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Comprehensive analytical report on crop performance using ratio-based metrics

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Abstract

This comprehensive study aims to provide a detailed comparative analysis of crop performance by investigating the behavior of crops classified as exhibiting either high or low kilograms per hectare (KGH) productivity through the lens of three fundamental ratio-based indicators: production-to-area, yield-to-area, and yield-to-production. These ratios are critical metrics that help quantify land-use efficiency, productivity levels, and output stability, thereby offering a multi-dimensional perspective on agricultural performance. Such ratios indicate how crops behave under varying agronomic and environmental contexts. This study delves into crop performance by distinguishing them into two primary categories based on variance characteristics. High KGH crops are identified as those more susceptible to significant fluctuations due to factors such as climatic variability, market shifts, and biological vulnerabilities. Conversely, low KGH crops display relatively stable and predictable patterns of output, making them more reliable under standard farming conditions. The research utilizes both line and bar charts to effectively visualize the inter-crop differences and temporal trends in these ratios, highlighting patterns of consistency and volatility that characterize various crops. The findings aim to support enhanced data-driven decision-making in crop planning, agricultural land management, and policy formulation, particularly in regions facing significant variability in agricultural outputs due to climatic, environmental, or socio-economic factors. By carefully analyzing these ratios, the study not only sheds light on crops with superior resilience and efficiency but also identifies those prone to instability, offering valuable insights for stakeholders in the agricultural sector.

Keywords: Agricultural productivity, bar chart analysis, crop performance, crop planning and policy, crop yield stability.

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Contents

Contribution of this paper to the literature
By analyzing the defined ratios, our study not only sheds light on crops with superior resilience and efficiency but also identifies those prone to instability, offering valuable insights for stakeholders in the agricultural sector. The terminology itself is new and not available in previous studies.

1. Introduction

Agricultural productivity remains a cornerstone of food security, economic resilience, and rural development. Conducting a quantitative evaluation through ratio-based metrics provides a nuanced perspective on how crops behave under varying agronomic and environmental contexts. This study delves into crop performance by distinguishing them into two primary categories based on variance characteristics. High KGH crops are identified as those more susceptible to significant fluctuations due to factors such as climatic variability, market shifts, and biological vulnerabilities. On the other hand, Low KGH crops display relatively stable and predictable patterns of output, making them more reliable under standard farming conditions. This classification supports targeted agricultural decision-making, particularly when assessing risk, input optimization, or crop selection for specific agro-ecological zones.

The dataset employed in this study originates from India's agricultural statistics and encompasses state-wise data for a diverse range of principal crops. The temporal coverage spans financial years 2001–02 through 2015–16, allowing a longitudinal analysis of trends and variability in crop performance. This dataset includes key variables such as the area under cultivation (hectares), total production (metric tonnes), and yield per hectare for each crop across multiple states. The data was compiled from government records and agricultural statistical publications (source to be specified), providing a comprehensive basis for calculating ratio-based metrics that reflect productivity and efficiency. This rich dataset enables an in-depth assessment of how crop outputs evolve over time across different agro-climatic zones and socio-economic conditions, making it instrumental for data-driven agricultural policy and planning.

A global dataset of crops is considered in Iizumi and Sakai [1] and the authors perform an analysis over a time period of around 35 years. They take wheat, rice, soybean, and maize and obtain the yield time series of these crops. Senapati and Goyari [2] have divided their study period into three distinct phases: pre-green, early phase, and post-green revolution period, and compared the growth rates during these periods. The development and regulatory challenges of genetically modified crops in India are discussed in Shukla et al. [3]. Their work highlights both scientific progress and policy barriers. This study extends the discussion by visually analyzing crop performance across Indian states. Reddy et al. [4] improved crop simulation in CLM5 using long-term site-level data for Indian crops. Their work enhanced model accuracy for wheat and rice growth patterns. Building on this, our study visually analyzes crop performance across Indian states for better planning. Long-term trends in millet cultivation across India are examined in Yamuna et al. [5]. They reported declining area and production but stable or improving yields. This study builds on their insights through visual analysis of crop performance across states. The extremes of crop yields in India using extreme value theory are analyzed in Lakshmi Kumar et al. [6]. Their study highlights regional differences in yield variability and stresses the need to consider extreme events in agricultural planning to improve food security. State-wise yields of major food crops in India for 2014–15 using statistical methods are analyzed in Talukdar et al. [7]. The study revealed significant regional differences in productivity, emphasizing the need for targeted strategies to improve crop yields. The growth and sustainability of major crops in Haryana are studied in Bagaria and Jatav [8], highlighting positive trends due to water-efficient practices. Their findings stress the need for sustainable agriculture to ensure long-term food security. Changing crop patterns and diversification in Koch Bihar, West Bengal, focusing on six key crops, are considered in Islam and Das [9]. Their analysis revealed significant shifts influenced by environmental and socio-economic factors. An analysis of four decades of data to assess trends in the area, production, and yield of key crops in Bangladesh is done in Akhter et al. [10]. Their findings reveal significant growth in rice and wheat yields, while jute cultivation experienced a decline, highlighting the need for adaptive agricultural strategies. A survey of agricultural datasets to enhance crop yield prediction using machine learning algorithms is conducted in Tripathi et al. [11]. Their study emphasizes the importance of accurate yield forecasting for precision agriculture and food security. The growth patterns of oilseed crops in India are considered in Reddy and Immanuelraj [12], revealing significant spatial and temporal disparities. Their study highlights the need for targeted strategies to enhance oilseed productivity and reduce reliance on imports. A comprehensive global analysis of crop yield trends and variability using 8,088 country-crop yield series from FAO data is conducted in Arata et al. [13]. Employing robust statistical methods, they identified a slowdown in yield growth and increased variability in certain regions, highlighting implications for global food security and the need for adaptive agricultural policies. A systematic review on the application of data analytics in crop management is conducted in Chergui and Kechadi [14]. Their study emphasizes how digital agriculture leverages big data and advanced technologies to enhance productivity, optimize resource use, and promote sustainable farming practices. Global crop yield variability from 1981 to 2010 is analyzed in Iizumi and Ramankutty [15], attributing significant changes to climate change. Their study highlights the increasing impact of climate factors on yield stability, emphasizing the need for adaptive agricultural strategies. Long-term trends in foodgrain yield, area, and production in India are examined in Shaharshad et al. [16]. Their analysis highlights how both short-term and long-term factors influence agricultural output dynamics. Growth trends and structural changes in India's commercial crop production from 1980 to 2020 are studied in Kutty [17], highlighting the impact of policy reforms on agricultural productivity. A dynamic-statistical biomass model to predict crop yields in Kazakhstan, utilizing 21 years of regional data (2000–2021), is developed in Sadenovaa et al. [18]. The model demonstrated strong correlations with official statistics, indicating its robustness against meteorological variability.

2. Methodology

The analytical framework employed in this study is centered on a comprehensive evaluation of three critical productivity ratios Production-to-Area, Yield-to-Area, and Yield-to-Production across the two major crop categories distinguished by their KGH behavior. Each ratio serves a unique purpose in unraveling different aspects of crop performance and land-use efficiency. The methodology involves systematically processing the dataset to compute these ratios for every crop and every state-year combination within the study period. These calculations form the backbone of subsequent visual analyses.

Both line and bar plots are employed as key visualization tools to analyze the temporal and cross-sectional trends of these ratios. Bar plots provide an intuitive understanding of inter-crop performance by clearly displaying the magnitude of ratios in selected years, thereby facilitating easy comparison of productivity and efficiency among crops. On the other hand, line plots reveal the temporal evolution of these ratios, capturing fluctuations, peaks, and troughs that characterize the high- and low-performing crops over time. This dual approach helps to uncover both steady trends and volatility, which are essential for understanding the underlying factors driving crop performance.

