



Trend, Growth and Sustainability of Tea Production in Assam: An Analysis

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ABSTRACT

Background: The present study examines the growth, instability, and sustainability of tea production in Assam during the period 2010–2024. Tea remains one of the most important plantation crops in Assam and plays a significant role in the regional economy and rural livelihoods. However, concerns regarding productivity stagnation, resource dependence, and long-term sustainability have increasingly emerged in recent years.

Methods: The study employs a time-series analytical framework to assess trends in area, production and yield of tea in Assam. Growth rates, instability indices, and coefficient of variation measures were used to analyse production dynamics. The Augmented Dickey-Fuller (ADF) test was applied to examine stationarity, while Durbin-Watson statistics were used to detect autocorrelation in the data series. The findings were further interpreted using the sustainability perspectives of Herman E. Daly and Robert M. Solow.

Result: The results reveal a modest positive growth in tea production (0.93% per annum). The results indicate that production increases are largely extensive rather than productivity-driven, with area expansion under tea cultivation (1.05%) and a negative and statistically insignificant yield (-0.13%). Instability analysis shows that yield is the most volatile component, reflected by the highest CDV of 11.60%. In contrast, the area under tea remains relatively stable, highlighting the dominance of area expansion in driving output growth. Time-series diagnostics further reveal non-stationarity in area and yield, as confirmed by the augmented dickey-fuller test. Additionally, durbin-watson statistics point to positive autocorrelation, implying persistence of shocks within the system. Interpreted through the sustainability frameworks of Herman E. Daly and Robert M. Solow, the findings suggest that the tea sector of Assam currently follows an unsustainable growth trajectory, as it relies on resource expansion rather than efficiency gains, which is necessary for long-term sustainability

Key words: Sustainability, Tea.

INTRODUCTION

Tea has been an integral part of human culture for over 4,000 years, which was originated in ancient China and used as a medicinal beverage. Commercial tea cultivation in India began in the early 19th century and Assam, a state of North East India holds a special position in this history. In Assam the discovery of Assam tea plant was attributed to robert bruce, a scottish adventurer. Bruce was in close touch with maniram dutta baruah popularly known as maniram dewan who also introduced him to a singpho chief beesa gam and supposed to be seen growing tea plants in Rangpur area (Presently sivasagar) during his visit in the year 1823 on a trading mission (Tea World, KKHSOU, 2018). However, it did not materialize due to his sudden death and in the year 1824, his brother charles alexander bruce met singpho chief beesa gam, who offered some tea saplings and seeds to him. These tea plants were available in the jungle of upper Assam and indigenous people used to drink the brew even before its discovery.

Assam tea industry took off and grew. In recent years, Assam contributes more than half of total tea production in India .The tea industry is a vital component of the agrarian economy of the Assam and it significantly contributes to employment, export earnings and promotes entrepreneurship among small tea growers. However, recent trends indicate growing concerns about the sustainability of tea production

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due to various factors including climate variability, rising costs of cultivation, labour shortages and market uncertainties.

Over time, the sector has experienced fluctuations in production, area and yield, reflecting both structural and environmental dynamics. While production trends are often used as an indicator of sectoral performance, they do not necessarily capture the sustainability of growth. A comprehensive assessment requires examining whether output expansion is driven by productivity improvements or resource expansion.

The concept of sustainability in agriculture expands beyond mere growth and encompasses economic viability, environmental stability and resource efficiency. According

to Daly (1996), articulated in beyond growth: The economics of sustainable development argues that in mature economic systems, the emphasis should shift from quantitative expansion to qualitative improvement. In the context of plantation crops such as tea, this supports a “better, not bigger” approach, where gains in productivity arise from technological innovation and ecological management rather than the expansion of cultivated land into natural ecosystems.

Empirical evidence suggests that agricultural growth in developing regions often follows an extensive pattern, where production increases are driven primarily by expansion of land rather than improvements in productivity (Hazell, 2009). Such growth patterns raise concerns about long-term sustainability of crop. In this context, analysing the trends in area, production and yield, along with their growth rates and instability, becomes essential for understanding the sustainability of the tea sector. The present study aims to evaluate the growth and sustainability of tea production in Assam by integrating trend analysis, instability measures and time-series analysis.

