain legumes over the overall study period (1970–71 to 2019–20).

<i>Pulse crop</i>	<i>Variable</i>	<i>Trend slope</i>	<i>Trend indicator</i>	<i>95% Critical bound [Lower, Upper]</i>	<i>Trend result</i>
<i>Pigeon pea</i>	Area	1.1890	2.7733	[-0.2579, 0.2579]	Increase (S)
	Production	1.3481	4.5284	[-0.1452, 0.1452]	Increase (S)
	Yield	5.8560	2.2790	[-0.4242, 0.4242]	Increase (S)
<i>Black gram</i>	Area	4.7231	2.8098	[-0.2388, 0.2388]	Increase (S)
	Production	0.1509	0.1687	[-0.2574, 0.2574]	Increase (NS)
	Yield	-4.0976	-1.9606	[-0.3087, 0.3087]	Decrease (S)
<i>Green gram</i>	Area	5.4704	2.3426	[-0.2865, 0.2865]	Increase (S)
	Production	0.5168	0.4401	[-0.1797, 0.1797]	Increase (S)
	Yield	-3.4272	-1.7066	[-0.2776, 0.2776]	Decrease (S)
<i>Field pea</i>	Area	0.3389	4.7557	[-0.0106, 0.0106]	Increase (S)
	Production	0.3314	8.4842	[-0.0223, 0.0223]	Increase (S)
	Yield	4.6768	2.1143	[-0.7602, 0.7602]	Increase (S)
<i>Cowpea</i>	Area	1.4012	21.2883	[-0.0444, 0.0444]	Increase (S)
	Production	1.0042	29.1713	[-0.0480, 0.0480]	Increase (S)

	n				
	Yield	4.5216	2.1359	[-0.4495, 0.4495]	Increase (S)
Horse gram	Area	-2.5878	-2.0191	[-0.4579, 0.4579]	Decrease (S)
	Productio	-2.2060	-3.6443	[-0.3954, 0.3954]	Decrease (S)
	n				
	Yield	-3.6720	-1.9610	[-0.3511, 0.3511]	Decrease (S)
Bengal gram	Area	-0.1153	-0.7578	[-0.0231, 0.0231]	Decrease (S)
	Productio	0.0848	0.9502	[-0.0206, 0.0206]	Increase (S)
	n				
	Yield	4.5232	1.9725	[-0.3194, 0.3194]	Increase (S)
Total pulses	Area	8.8054	1.3519	[-1.0139, 1.0139]	Increase (S)
	Productio	0.5025	0.1493	[-0.4381, 0.4381]	Increase (S)
	n				
	Yield	-2.1920	-1.0740	[-0.3015, 0.3015]	Decrease (S)

Note :S = statistically significant at the 5% level; NS = not significant. Significance is classified by comparing the trend slope with the reported 95% confidence limits. Positive and negative slopes denote increasing and decreasing trends, respectively.

Source: Author's calculations based on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).