Special attention is given to evaluating performance thresholds, such as the 5 KGH benchmark, which helps differentiate between highly productive and moderately performing crops. This threshold also assists in policy prioritization by flagging crops that exceed or fall below critical productivity levels. By integrating these ratio analyses with visual tools, the study provides policymakers, researchers, and farmers with actionable insights, enabling more informed decisions related to crop selection, resource allocation, and resilience building in agriculture.

3. Ratio Metrics and Analysis

3.1. Ratio of Production to Area

The ratio of production to area serves as a fundamental indicator of output efficiency, measuring how much crop yield (typically in tons) is produced per unit of land (e.g., hectare). This ratio is essential in assessing the agricultural productivity of land, especially in contexts where cultivable land is scarce or subject to degradation. By comparing output relative to the area under cultivation, this metric helps evaluate the intensity and effectiveness of land use, offering valuable insights into which crops optimize production under prevailing environmental and agronomic conditions.

In the case of high KGH crops, the data visualizations, particularly line plots, reveal substantial instability and fluctuation, as shown in Figure 1. The peaks and troughs observed highlight the unpredictable nature of production outcomes, which can be attributed to erratic rainfall, pest infestations, soil fertility variations, and inconsistent input application. These fluctuations, visualized further in Figure 2, make high KGH crops less dependable from both an economic and policy standpoint.

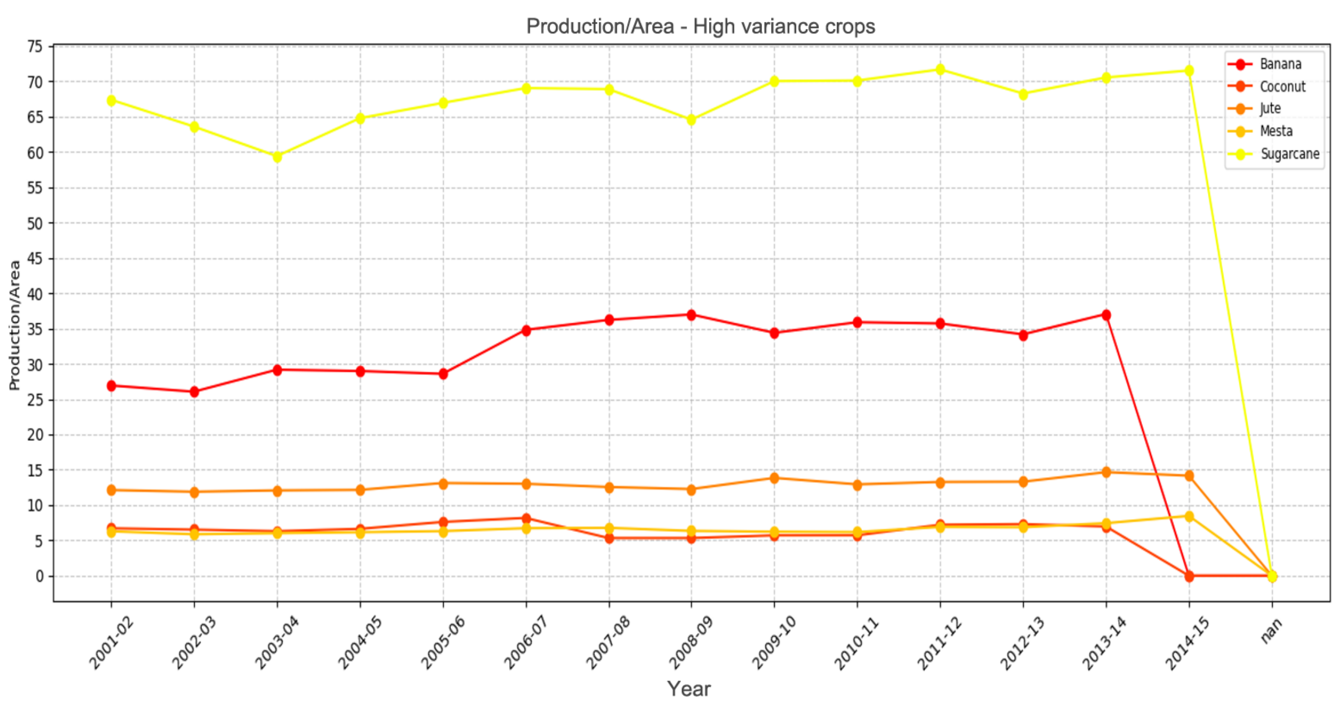

Figure 1. Production/Area – High KGH crops.

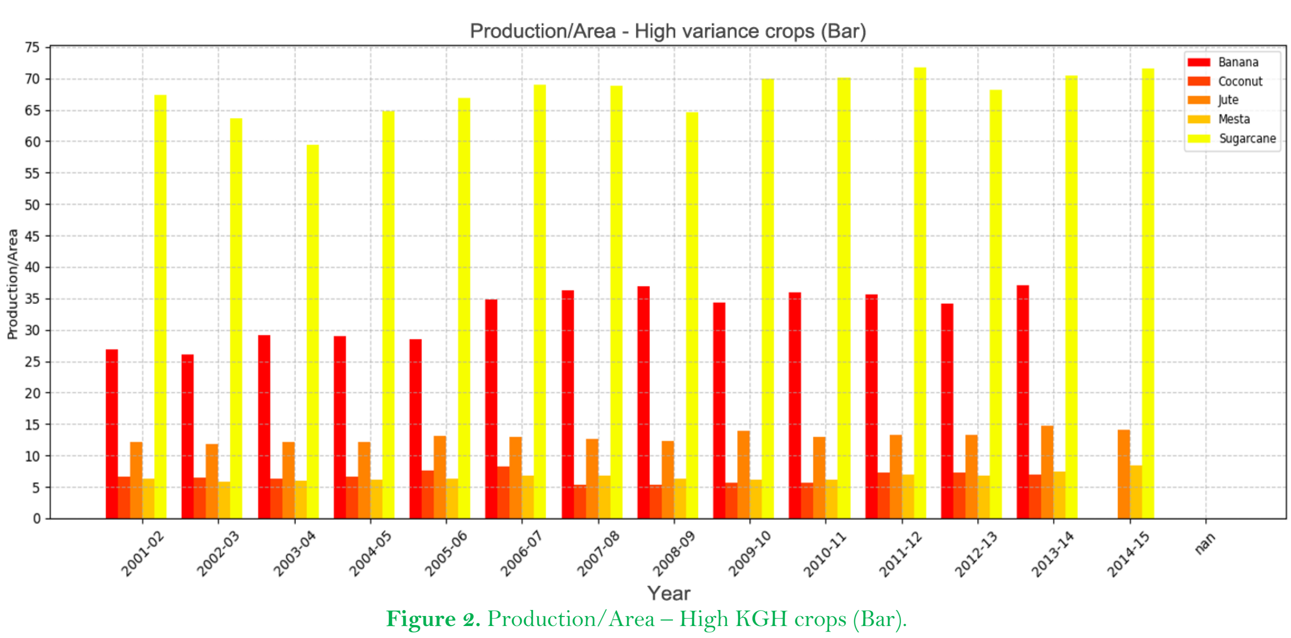

Figure 2. Production/Area – High KGH crops (Bar).

