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MODELING AND FORECASTING OF TEA PRODUCTION IN INDIA

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ABSTRACT

There are many measures of the importance of a crop to the economy, including its area, output, and yield increase. The current study will look at the growth rates of tea acreage, output, and yield in India using training data from 1918 to 2015 and testing data from 2016 to 2018. Using the data acquired, the ARIMA model and State Space Models were used to anticipate the area, production, and yield of tea from 2021 to 2027. According to the data, tea production in India is expected to reach 607 thousand hectares by2027, reflecting a 3.93 percent increase between 2021 and 2027. India's tea production is expected to reach 1486 thousand tonnes in2027, reflecting a 10.56 percent increase between 2021 and 2027. However, the tea production in India is expected to reach 2449 kg/hectare between 2021 and2027, reflecting a 4.12% increase over the preceding five-year period. The most essential tools for increasing tea production were area expansion and yield increase. As a result, the emphasis should be on expanding the area by exploiting available land and boosting productivity through technological advancements, varietal research, and the enhancement of agricultural advisory services across India.

Keywords: Growth rate, Trend, Area, Production Tea, India, ARIMA, Forecast, State Space Models.

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INTRODUCTION

A close second to water in terms of global consumption is tea, with roughly two-thirds of the global population partaking (Khan and Mukhtar, 2013). Tea has a wide variety of products, from teabags to tea leaves, flavorings to non-flavorings, black tea to green tea, etc., allowing consumers to adjust to their own preferences and tastes (Karwowska, 2019). If the production process and post-harvest treatment are followed correctly, tea might be black, green, or oblong in color (Priya *et al*., 2015). In terms of production and consumption, black tea is the most popular in the world, followed by green tea, which is most popular in China and Japan, respectively (Wierzejska, 2014). Besides its wonderful flavor and perfume, tea offers a long list of health benefits, including the capacity to slow the growth of tumors, prevent heart disease and obesity, and lessen the risk of developing atherosclerosis (Wang *et al*., 2010). In addition to its numerous health benefits, tea is an important commercial crop in China, helping to drive the country's economy forward. In addition, it employs people from lower socioeconomic groups, such as women (Jain, 2011).

China, India, Sri Lanka, Keyna, and Indonesia are the world's top tea producers, together accounting for 70% of global production (Majumdar and Srirangam,, 2010; Zakir, 2017). Tea is a 200-year-old agro-based sector in India under the control of the country's Union government. In 1953, the Tea Act was passed, establishing the Tea Board to keep tabs on and promote the country's tea production, processing, exports, and imports. India is the world's second-largest tea producer, with the second-largest tea plantation area, and the fourth-largest tea exporter. India is the world's largest producer and exporter of tea, occupying around 12% of the global cultivable land and producing 20% of the world's total output. Although India is ranked 10th in the world in terms of tea production, its value yield is over double the world average (Basu et. al., 2010). While the plantation is indigenous to eastern and northern India, it is now grown in both the north and south of the country (Arya, 2013). North India contributes 86% of the country's overall output; the balance comes from the southern states of Tamil Nadu and Kerala. About half of India's tea is produced in Assam, which is the nation's leading tea producer. Because huge plantations aren't interested in expanding their land, small-scale tea planting is more feasible and practical, which is why it hasn't had as much success in non-traditional places (Kumar et. al., 2008).

Tea production forecasting is critical since the beverage crop is a key component of India's export basket, helping the country gain foreign cash. As a result, the current study is being undertaken to forecast tea production in the country. The ARIMA (Autoregressive Integrated Moving Average) model was chosen for prediction since it has been utilized and accepted by many other researchers. Mishra *et al*. (2012) used the ARIMA model to anticipate tea production, yield, and exports in India for the year 2020. Dhekale *et al*. (2014) used the ARIMA model to model and forecast tea output in West Bengal. They also created a new methodology for calculating weather and other indices that used direct influences from path coefficients and proved to be superior to the old methods. Rahman (2017) tested eleven ARIMA models and discovered that ARIMA (1,1,2) was the best fit for forecasting tea production in Bangladesh. Hossain and Abdulla (2015) also conducted tea forecasting in Bangladesh and discovered the ARIMA (1,2,1) model to be the best fit by utilizing the Run test and Jarque and Bera test analysis, which was accompanied by residual analysis.Mishra *et al*. (2021a) forecasted milk production in South Asian countries and China and found that all methods are not equally effective in forecasting. Mishra *et al*. (2021b) also carried out a study to find out the most suitable model for forecasting of sugarcane production in India.