MATERIALS AND METHODS

This study is based on a quantitative time-series analysis using secondary data on tea production, area and yield in Assam for the period 2010-2024, collected from tea board of India Official Website, the Statistical Handbook of Assam and NER, Databank.

The compound annual growth rate (CAGR) of tea area, production and yield was estimated using a log-linear regression model of the following form:

$$\ln(Y_t) = \alpha + \beta t + \epsilon t$$

- Where,
- $\ln(Y_t)$: Natural logarithm of variables (Production, area, yield) in year t .
- t : Time index (1 = 2010, 2 = 2011, ..., 14 = 2024).
- α : The intercept.
- β : The growth rate parameter.
- ϵt : The error term..

The natural logarithm of variables was taken as the dependent variable, while time was treated as the independent variable. From the estimated regression, the coefficient of the time variable (b) was obtained. The compound annual growth rate was then derived by transforming the coefficient using the antilog as:

$$\text{CAGR} = (e^b - 1) \times 100$$

Instability is examined using cuddy-della valle (CDV) index test. The CDV Index was calculated as:

$$\text{CDV} = \text{CV} \times (\sqrt{1 - \text{AdR}^2})$$

Where,

C.V- Coefficient of variation in per cent.

AdR^2 : Coefficient of determination from a time trend regression adjusted for its degree of freedom.

To ensure statistical validity, augmented dickey-fuller (ADF) test is used to check stationary and durbin-watson statistic is used to detect autocorrelation.

The DW statistic is interpreted as:

- $\text{DW} \approx 2 \rightarrow$ no autocorrelation.
- $\text{DW} < 1.5 \rightarrow$ positive autocorrelation.
- $\text{DW} > 2.5 \rightarrow$ negative autocorrelation.

Integration of sustainability framework

The sustainability of tea production is analysed using ideas from Daly (1996) and Solow (1956). Daly focuses on maintaining a stable and balanced system, while Solow helps explain how production grows over time.

Tea production is expressed as:

$$\text{Production} = \text{Area} \times \text{Yield}$$

Based on this, sustainability is assessed by examining whether growth is driven by expansion of area or improvement in yield. Productivity-led growth is considered more sustainable, while dependence on land expansion reflects resource pressure.

In addition, the stability and consistency of production over time are considered important indicators of sustainability. Lower fluctuations indicate a more stable system, whereas higher variability and persistence of shocks suggest structural weaknesses and reduced resilience.

RESULTS AND DISCUSSION

The results (Table 1), indicate that production and area show statistically significant positive trends, whereas, yield shows a declining trend. The higher growth rate of area (1.05%) than that of production (0.93%), reveals that the output increases might be largely area driven rather than productivity driven. This is in accordance with the findings of Hazell (2009), who noted that in traditional agricultural systems, output growth often relies more on land expansion than technological progress. Jain and Sharma (2026), reported that tea productivity in Assam, is closely associated with labour and management dynamics, indicating structural dependence of tea production on traditional production practices.

Table 1: Trend and regression results for tea sector in Assam (2010-2024).

Variable	Intercept	Coefficient (β)	t-value	p-value	R ²	F-value	CAGR (%)
Production	6.397	0.00923	2.952	0.012*	0.421	8.71*	0.93
Area	5.713	0.01048	5.201	0.000*	0.693	27.05*	1.05
Yield	7.593	-0.00126	-0.295	0.773 NS	0.007	0.087 NS	-0.13

Note: *Significant at 5% level; NS = Not significant.

Similarly, Chand (2010) observed stagnation in yield growth in several plantation crops in India. The results also exhibit that growth rate of area (1.05) is greater than that of yield (-0.13). According to Solow (1956), this pattern reflects extensive growth, where output expansion is driven by increased use of inputs rather than improvements in efficiency.

The results (Table 2) exhibit that yield has the highest instability (11.60%), compared to that of production (7.14%) and area (2.95%). High instability in yield indicates that productivity is highly fluctuating over time. This might be due to climatic variability, pest incidence and inefficient management practices, which are common challenges in plantation crops. Similar result was also revealed by Sharma *et al.* (2022). In addition, Das and Ahmed (2026) reported that tea leaf diseases significantly affect productivity and sustainability of tea cultivation, highlighting the importance of efficient disease management practices in maintaining stable tea yields. From the perspective of Daly (1996), stable production systems are essential for sustainability. High variability in yield reflects ecological imbalance and inefficient use of resources, which reduces the ability of the sector to withstand environmental shocks. Thus, the observed high instability in yield suggests that, the tea production system is ecologically vulnerable and structurally weak, even though the area under cultivation remains relatively stable.

