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Growth and Variability Analysis of Major Fruits and Vegetables Cultivation in Assam

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Abstract

Assam has a predominantly agrarian economy and most of the people in the state are dependent on agriculture. This dependence is attributable to the diverse geographical and climatic conditions that support a wide range of crops in the state. Tea, rice, wheat, maize, and oilseed are some major crops dominating the agricultural landscape of the state. In addition to these staple crops, horticultural crops such as banana, potato, tapioca, onion, sweet potato, orange, papaya, and pineapple are widely cultivated in various districts of Assam. This study analyses trends in the area and production of major fruits and vegetables in Assam from 2004-05 to 2022-23 using CAGR and Coefficient of Variation (CV). The study highlights growth disparities among eight major horticultural crops including banana, potato, tapioca, onion, sweet potato, orange, papaya, and pineapple. Production has increased for crops like banana, potato, onion, pineapple, orange, papaya and tapioca, though growth remains uneven across crops. Onion recorded the highest production CAGR (9.82%), indicating rapid expansion, whereas sweet potato exhibited negative growth, reflecting declining cultivation. Variability analysis shows that onion production was highly unstable (CV=69.90%), while sweet potato remained the most stable (CV=10.82%). In terms of area, orange showed the highest fluctuation (CV=26.10%), whereas banana exhibited the most stability (CV=6.97%). These results indicate that horticultural growth in Assam is characterized by both expansion and instability, requiring crop-specific interventions. This research highlights the need for better infrastructure, climate-resilient farming, post-harvest management and stronger market linkages.

Keywords: Assam, Coefficient of Variation, Compound Annual Growth Rate, Fruits and vegetables, Horticulture

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Introduction

Horticulture has emerged as an important component of agricultural transformation in India. It contributes significantly to farm income, nutrition, employment, and export earnings (Singh & Singh, 2020). With increasing population, climate risk, dietary diversification and pressure on land resources, horticulture offers a viable alternative to traditional food grain cultivation (Chand, 2017). India is currently the second-largest producer of fruits and vegetables globally, accounting for nearly 12% of global fruit production and 14% of global vegetable production (NHM, 2023). Within the national context, the state of Assam has a unique position in agriculture because of its agro-climatic condition, organic potential and rich biodiversity. North-East India is dominated by marginal farmers where low productivity, limited use of inputs, fragmented land and infrastructural deficits pose constraints (Ray et al., 2021). Furthermore, fruits and vegetables have increasingly become an important component of livelihood diversification in the region. Horticultural crops offer higher returns per unit area, shorter production cycles, and opportunities for employment generation compared to traditional food crops (Borah & Chetia, 2020). Assam, blessed with fertile alluvial soils and high rainfall, possesses comparative advantages in crops such as banana, pineapple, orange, papaya and potato.

Horticultural crops play a significant role in Assam's rural economy, contributing to food security, income generation, and livelihood diversification. Over the past two decades, fruits and vegetables have gained importance because of changing dietary preferences, expanding market demand, and government incentives. Assam contributes significantly to India's banana, pineapple, and citrus output, yet productivity levels remain below national averages due to infrastructural, environmental and market-related constraints. This paper focuses on the following objectives: (i) to examine changes in production and area under major fruits and vegetable crops in Assam between 2004-2005 and 2022-2023; (ii) to compute and interpret the Compound Annual Growth Rate (CAGR) and Coefficient of Variation (CV) for each crop; and (iii) to suggest agricultural policy recommendations for sustainable horticultural development in Assam.

Study Area

Assam, a northeastern state in India, is a region of immense geographical and cultural significance. Assam is nestled in the Brahmaputra Valley, surrounded by the Eastern Himalayas to the North and the Patkai hills to the east (Goswami, 2018). Assam's unique geographical conditions, such as fertile plains and available water resources, make it an ideal location for agricultural activities. The climate of Assam is characterized by high average annual rainfall of around 2500mm (Barua & Hazarika, 2020). The state's agricultural sector is predominantly rice-based, with crops such as rice, maize and pulses being major contributors to the state's economy (Saikia & Das, 2019). However, factors such as soil erosion, flooding and climate change have affected the state's agricultural productivity (Bhattacharya & Bora, 2021). The river