In contrast, low KGH crops exhibit a much more predictable trend in their production-to-area ratio. Bar charts, such as in Figure 4, demonstrate uniform and steady performance, while line plots in Figure 3 display smooth, consistent curves, indicating resilience and adaptability. These characteristics imply that low KGH crops benefit from stable environmental conditions, optimized agronomic practices, and improved seed genetics, making them ideal for land productivity enhancement.

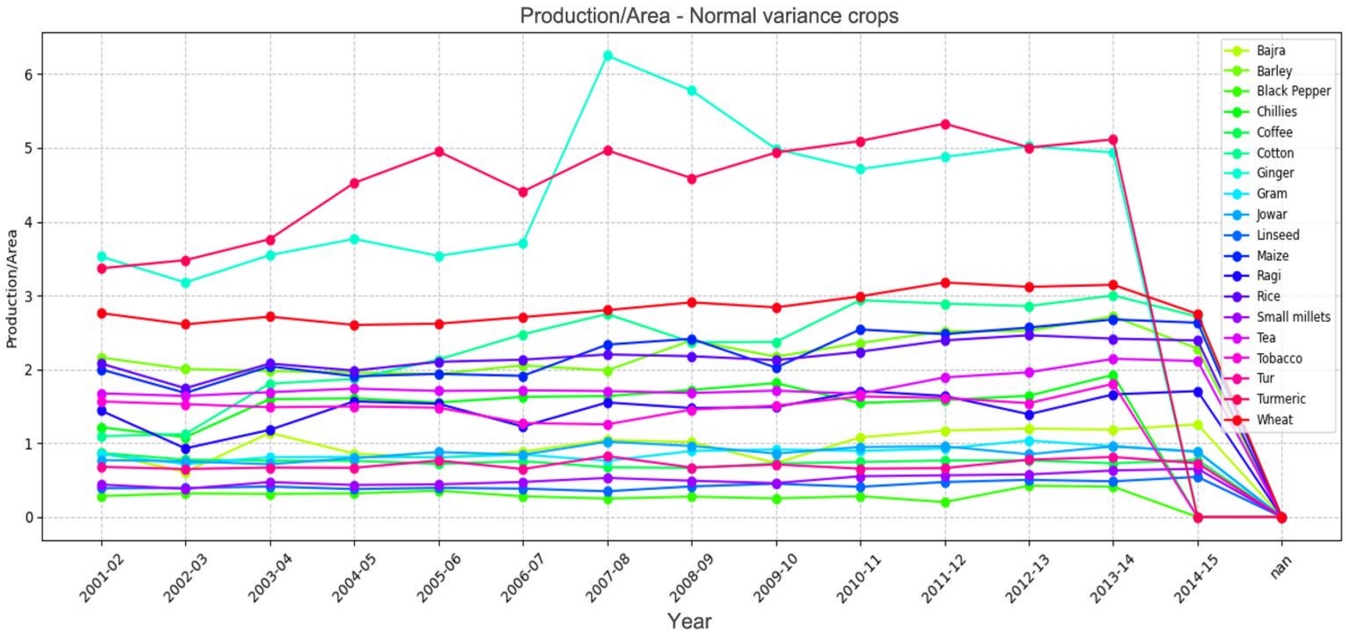

Figure 3. Production/Area – Low KGH crops.

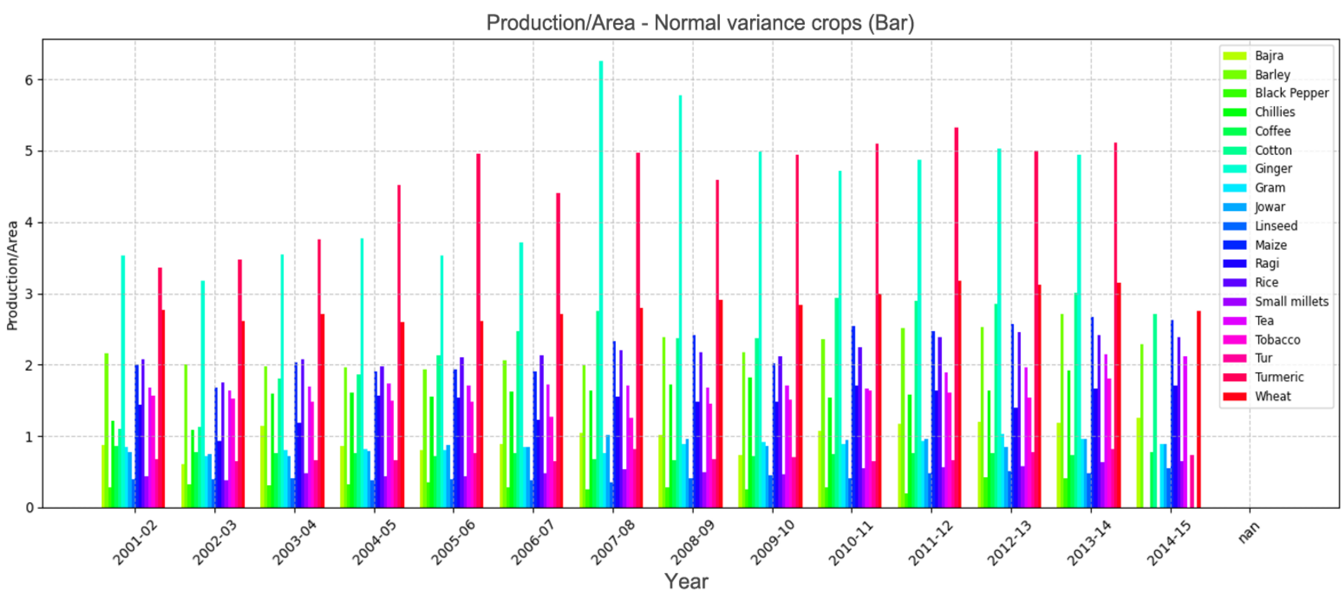

Figure 4. Production/Area – Low KGH crops (Bar).

Mathematical Formula:

$$P/A = \frac{\text{Total Production (kg)}}{\text{Cultivated Area (hectares)}}$$

This ratio measures how many kilograms of crop are produced per hectare, reflecting land productivity.

Statistical Classification:

The Production-to-Area ratio is used to classify crops into High KGH and Normal KGH groups based on a threshold value of 5 kg/ha. Crops with P/A values exceeding 5 kg/ha are designated as High KGH, indicating exceptionally high land productivity but often accompanied by higher variance (greater year-to-year fluctuations). Examples include sugarcane, cotton, and banana, which frequently surpass this threshold, with sugarcane reaching peaks over 70 kg/ha.

Crops consistently below the 5 kg/ha threshold fall into the Normal KGH category. These crops, such as rice, maize, and wheat, generally show lower but steadier production per hectare. Statistically, high KGH crops exhibit higher variance (standard deviation) in P/A values, reflecting sensitivity to environmental factors and management practices, while normal KGH crops show tighter clustering around their mean P/A, indicating stability.

The Production-to-Area ratio plot clearly demonstrates which crops utilize land most efficiently in terms of raw output. Crops like Sugarcane and Banana dominate this visualization, with Sugarcane frequently exceeding 70 KGH and peaking beyond 75 KGH in certain years, showing extremely high land productivity. Cotton follows with notable consistency, often surpassing the 5 KGH threshold, classifying it within the high-efficiency crop group. This visual behavior confirms Sugarcane's and Cotton's suitability for regions prioritizing land maximization. However, the statistical distribution of these values reveals significant year-to-year fluctuations, as evidenced by the irregular bar heights across the timeline, indicating high variance. Such variability underlines environmental dependency and sensitivity to factors like rainfall, fertilizer input, and agronomic management. On the other hand, crops like Maize, Wheat, and Paddy remain steadily clustered in the range of 2–4 KGH, with minimal deviation across years, reflecting stable and predictable land performance. This contrast, visually and statistically apparent in the plot, serves as a direct basis for classifying crops into high and normal KGH categories and is critical when prioritizing land allocation strategies in fluctuating agricultural zones.