MATERIALS AND METHODS

Dataset is yearly data from 1918 to 2020 about Area, Production and Yield Rate of Tea in India, we used training data from 1918 to 2015 and testing last 5 years from 2016 to 2020.Present study data is collected from www.indiastat.com.The flow diagram of present work given in figure A

Estimation Models: To forecast tea production up to year 2027 and used ARIMA model**:**

ARIMA Model: ARIMA models are the most commonly used statistical models for time series forecasting because they describe the autocorrelation in the data (Box *et al*., 2015). According to their nomenclature, these models are grouped into three categories (Autoregressive – Integrated – Moving Average) (p, d, q).

The term autoregressive (p) refers to the prediction of a variable using a linear set of its preceding values; the model of order p can be stated as (Mishra *et al*., 2021a):

$$y_t = c + \beta_P y_{t-p} + \varepsilon_t \quad (4)$$

Whereβ_P: parameters of model, P: lag order of the autoregressive process, ε_t: error term. Integrated (d) refers to the degree of stationary of a variable that is determined using ADF test (Devi et.al.,2021;Sarder et.al.,2021 and Mishra et.al.,2021c).

Moving average (q): uses past forecast errors in regression. The equation will be in the form:

$$y_t = c + \varepsilon_t + \beta_q \varepsilon_{t-q} \quad (5)$$

Whereβ_q: parameters of model, q: lag order of the moving average, ε_t: error term.

Whereas (d) is decided by the ADF test, (p) and (q) are determined by the autocorrelation function (p) and the partial autocorrelation function R(p), which are supplied by Mishra *et al*., 2021b):

$$\boldsymbol{\rho}(p) = \frac{C \quad (y_t, \boldsymbol{y}_{t+p})}{\sigma^2} \quad (\mathbf{6})$$

$$(\boldsymbol{\rho}(p-1) \quad \boldsymbol{\rho}(p-2) \ldots. \quad \boldsymbol{\rho}(0)) \ (\beta_q) = R(p) \quad (7)$$

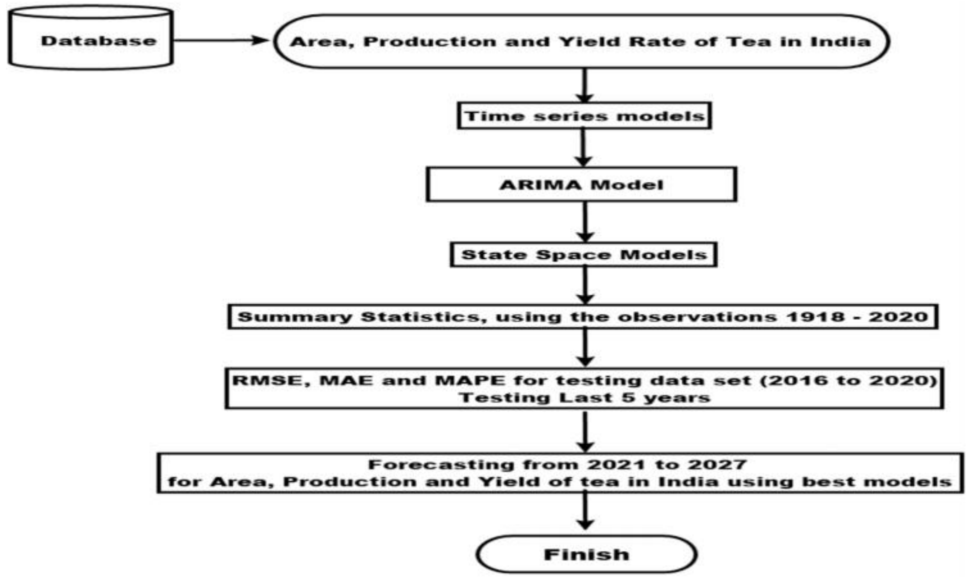


Figure A: Schema of Tea production in India

RESULTS AND DISCUSSION

The dataset contains annual data from 1918 to 2020 about the area, production, and yield rate of tea in India. We used training data from 1918 to 2015 and testing data from 2016 to 2020 for the last five years of the dataset.