Brahmaputra that flows through the middle of the state plays a crucial role in shaping the state's agricultural landscape (Goswami, 2018). The river's annual floods bring nutrient-rich silt, making the lands suitable for cultivation (Barua & Hazarika, 2020). However, annual floods pose a significant threat to agricultural productivity and livelihoods (Bhattacharya & Bora, 2021). Assam's agricultural sector is also characterized by a diverse range of crops, including tea, fruits, and vegetables (Saikia & Das, 2019). The state's tea industry is particularly notable, with Assam tea being renowned globally for its quality (Goswami, 2018). In recent years, there has been a growing focus on promoting sustainability in agricultural practices and crop diversification in Assam (Barua & Hazarika, 2020). The state's agricultural research and development efforts are mainly focused on improving crop productivity, reducing vulnerability to climate change, and promoting sustainable agriculture (Bhattacharya & Bora, 2021). Various institutions of Assam like the Assam Agricultural University play a crucial role in promoting agricultural development in the state by working closely with policymakers and farmers (Saikia & Das, 2019). The agro-climatic diversity of the state, with its warm humid climate, alluvial soils, and abundant rainfall, creates particularly favourable conditions for the horticultural crops examined in this study, including banana, pineapple, orange, papaya, potato, sweet potato, tapioca, and onion.

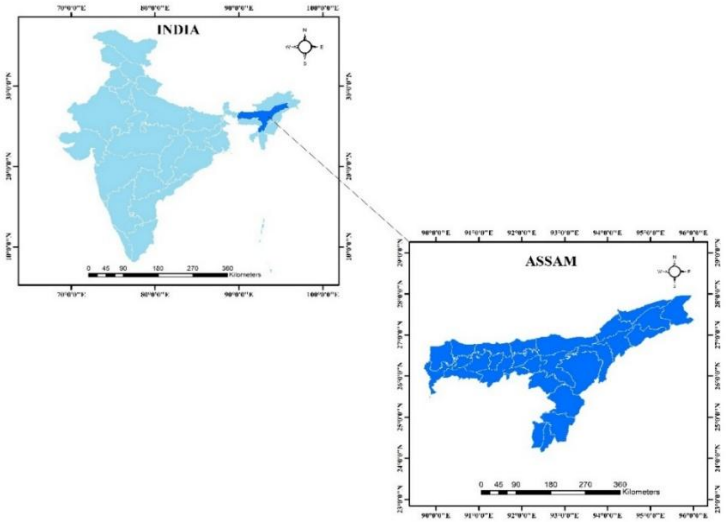

Fig. 1: The location map of the study area

Source: Prepared by the researcher in the ArcGIS software

Methodology

This research is mainly based on secondary data. For the review of literature, published sources including online journals, articles, research papers, and government reports were consulted. The study area map was generated in ArcGIS

using Survey of India (SOI) shapefiles. The area and production data of the eight horticultural fruits and vegetables of the years 2004-2005 to 2022-2023 were collected from the Directorate of Economics and Statistics (DES), Khanapara, Guwahati. These data are used to compute growth by using the Compound Annual Growth Rate (CAGR) formula, while the variability was assessed through the Coefficient of Variation (CV). The data include production (in metric tonnes) and area (in hectares) for banana, pineapple, orange, papaya, sweet potato, potato, tapioca and onion. The methodology follows standard agricultural statistical analysis.

Formulas used for calculating CAGR and CV are as follows-

i. $CAGR\ (\%) = (V_f/V_i)^{1/t} - 1) \times 100$

Here, CAGR = Compound Annual Growth Rate, V_f = Final Value, V_i= Initial Value, t = Time

ii. $CV\ (\%) = (SD/M) \times 100$

Here, CV = Coefficient of Variation, SD = Standard deviation, M = Mean or Average

Trend of production and area of some major horticultural crops in Assam

Trend analysis is a vital method in geography that enables researchers to identify patterns and changes over a period of time. Figures 2 and 3 illustrate how the trends of the eight selected crops, namely banana, pineapple, orange, papaya, potato, sweet potato, tapioca and onion, have changed over the study period (2004-2005 to 2022-2023) in terms of area and production.