3.2. Ratio of Yield to Area

The ratio of yield to area is another crucial performance metric, reflecting the efficiency of land use in producing a normalized crop output. Unlike the production ratio, this metric often accounts for factors such as weight, quality, or moisture content. It is particularly useful in modern agriculture, where maximizing both quantity and quality from available land is critical.

For high KGH crops, this ratio shows substantial inconsistency. Line plots, such as in Figure 5, display sharp spikes followed by abrupt declines, indicating sensitivity to environmental and market changes. Figure 6 is a bar chart representation that highlights this volatility even further. Peaks may reflect favorable weather or robust input use, while dips often suggest stressors like droughts, pest attacks, or supply shortages. These erratic trends make planning around such crops a risky endeavor.

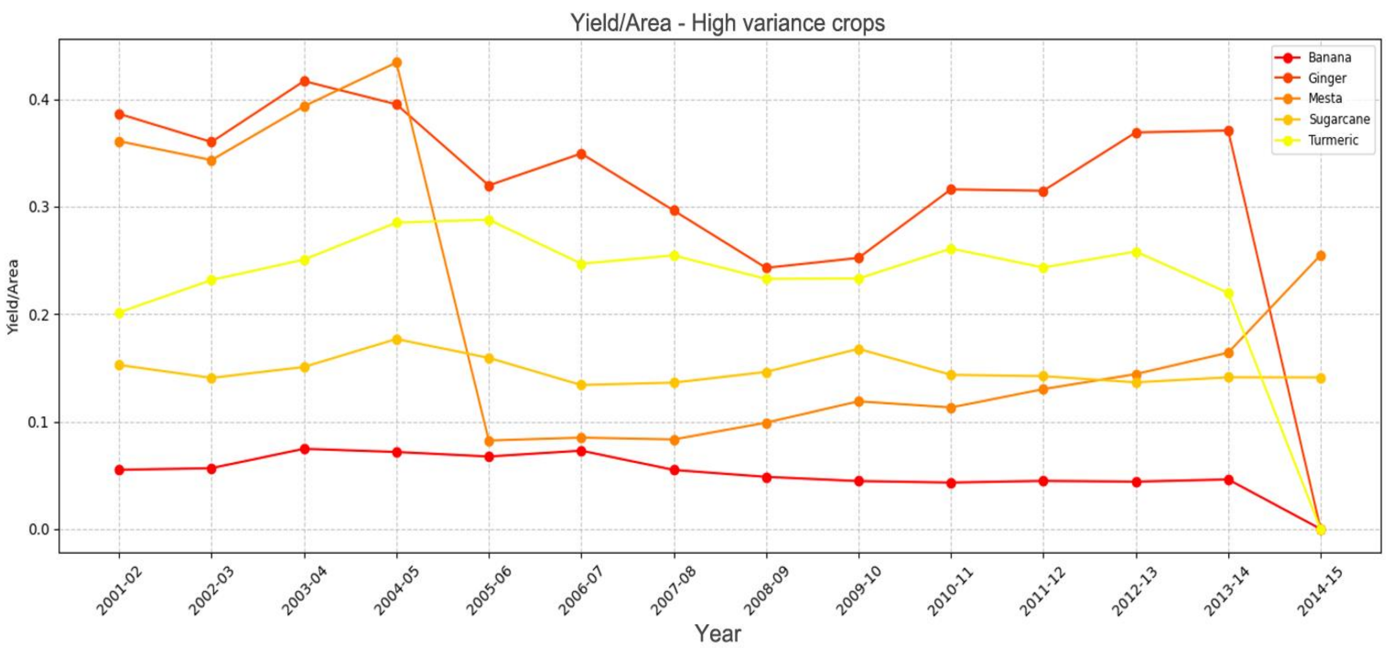

Figure 5. Yield/Area – High KGH crops.

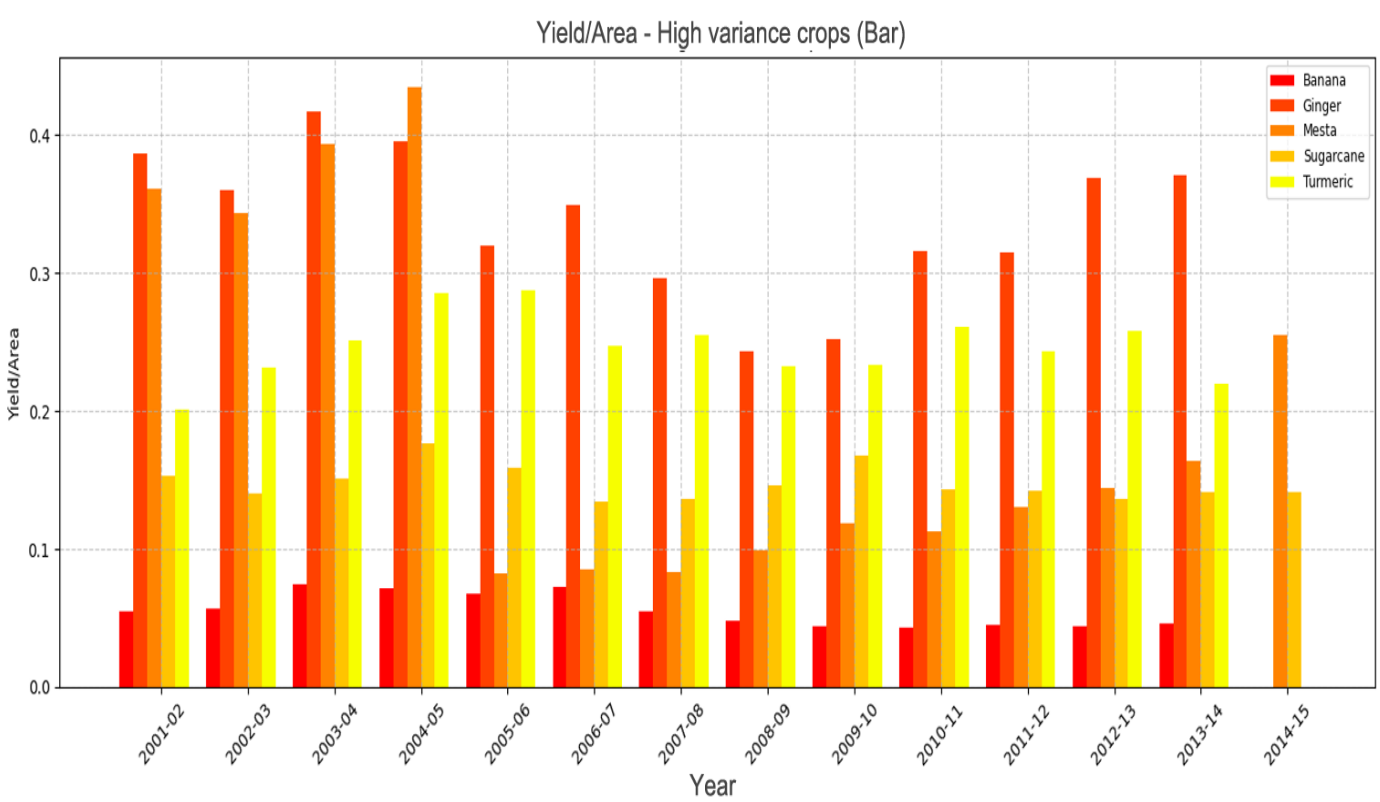

Figure 6. Yield/Area – High KGH crops (Bar).