From 1918 to 2020, India's tea acreage expanded from (237.57) thousand to (579.35) thousand hectares, according to our research. There were (390.21) thousand hectares of tea plantations in India on average. Small outliers were evident in the data, as seen by an exaggerated value of Kurtosis (-0.52). Skewness (0.90) indicates that there is a prospect of growth in India's tea region. There has been a significant increase in the amount of tea produced in India throughout this time period. The country's annual tea production was (528.19) metric tons on average. Example Kurtosis was (-0.42), which indicates a mesokurtic distribution of the data. The presence of a positive skewness (0.80) value suggests that India's tea production could expand in the future. From (434) kilograms per hectare to (2341) kilograms per hectare, the tea yield in India has risen throughout this time span. India's average yield of (1240.5) Kg. / Hectare of tea. Example: The (-1.11) kurtosis number indicates that there are some minor anomalies in the data. The distribution is nearly symmetric after a positive skewness (0.23) of between -0.5 and 0.5.

Table 2 lists the top selected ARIMA models, which were chosen based on the following criteria: Akaike, Root mean squared error, Mean absolute error, Mean absolute percentage error, Maximum number of significant coefficients.

Table 1: Summary Statistics, using the observations 1918 – 2020.

Maximum	Minimum	Median	Mean	Variable
579.35	237.57	353.36	390.21	Area
1377	124.41	402.49	528.19	Production
2341	434	1146	1240.5	Yield
Ex. kurtosis	Skewness	C.V.	Std. Dev.	Variable
-0.52	0.90	0.24	95.78	Area
-0.42193	0.80636	0.65184	344.30	Production
-1.1196	0.23555	0.43024	533.72	Yield

Table 2: ARIMA Model fitted for Area, Production and Yield of tea in India for training data set (1918 to 2015).

	MODEL	Akaike Information Criterion (AIC)	Bayesian Information Criterion (BIC)	MAE	RMSE	MAPE
Area	ARIMA (0,1,1)	833.5	841.41	6.72	13.97	1.87
Production	ARIMA (4,1,4)	960	986.32	17.15	23.13	4.25

Yield	ARIMA (0,1,1)	1153.9	1161.79	47.83	67.2	4.84

Table 3: State Space Models for Area, Production and Yield of tea in India for training data set (1918 to 2015).

Structural time series models for Area, Production and Yield of tea in India										
	Component	Value	Std. Err	t-stat	Prob	Akaike Information Criterion (AIC)	Bayesian Information Criterion (BIC)	within-sample RMS	MAE	MAPE
Area	Level	569.5218	8.832	64.4873	0				2.9889	0.861
	Slope	4.5018	1.996	2.2549	0.0264					
	AR1	0.0807	5.393	0.015	0.9881	8.1891	8.3738	6.7227		
Production	Level	1219.87	36.097	33.7942	0				2.1367	0.5759
	Slope	23.97	3.886	6.1676	1.83E-08					
	AR3	-11.28	35.566	0.3172-	0.7518	9.1392	9.3766	2.8436		
Yield	Level	2086.02	94.674	22.0337	0				14.7584	1.5794
	Slope	15.8	3.983	3.9668	1.41E-04					
	AR1	45.47	92.267	0.4928	0.6233	11.2348	11.393	20.9348		