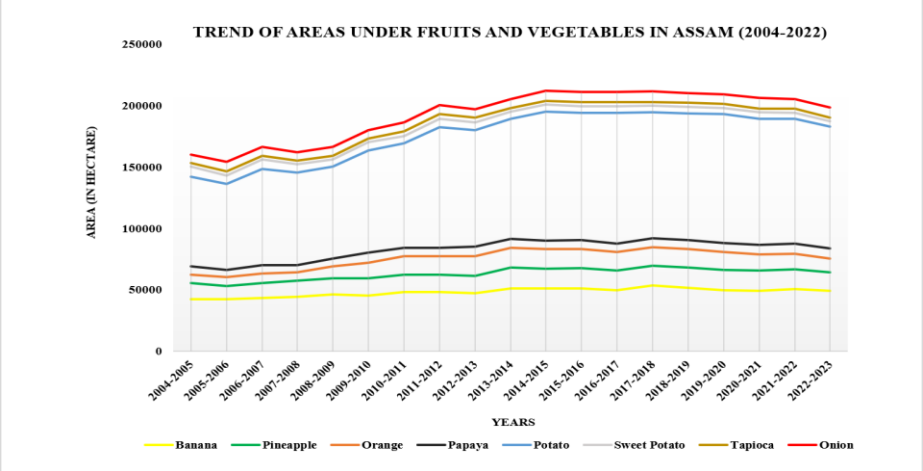

Fig. 2. Trend of area under Fruits and Vegetables in Assam (2004-2005 to 2022-2023)

The trend in cultivated area reveals distinct patterns among crops over the study period (Figure 2). Potato and banana consistently occupy the largest share of cultivated land, while onion also shows a gradual increase. From 2004 to around

2014-15, most crops exhibit a steady increase in area, followed by a phase of stagnation or slight fluctuation. Crops such as papaya, pineapple, and sweet potato maintain relatively smaller areas throughout the period, indicating limited expansion. Sweet potato, in particular, shows a declining trend in area, suggesting reduced farmer preference.

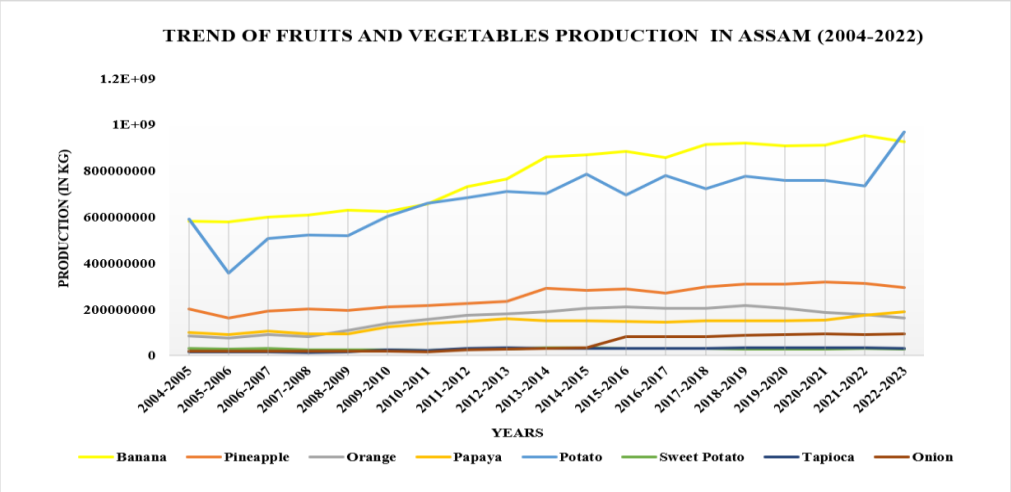

Fig. 3. Trend of Fruits and Vegetables production in Assam (2004-2005 to 2022-2023)

Production trends broadly correspond with area patterns but also reflect yield differences. Banana and potato dominate production throughout the period, indicating both large area coverage and relatively higher productivity (Figure 3). A sharp increase in banana production is observed in the later years, especially after 2018, suggesting improved cultivation practices or favourable conditions. Onion, despite moderate area, shows significant growth in production, indicating improved yield performance. In contrast, sweet potato exhibits a declining production trend, while tapioca, despite showing overall growth over the study period, displays considerable year-to-year fluctuation. Overall, the relationship between area and production is positive but not proportional, highlighting differences in crop productivity.