Conversely, low KGH crops display minimal variation in yield-to-area ratios. This is clearly depicted in Figure 7 and Figure 8, where both line and bar plots reflect a smooth and consistent performance trend. This stability arises from controlled agronomic conditions, including dependable irrigation, the use of hybrid seeds, and reliable fertilizer access. Such uniformity enables better input planning, more predictable income for farmers, and improved policy effectiveness.

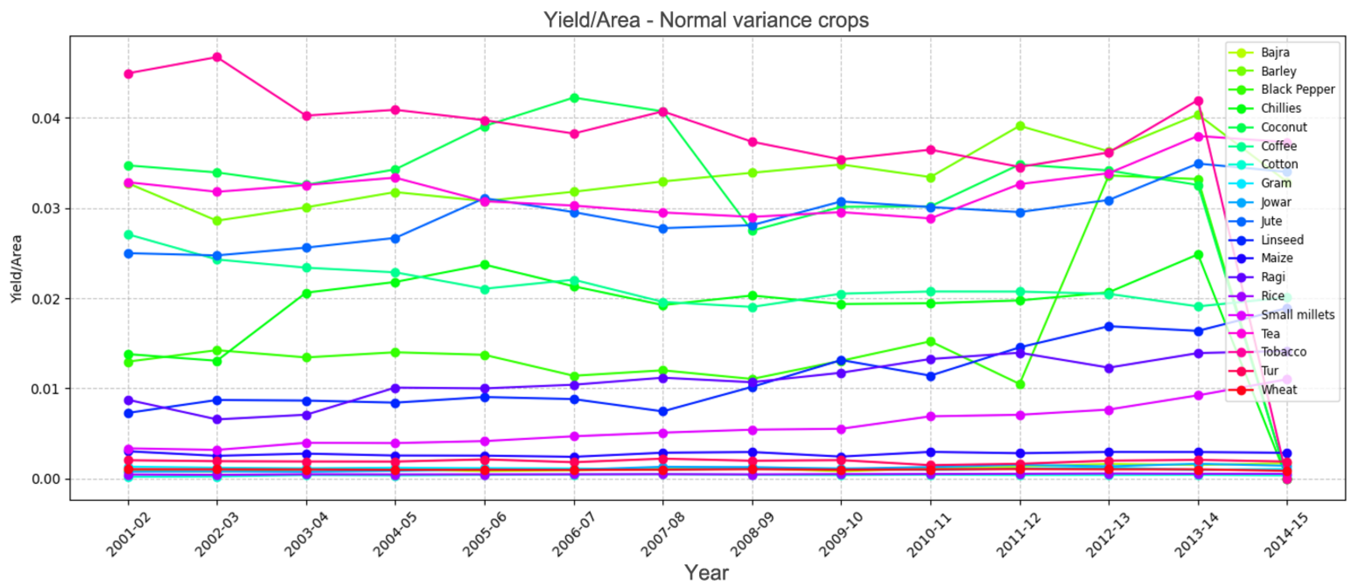

Figure 7. Yield/Area – Low KGH crops.

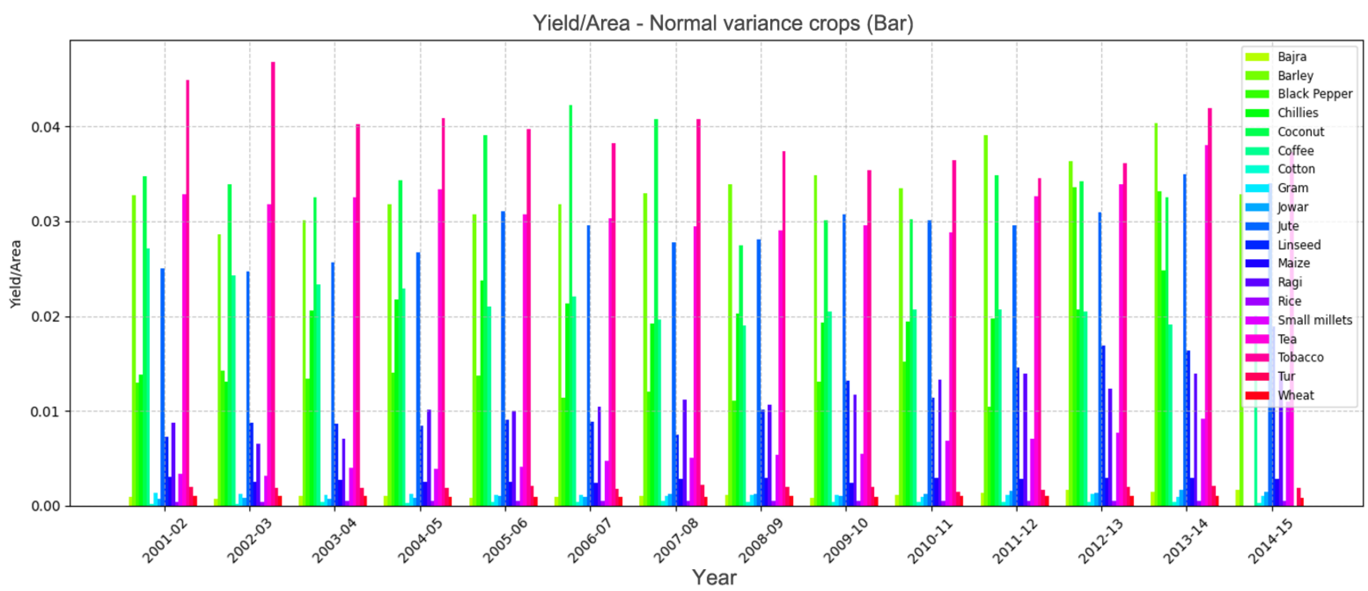

Figure 8. Yield/Area – Low KGH crops (Bar).

Mathematical Formula:

$$Y/A = \frac{\text{Yield (normalized or weighted)}}{\text{Cultivated Area (hectares)}}$$

This ratio accounts for yield adjusted by quality factors, normalized per hectare.

Statistical Classification:

In the statistical context, the Yield-to-Area ratio is analyzed to distinguish crop groups based on their average ratio and variance. Crops with Y/A values notably above 0.1 (or similarly high thresholds relevant to the data range) and high inter-annual variability are classified as high KGH crops. For instance, ginger shows Y/A spikes around 0.42 with sharp drops, indicating high variance and unstable yield performance.

Normal KGH crops tend to have Y/A ratios clustered within a narrower band (e.g., 0.02 to 0.035) and exhibit low variance, signifying consistent yield quality per hectare. Statistically, the difference between high and normal KGH is evaluated using measures like standard deviation and coefficient of variation, identifying crops with stable versus volatile yield efficiency.