The results of ADF test presented in the Table 3 exhibit that production is stationary with more negative value (-4.699). This means production is stable and fluctuates around a constant average. On the other hand, area (-0.9058) and yield (-1.316) are non-stationary. This means they have trends over time and do not return to a stable average. Dickey and Fuller (1981) explained that changes in technology, climate and farming practices can cause these trends. Therefore, the non-stationary behaviour of area and yield shows that the tea sector is changing over time. But it also means there is no long-term stability, which raises concerns about sustainability. The present study also supports the findings of Saha *et al.* (2021), who reported that the tea sector in Bangladesh is changing

over time, with increases in area, production and yield. This pattern suggests that area and yield are non-stationary, which raises concerns about long-term stability and sustainability.

The DW statistics (Table 4) exhibit positive autocorrelation in production and strong positive autocorrelation in area and yield. This suggests that past shocks persist over time, which is typical in agricultural systems where production decisions and climatic effects are interdependent.

Empirical evidence from other agricultural systems further supports this observation. For instance, soybean production in the Matopiba region of Brazil shows significant positive autocorrelation, particularly in western Bahia and central Matopiba, indicating that expansion is non-random and shaped by localized agro-climatic conditions and management practices (Araújo *et al.*, 2020).

Similarly, in perennial crop systems such as tea, the effects of climatic conditions, soil quality and past management practices persist across periods, which highlight the presence of serial dependence in production variables. Tea yield in Northeast India is influenced by climatic factors such as rainfall, soil characteristics like organic carbon content and past management practices such as plant age and fertilizer application. These factors reflect both serial dependence and structural interdependence in production dynamics (Dutta *et al.*, 2010). Therefore, the observed autocorrelation in the present study aligns with both theoretical expectations and empirical findings, stressing upon the fact, that agricultural production systems are inherently influenced by temporal continuity and structural interdependence.

The analysis shows that tea production in Assam is increasing mainly due to expansion of cultivated area rather than improvement in yield. This indicates a growth pattern mainly due to the expansion of land, which is less sustainable in the long run. According to Solow (1956), sustainable growth should come from better productivity, not just increased use of resources. At the same time, yield shows high fluctuations compared to area, showing instability in production. From the perspective of Daly (1996), a sustainable system should be stable and balanced. High variability in yield reflects ecological stress and weak production efficiency. Further, the presence of long-term fluctuations and persistence of shocks indicates that the sector does not adjust quickly to changes. This reduces resilience and makes the tea sector more vulnerable to climatic and market disturbances.

Table 2: Instability measures (CV and CDV).

Variable	CV (%)	CDV (%)
Production	8.99	7.14
Area	5.13	2.95
Yield	8.74	11.60

Table 3: Augmented dickey fuller (ADF) test results.

Variable	ADF statistic	Critical value (5%)	p-value	Decision
Production	-4.699	-3.104	0.0001	Stationary*
Area	-0.426	-3.104	0.9058	Non-stationary (NS)
Yield	-1.316	-3.233	0.6220	Non-stationary (NS)

Note: *Significant at 5% level.

Table 4: Durbin watson (DW) statistics.

Variable	DW value	Interpretation
Production	1.16	Positive autocorrelation
Area	0.86	Strong positive autocorrelation
Yield	0.83	Strong positive autocorrelation

Overall, the findings suggest that tea production in Assam depends more on expansion of land and shows instability in productivity. A shift towards productivity improvement and stability in yield is essential for long-term sustainability.

Sustainable tea cultivation also depends on efficient resource utilization and diversification within tea-based farming systems. Buragohain (2015) observed that intercropping practices in small tea plantations of Assam improve resource use efficiency and provide additional income opportunities to tea growers. Such diversified production systems may help improve ecological balance and economic sustainability in the tea sector.

CONCLUSION

The study concludes that tea production in Assam is following an extensive growth pattern driven by land expansion rather than productivity improvement. High yield instability and persistent structural issues raise concerns about long-term sustainability. A shift toward productivity enhancement, technological adoption and sustainable resource management is essential to ensure resilient and sustainable growth in the tea sector.

Disclaimers

The views and conclusions expressed in this article are solely those of the author and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

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