The computation and interpretation of the Compound Annual Growth Rate (CAGR) and Coefficient of Variation (CV) for each crop

The analysis of Compound Annual Growth Rate (CAGR) reveals significant variation in production growth across crops (Table 1). Onion recorded the highest growth rate (9.82%), indicating rapid expansion in production over the study period. Tapioca (4.73%), orange (3.83%), and papaya (3.61%) also exhibited moderate positive growth, while potato (2.78%), banana (2.60%), and pineapple (2.19%) showed steady but relatively slower growth. In contrast, sweet potato experienced a negative growth rate (-0.35%), reflecting a decline in production (Figure 4).

The Coefficient of Variation (CV) indicates substantial differences in production stability. Onion recorded the highest variability (69.90%), suggesting high instability and sensitivity to external factors such as market fluctuations or climatic conditions. Tapioca (31.64%) and orange (30.95%) also exhibited relatively high variability. Papaya (20.60%), pineapple (20.10%), and potato (20.16%) showed moderate variability, while banana (18.18%) demonstrated comparatively stable production. On the other hand, sweet potato showed the lowest variability (10.82%), indicating stable but declining production (Table 1).

Table 1. CAGR and CV of the eight major fruits and vegetables production

Production of fruits and vegetables (in metric tonnes)	2004-2005	2022-2023	CAGR (%)	Coefficient of Variation (%)
Banana	581000000	922986000	2.6	18.177618
Pineapple	199000000	293989000	2.19	20.0984072
Orange	82000000	161426000	3.83	30.95278344
Papaya	99000000	187552000	3.61	20.59633407
Potato	589000000	965654000	2.78	20.15791088
Sweet Potato	28000000	26273000	-0.35	10.82405755
Tapioca	13000000	29906000	4.73	31.63937198
Onion	17000000	91793000	9.82	69.90307651

Source: Data compiled from the Statistical Handbook of Assam (2004-2023), published by the Directorate of Economics and Statistics (DES), Government of Assam, Khanapara, Guwahati.

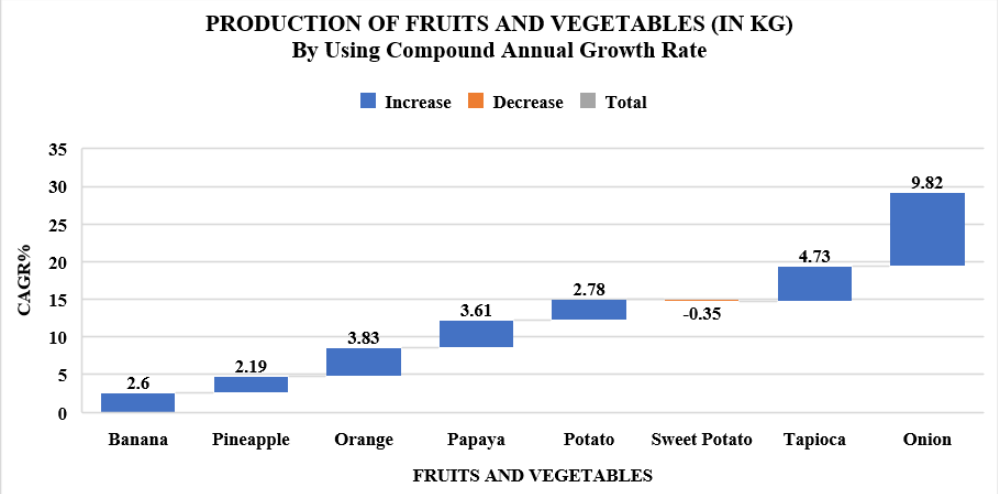

Fig. 4. Compound Annual Growth Rate (CAGR) of fruits and vegetables production

The analysis of area under cultivation shows that orange recorded the highest positive growth (CAGR=2.67%), indicating increasing farmer interest and possible market demand (Table 2). Papaya (1.03%), potato (1.70%), banana (0.84%), pineapple (0.83%), and onion (0.74%) also showed positive growth, though at a slower pace. In contrast, sweet potato (-3.09%) and tapioca (-0.26%) experienced negative growth, suggesting a shift away from these crops (Figure 5).