The Yield-to-Area ratio plot emphasizes quality-adjusted production relative to land use, visually distinguishing high-value crops from more stable staples. Crops such as Ginger, Black Pepper, and Turmeric stand out with bar heights reaching 0.42 and sometimes even higher, particularly in years like 2003–04 and 2005–06 for Ginger. These values are significantly above those of other crops, where the majority such as Rice, Maize, and Wheat cluster consistently between 0.02 and 0.035. The wide spread and sharp fluctuations among the high Y/A crops suggest strong input responsiveness but also highlight volatility. This variability is evident from the irregular and steeply rising or falling bars across years, indicating sensitivity to climatic or economic stressors. In contrast, the flat and even distribution of Y/A ratios in staples demonstrates agronomic stability, achieved through regulated irrigation, hybrid seed use, and consistent cultivation practices. These statistical trends in the bar plot underscore how this ratio can be used not only to assess land performance but also to inform precision agriculture decisions, guiding investments into crops that either demonstrate stable returns or require controlled environments to mitigate risks.

3.3. Ratio of Yield to Production

The ratio of yield to production offers insights into how yield performance aligns with total output. While less commonly used, it reveals whether gains in yield translate proportionately into production or if inefficiencies such as post-harvest losses are present. This metric is especially useful for identifying gaps in crop conversion efficiency.

High KGH crops tend to display wide variability in this ratio. Line and bar charts, as presented in Figure 9 and Figure 10, show erratic values. These issues could stem from increased area not leading to proportional yield gains or losses in the supply chain. The discrepancies suggest that yield improvements in these crops do not always result in scaled production, limiting their reliability.

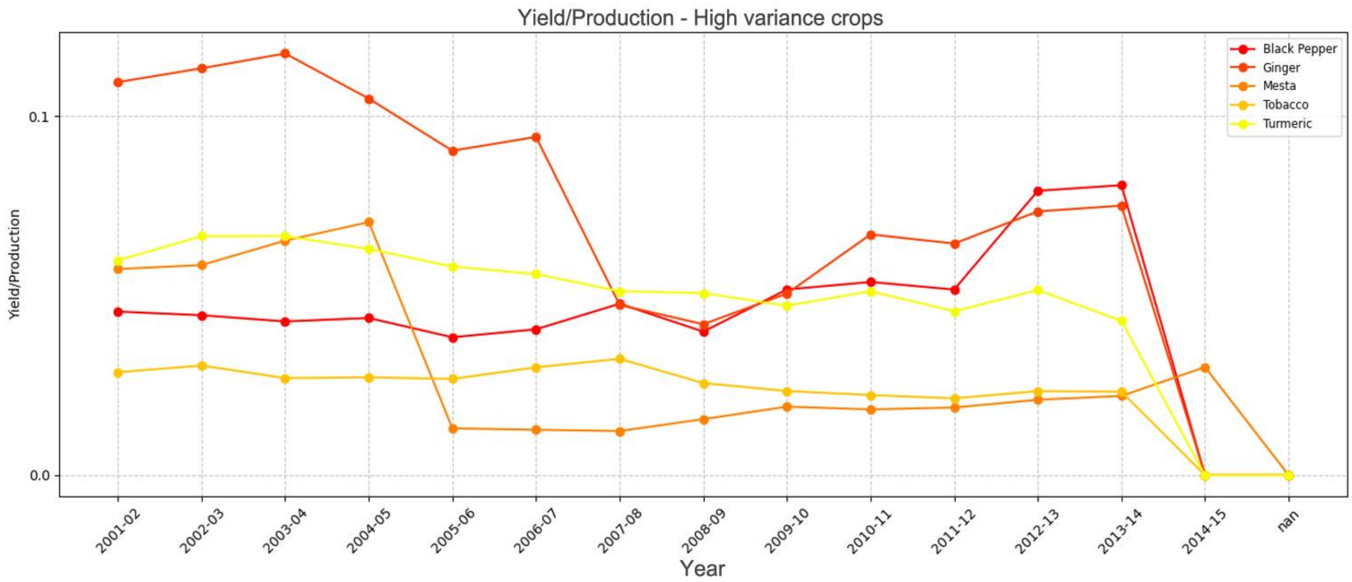

Figure 9. Yield/Production– High KGH crops.

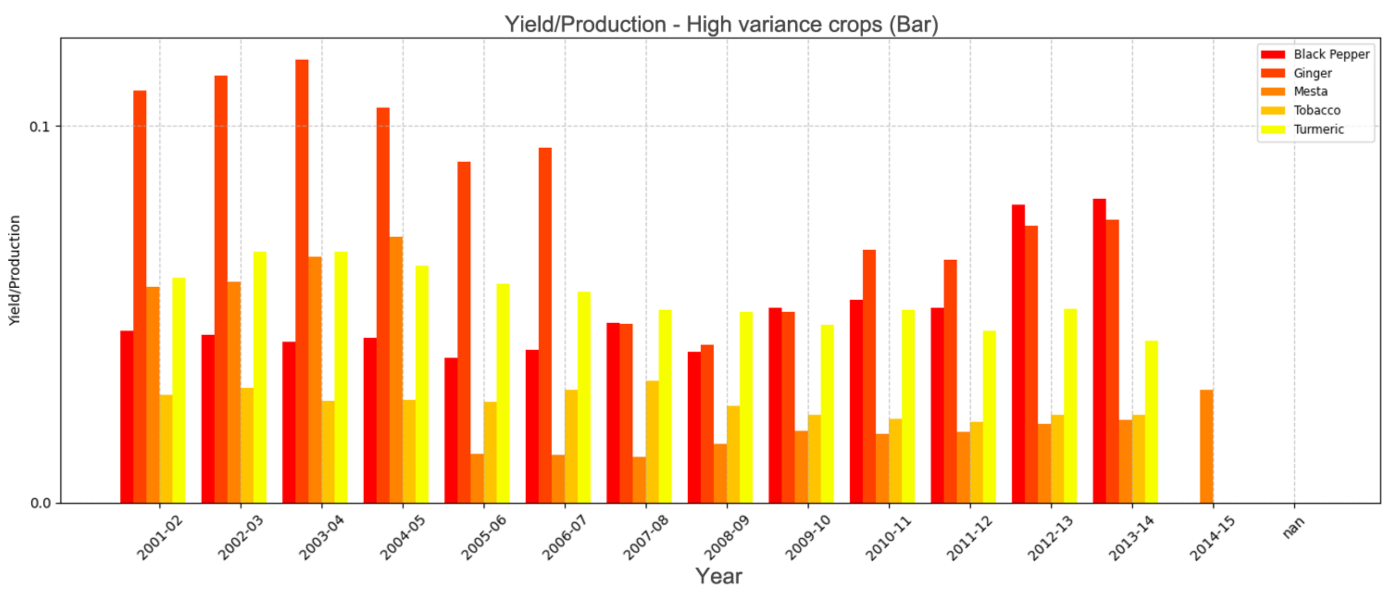

Figure 10. Yield/Production– High KGH crops (Bar).

In contrast, low KGH crops typically exhibit stable and higher yield-to-production ratios, as seen in Figure 11 and Figure 12. This alignment indicates that improvements in yield translate directly into overall production, which points to greater operational efficiency. Such crops are more suited for scale-up and offer a better return on investment.