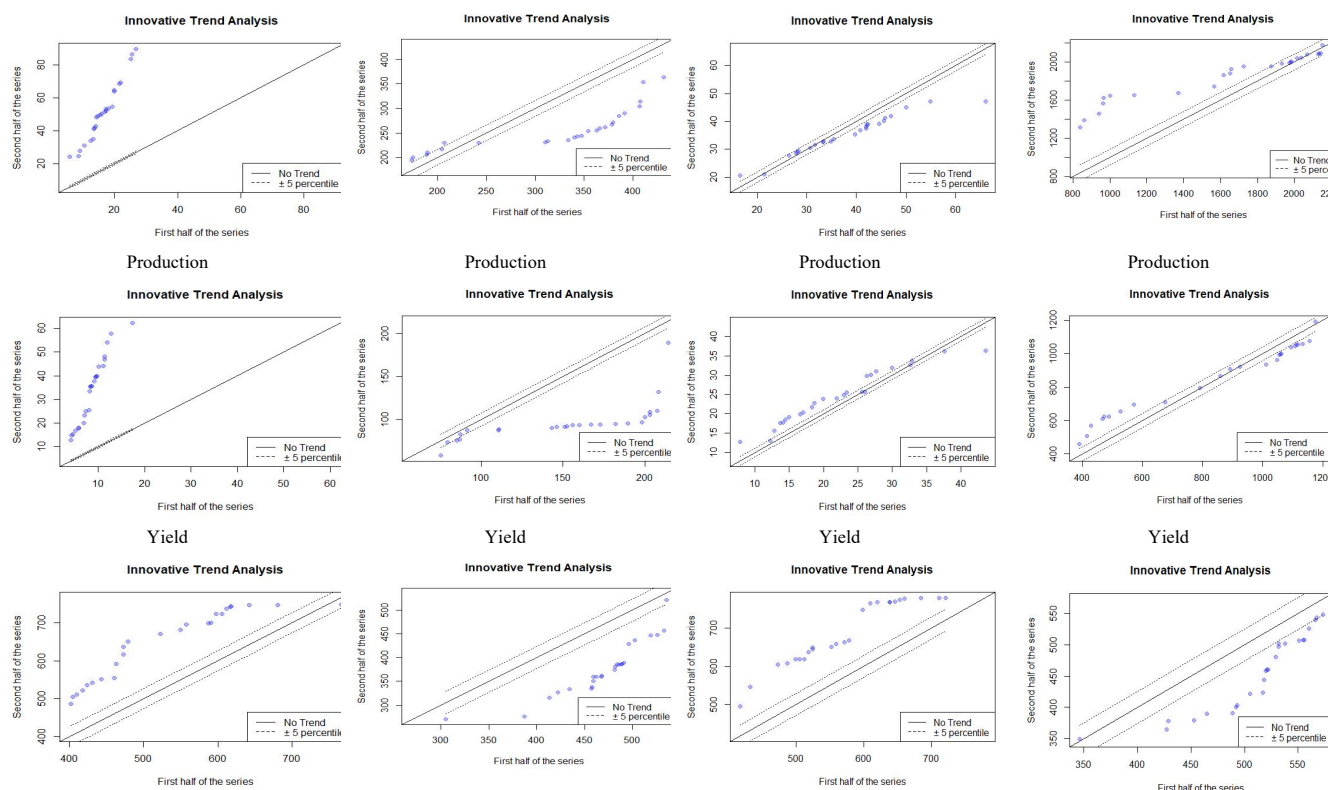


Figure 3. Innovative Trend Analysis plots for the area, production and yield of major grain legumes over the overall study period (1970–71 to 2019–20).

Note: The 45-degree line 1:1 the no-trend condition. Points above the line indicate an increasing trend, points below the line indicate a decreasing trend, and points distributed close to the line suggest no clear trend. The dashed lines represent the significance or confidence limits shown in the ITA plots.

Source: Author's calculations and graphical presentation based on Five Decades of Odisha Agriculture Statistics (Department of Agriculture and Farmers' Empowerment, Government of Odisha, 2020).

(iv) Inter-period Comparison.

It is evident from the study that all pulse crops experienced significant growth during Period I. However, over time, the pattern of growth changed, and policy focus became more selective, taking into account crop-specific conditions. In Period II, the performance became uneven and crop-specific, with some crops showing growth while others declined sharply. Field pea and cowpea recorded improvements in area, production, and yield. In contrast, pigeon pea maintained production growth despite a decline in its cultivated area. Horse gram experienced a substantial reduction in area, making it the weakest performer. Over the long term, field pea showed the best performance across all dimensions, whereas horse gram remained the most vulnerable. The area under cultivation of black gram and green gram remained consistently high over the long period along with a reasonable level of production. However,

their yield did not show significant improvement over time. To understand growth patterns across different periods, it is not sufficient to focus only on aggregate pulse statistics. Such an approach can conceal important crop-specific trends. Even if the total cultivated area of pulses increases overall yield may remain stagnant as growth patterns can vary widely across crops. Therefore, it is essential to analyse each crop separately rather than relying solely on aggregate data. This approach helps in clearly identifying the real issues affecting each crop whether they relate to declining area, low or stagnant yield or both.

Conclusion.

The findings have several implications for pulse policy in Odisha. The observed differences in area, production, and yield trends across crops and periods suggest that a uniform policy approach may not be equally effective for all pulse crops. Greater attention is needed to improving productivity through access to quality seeds, suitable short duration varieties, better crop management practices and timely extension services, particularly in areas where yield growth remains weak. Since pulses are largely cultivated under rainfed conditions, measures that reduce climate-related production risks, including improved water management and crop specific support may also be useful. At the same time stable markets effective procurement and appropriate price incentives could encourage farmers to retain or

expand pulse cultivation where more profitable competing crops create pressure on pulse area. Policies should thus combine productivity enhancement with market and risk-support measures rather than focusing on production alone.

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