Variability in cultivated area was relatively lower compared to production. Orange exhibited the highest fluctuation (CV=26.10%), indicating inconsistent expansion. Sweet potato (17.32%) and potato (13.95%) also showed moderate variability, followed by pineapple (12.39%) and tapioca (11.22%). Papaya (9.76%) and onion (8.07%) exhibited relatively low variability. In contrast, banana recorded the lowest variability (CV=6.97%), reflecting stable and consistent land allocation. This suggests that area decisions are relatively more stable than production, which is more sensitive to external factors (Table 2).

Table 2. CAGR and CV of the eight major fruits and vegetables area

Area of fruits and vegetables (in hectares)	2004-2005	2022-2023	CAGR (%)	Coefficient of Variation (%)
Banana	42000	48868	0.84	6.967043
Pineapple	13000	15108	0.83	12.38727
Orange	7000	11252	2.67	26.09978
Papaya	7000	8431	1.03	9.758206
Potato	73000	99029	1.7	13.94898
Sweet Potato	8000	4540	-3.09	17.31633895
Tapioca	3000	2858	-0.26	11.22949
Onion	7000	7999	0.74	8.070714

Source: Data compiled from the Statistical Handbook of Assam (2004-2023), published by the Directorate of Economics and Statistics (DES), Government of Assam, Khanapara, Guwahati.

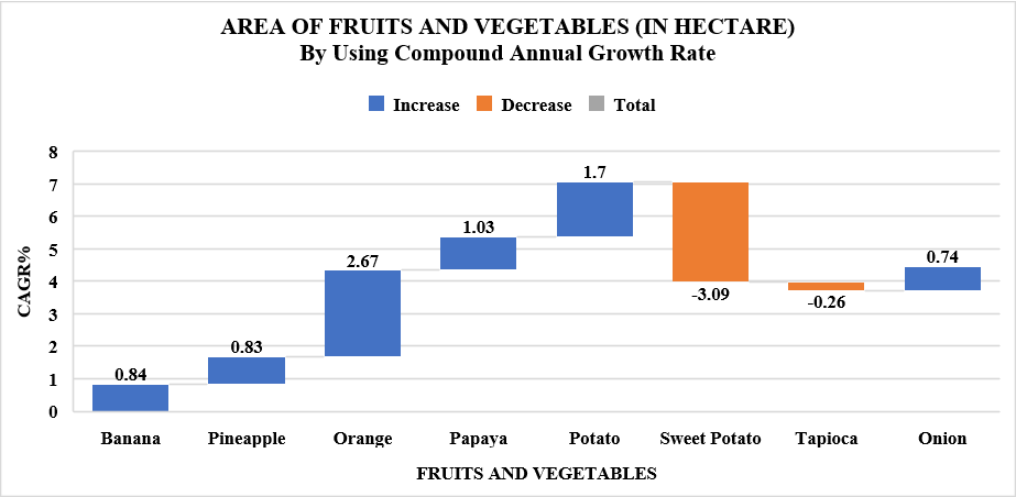

Fig. 5. Compound Annual Growth Rate (CAGR) of fruits and vegetables area

Policy Recommendations for Sustainable Horticultural Development in Assam

Sustainable horticultural development in Assam requires a comprehensive policy framework that addresses structural, technological, and institutional challenges while promoting environmentally sound practices. One of the foremost strategies is the promotion of crop diversification and integrated farming systems. The agricultural sector in Assam has experienced relatively slow growth, making diversification essential for enhancing productivity and resilience. As suggested by Charingia and Borthakur (2022), the adoption of integrated practices such as organic farming, green manuring, and crop rotation can significantly improve soil health and sustainability. Furthermore, integrating horticulture with allied activities like livestock, dairy, and fisheries has proven effective in increasing farm income and productivity (Meena et al., 2022), especially for small and marginal farmers who constitute nearly 87% of the total agricultural holdings in the state.