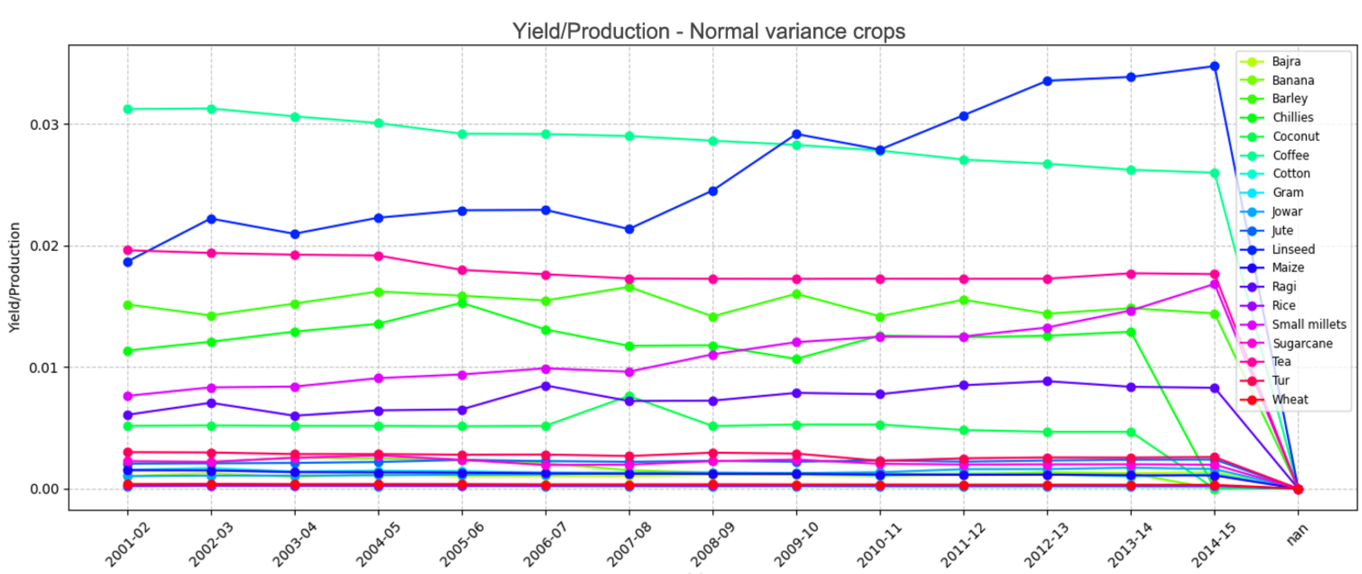

Figure 11. Yield/Production– Low KGH crops.

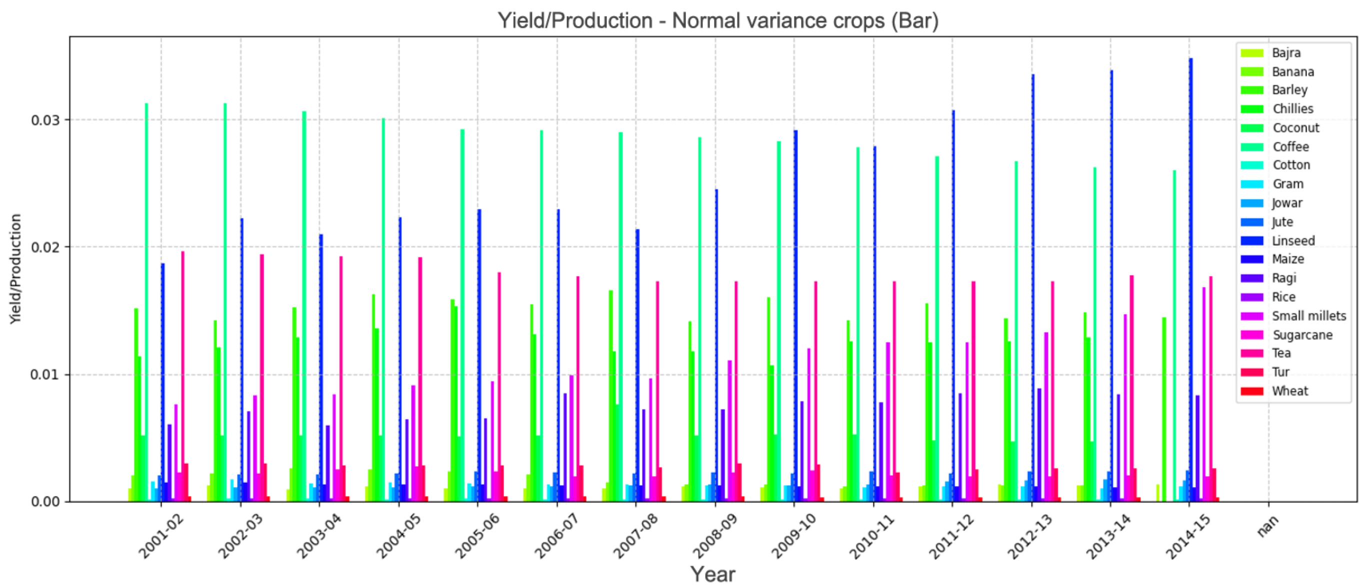

Figure 12. Yield/Production– Low KGH crops (Bar).

Mathematical Formula:

$$Y/P = \frac{\text{Yield (kg)}}{\text{Total Production (kg)}}$$

This ratio reflects the consistency or proportionality between yield and production.

Statistical Classification:

Statistically, the Yield-to-Production ratio is used to assess operational efficiency beyond raw yield or production numbers. Crops with Y/P ratios fluctuating widely ranging, for example, from 0.02 to 0.12 are classified as high KGH due to irregular efficiency patterns. Black pepper and tobacco demonstrate such variable Y/P ratios, indicating inconsistencies such as post-harvest losses or processing inefficiencies.

In contrast, crops exhibiting a near-linear relationship in Y/P, with ratios consistently clustered around lower stable values (e.g., 0.015 to 0.035), fall under Normal KGH. This stability suggests effective conversion of yield gains into production increments, marking operational efficiency.

Variance metrics, trend analysis, and standard deviation are used statistically to differentiate these categories, highlighting crops with consistent versus inconsistent yield-to-production relationships.

The Yield-to-Production ratio plot provides a clear visualization of the internal relationship between yield and total output. High values in this plot such as those for Black Pepper and Mesta, often reaching 0.1 to 0.12 indicate that the yield (possibly quality-adjusted) constitutes a significant portion of total production, highlighting potential inefficiencies in scaling up or post-harvest processing. These elevated bars contrast with the more consistent lower ratios for crops like Maize, Wheat, and Rice, where values range between 0.015 and 0.035. This suggests that in these staple crops, increases in yield proportionally translate into overall production, reflecting operational efficiency. From a statistical perspective, the high variability observed in the bar heights for crops like Turmeric and Ginger points to inconsistency in yield-to-output translation, which may result from unpredictable losses or input/output mismatches. Visually, the irregular bar heights for such crops differ markedly from the even, linear patterns seen in staples, reinforcing their classification as high-variance crops and highlighting their suitability for more controlled, investment-intensive cultivation systems. This ratio, as depicted in the plot, is essential for diagnosing systemic inefficiencies and guiding research or infrastructure investments.

4. Key Findings

The comparative analysis of high KGH and low KGH crops through the lens of the three-ratio metrics reveals clear patterns and distinctions. High KGH crops exhibit significant volatility across all ratios, indicating inconsistent performance. While they may demonstrate high yields or production levels in certain years, these instances are not reliable and often arise under specific, favorable conditions. This unpredictability limits their potential for stable food supply planning, commercial investment, and policy support. The inherent risk associated with high KGH crops calls for careful consideration before large-scale promotion.

In contrast, low KGH crops consistently show a strong alignment between area, yield, and production. This makes them more dependable for agricultural stakeholders, from farmers and supply chain actors to policymakers. Their performance across all three ratios particularly in yield-to-area and yield-to-production suggests high efficiency, resilience, and scalability. These attributes make them excellent candidates for subsidy allocation, research funding, and national food security strategies.