Efficient water management is another critical area requiring policy intervention. Water scarcity and inefficient irrigation practices continue to hinder horticultural productivity. Verma and Das (2025) identify major barriers to the adoption of micro-irrigation systems, including limited awareness and financial constraints. Therefore, policies must focus on expanding micro-credit facilities, providing targeted training, and designing irrigation systems suited to local agro-climatic conditions. Additionally, as emphasized by Bhatia and Singh (2023), incentivizing farmers to adopt water-efficient technologies is crucial for ensuring long-term sustainability of natural resources. Strengthening institutional mechanisms such as Farmer Producer Organizations (FPOs) and improving market linkages is equally important. Bhuyan et al. (2022) observe that many FPOs in Assam are still in a nascent stage and require technical guidance and financial support. Similarly, Gautam and Mallaiah (2024)

highlight the role of FPOs in providing institutional backing to small farmers, ensuring better price realization and improved livelihoods. Thus, government initiatives should focus on capacity building, infrastructure development, and establishing robust market networks to make FPOs commercially viable.

Another key recommendation is the development of a specialized horticulture mission tailored to the needs of North Eastern states. Although existing initiatives like the Horticulture Mission for North East and Himalayan states have contributed to growth, their outcomes have been inconsistent (Melo & Das, 2022). Strengthening these programs through better monitoring, enhanced technology transfer, and targeted incentives for high-value crops can significantly boost horticultural development in Assam. Promoting organic farming and sustainable input management is also vital for long-term ecological balance. Krithika et al. (2023) note that organic farming reduces dependence on synthetic inputs while improving soil fertility and reducing greenhouse gas emissions. Supporting evidence from Deka et al. (2021) indicates that environmentally friendly cultivation practices among small tea growers in Assam have not only improved environmental awareness but also created entrepreneurial opportunities, particularly among marginalized communities.

Further, strengthening agricultural extension services and capacity building is crucial for effective dissemination of modern technologies. Das and Borua (2017) identify several constraints, including inadequate training and lack of infrastructure among extension workers. Addressing these gaps through regular training programs, timely remuneration, and improved planning frameworks will enhance the outreach and effectiveness of extension services. Access to rural credit and financial inclusion remains a significant challenge that must be addressed. Medhi (2025) highlights that rural indebtedness and limited access to institutional finance continue to impede agricultural development in Assam. Policies should therefore aim to expand access to formal credit systems, including banks and microfinance institutions, with a particular focus on horticulture and value-added enterprises. Finally, promoting value addition and agribusiness development is essential for enhancing farmer income and employment generation. Establishing processing units, cold storage facilities, and agro-based industries can reduce post-harvest losses and improve market efficiency. Roy and Devi (2025) demonstrated that government initiatives such as Startup India can play a pivotal role in fostering agribusiness entrepreneurship, thereby contributing to rural development and economic growth. Collectively, these policy measures can pave the way for a resilient, sustainable, and economically viable horticultural sector in Assam.

Conclusion

The study reveals that horticultural development in Assam during the period 2004-2005 to 2022-2023 has been characterized by uneven and crop-specific growth patterns. Crops such as banana and potato continue to dominate both in cultivated

area and production, indicating their sustained importance in the state's agricultural economy. Among all crops, onion recorded the highest production growth rate (CAGR = 9.82%), despite only modest expansion in area, suggesting significant improvements in yield and input use efficiency. In contrast, sweet potato showed a negative growth trend in both area and production, reflecting declining farmer preference, low market demand, and reduced economic viability.

The analysis of variability further highlights substantial instability in certain crops. Onion production exhibited extremely high variability (CV = 69.90%), making it highly vulnerable to climatic fluctuations, price volatility, and market uncertainties. On the other hand, sweet potato showed comparatively low variability (CV = 10.82%), indicating a relatively stable but continuously shrinking production base. In terms of area, variability remained moderate across most crops, with banana showing the lowest fluctuation, indicating stable land allocation, while orange recorded the highest variability, reflecting shifting cultivation patterns and possible sensitivity to environmental and market conditions.

Overall, the findings suggest that although the horticulture sector in Assam is expanding, it is marked by structural imbalances, productivity disparities, and crop-specific risks. Therefore, there is a strong need for targeted policy interventions focusing on yield enhancement, technological adoption, diversification, risk management, and market stabilization to ensure sustainable and inclusive horticultural development in the state.

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