Among the three metrics, the Yield-to-Area ratio emerged as the most consistent and reliable across both crop categories, offering a clear indicator of land-use efficiency. Meanwhile, the Yield-to-Production ratio proved particularly useful in identifying internal inconsistencies and assessing readiness for large-scale farming operations. Combined, these ratios create a comprehensive framework for evaluating crop sustainability and productivity.

5. Policy Implications and Recommendations

Based on the analysis of ratio-based crop performance metrics, several policy and strategic recommendations emerge. First, government subsidies and agricultural support programs should prioritize crops that demonstrate consistent and high performance across both yield and production dimensions. These crops not only ensure stable returns for farmers but also contribute to food security and economic resilience at the national level.

High KGH crops, despite their risks, should not be dismissed entirely. Instead, they should be the focus of targeted innovation efforts, including the development of pest-resistant or drought-tolerant varieties, the promotion of adaptive farming techniques, and the establishment of insurance schemes that cushion farmers against environmental shocks. Research funding and public-private partnerships can play a key role in making these crops more reliable performers.

The three ratios analyzed in this report, Production-to-Area, Yield-to-Area, and Yield-to-Production, should be integrated into broader agricultural management systems. For example, they can serve as the foundation for crop insurance models, where premiums are based on volatility, or in credit scoring systems that assess the risk of lending to specific agribusinesses based on crop consistency. Additionally, coupling these metrics with climate, soil, and satellite datasets will enable the development of advanced predictive models, supporting precision agriculture and smarter resource allocation.

6. Conclusion

This multi-ratio analytical approach offers a robust and comprehensive decision-support framework for evaluating crop performance under varying agronomic and environmental conditions. By systematically examining the interrelationships among production, yield, and area through three distinct ratios production-to-area, yield-to-area, and yield-to-production this methodology provides granular insights into the efficiency, consistency, and potential scalability of agricultural outputs.

Through this lens, the contrast between high KGH and low KGH crops becomes particularly evident. While high KGH crops may demonstrate occasional surges in productivity, their unpredictable nature limits their reliability for long-term planning and investment. In contrast, low KGH crops consistently deliver stable performance across all key metrics, making them more suitable for scaling, strategic support, and policy prioritization.

The integration of visual tools such as bar and line plots not only enhances interpretability but also enables temporal and cross-sectional analysis. This visual representation aids researchers, agronomists, and policymakers in identifying both risk-prone crops that require targeted interventions and resilient varieties that merit broader promotion. When combined with complementary datasets such as climate patterns, soil conditions, and technological inputs, this framework can be further strengthened to guide evidence-based agricultural planning.

Ultimately, this approach promotes a more sustainable, scalable, and stable agricultural ecosystem. It equips stakeholders with the clarity needed to make informed decisions, allocate resources efficiently, and drive innovation in crop management and development.

References

[1] T. Iizumi and T. Sakai, "The global dataset of historical yields for major crops 1981–2016," Scientific Data, vol. 7, no. 1, p. 97, 2020. https://doi.org/10.1038/s41597-020-0433-7
[2] A. K. Senapati and P. Goyari, "Agricultural growth and production variability of principal crops in India: An empirical investigation," Advances in Plants & Agriculture Research, vol. 8, no. 1, pp. 45-51, 2018.
[3] M. Shukla, K. T. Al-Busaidi, M. Trivedi, and R. K. Tiwari, "Status of research, regulations and challenges for genetically modified crops in India," GM Crops & Food, vol. 9, no. 4, pp. 173-188, 2018/10/02 2018. https://doi.org/10.1080/21645698.2018.1529518
[4] K. N. Reddy *et al.*, "Improving the representation of major Indian crops in the Community Land Model version 5.0 (CLM5) using site-scale crop data," Geoscientific Model Development, vol. 18, no. 3, pp. 763-785, 2025. https://doi.org/10.5194/gmd-18-763-2025
[5] N. Yamuna, D. Kolekar, and N. Rakesh, "Trend and instability analysis of area, production, productivity of millets in India," Journal of Scientific and Reports, vol. 30, no. 8, pp. 686-999, 2024. https://doi.org/10.9734/jsrr/2024/v30i82290
[6] T. Lakshmi Kumar, H. Barbosa, S. Madhu, and K. Koteswara Rao, "Studies on crop yields and their extreme value analysis over India," Sustainability, vol. 11, no. 17, p. 4657, 2019. https://doi.org/10.3390/su11174657
[7] B. Talukdar, P. K. Chakravartty, and B. Sharma, "Analysis of state wise yield of major food crops in India for the year 2014-15," vol. 44, no. 2, 2023. https://doi.org/10.53555/jaz.v44i2.4543
[8] N. Bagaria and S. S. Jatav, "Growth dynamics and sustainability of major crops in Haryana, India," Indian Journal of Extension Education, vol. 61, no. 2, pp. 80-84, 2025. https://doi.org/10.48165/IJEE.2025.61215
[9] K. Islam and T. Das, "Changing patterns of crop combination, crop concentration and crop diversification regions: A case study based on six principal crops of Koch Bihar District, West Bengal, India," Egyptian Journal of Agricultural Research, vol. 103, no. 2, pp. 188-204, 2025. https://doi.org/10.21608/ejar.2024.282439.1536
[10] S. Akhter, J. R. Sarker, and K. R. Das, "Growth and trend in area, production and yield of major crops of Bangladesh," International Journal of Economics, Finance and Management Sciences, vol. 4, no. 1, pp. 20-25, 2016. https://doi.org/10.11648/j.ijefm.20160401.13
[11] A. Tripathi, B. S. Rathore, and D. Singh, "Survey paper on agricultural dataset for improving crop yield prediction using machine learning algorithms," International Journal of Computer Applications, vol. 184, no. 46, pp. 28-34, 2023. https://doi.org/10.5120/ijca2023922571
[12] V. K. Reddy and K. T. Immanuelraj, "Area, production, yield trends and pattern of oilseeds growth in India," Economic Affairs, vol. 62, no. 2, pp. 327-334, 2017. https://doi.org/10.5958/0976-4666.2017.00016.X
[13] L. Arata, E. Fabrizi, and P. Sckokai, "A worldwide analysis of trend in crop yields and yield variability: Evidence from FAO data," Economic Modelling, vol. 90, pp. 190-208, 2020. https://doi.org/10.1016/j.econmod.2020.05.006
[14] N. Chergui and M. T. Kechadi, "Data analytics for crop management: a big data view," Journal of Big Data, vol. 9, no. 1, p. 123, 2022/12/23 2022. https://doi.org/10.1186/s40537-022-00668-2
[15] T. Iizumi and N. Ramankutty, "Changes in yield variability of major crops for 1981–2010 explained by climate change," Environmental Research Letters, vol. 11, no. 3, p. 034003, 2016. https://doi.org/10.1088/1748-9326/11/3/034003
[16] C. Shaharshad, K. Manikandan, M. Priyadharshini, and M. Rishad, "Trends in yield, area, and production of foodgrains in India," International Journal For Multidisciplinary Research, vol. 7, no. 3, 2025. https://doi.org/10.36948/ijfmr.2025.v07i03.44350
[17] K. Kutty, "Growth trends of commercial crops production, area, and yield in india: An appraisement of the structural stability regression model," Estudios de Economía Aplicada, vol. 41, no. 1, p. 27, 2023. https://doi.org/10.25115/sae.v41i1.8625
[18] M. A. Sadenovaa, N. A. Beisekenova, M. Rakhymberdinaa, P. S. Varbanovb, and J. J. Klemešb, "Mathematical modelling in crop production to predict crop yields," Chemical Engineering, vol. 88, pp. 1225-1230, 2021. https://doi.org/10.3303/CET218820