Table 3 provides us with an estimate of the parameters for the State Space Models (SSMs). As a result of these factors, the training data set ("1918 to 2015") has the best model based on the lowest possible AIC /BIC/ RMSE /MAE/ MAPE values. When it comes to predicting tea production, the state space model beats ARIMA. In terms of prediction accuracy, the state space model has far higher accuracy than the ARIMA model, because all the accuracy metrics (AIC, BIC, RMSE, MAE and MAPE) are lower than the ARIMA model's. It is not necessary to require stationarity in these models for the state space model to reflect the complicated non-linear character of data series with a variety of distinct specifications, structural breaks, shifts, time-varying factors, and missing data. Dynamic timeseries can also be modeled using the state space paradigm. The ARIMA model must be stationary, while models that incorporate unobserved components may need to be employed to eliminate trend and seasonal effects from the ARIMA model. RMSE, MAE, and MAPE values in Table 4 show us the best State Space Models based on the testing data set ("2016 to 2020").

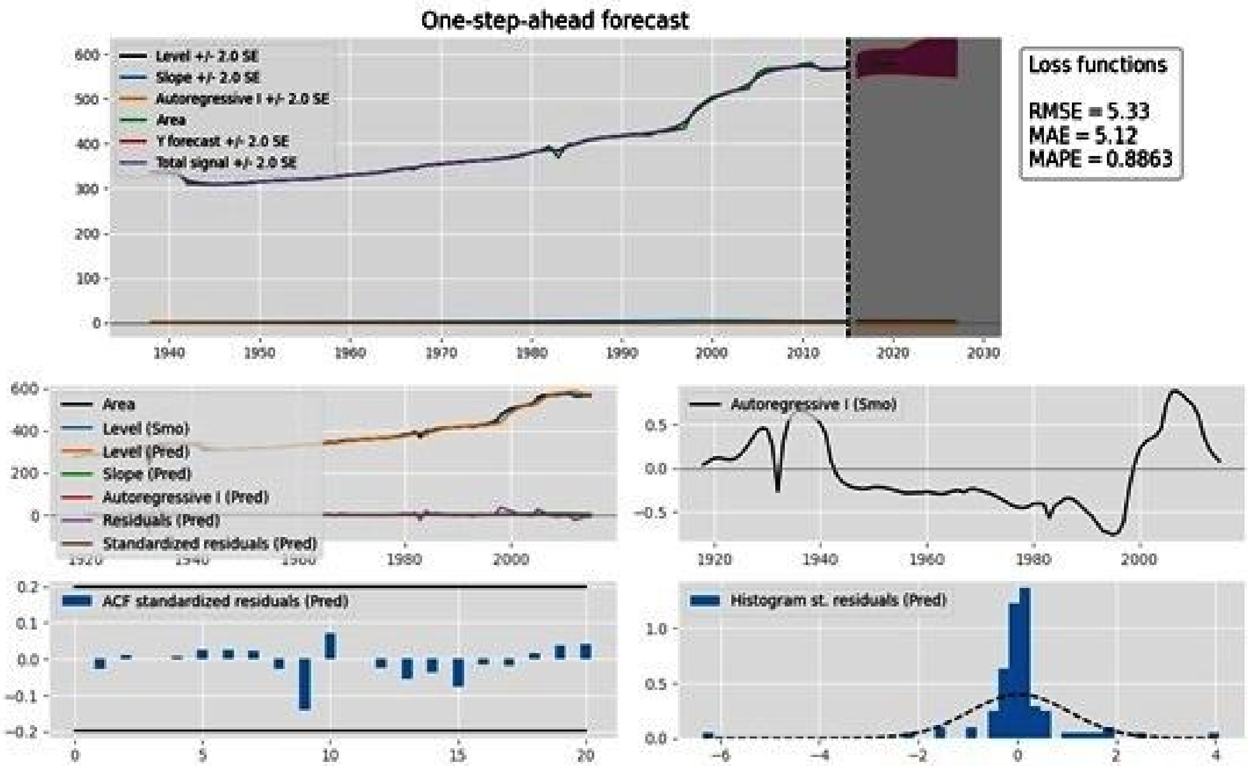
Table 4: RMSE, MAE and MAPE for testing data set (2016 to 2020).

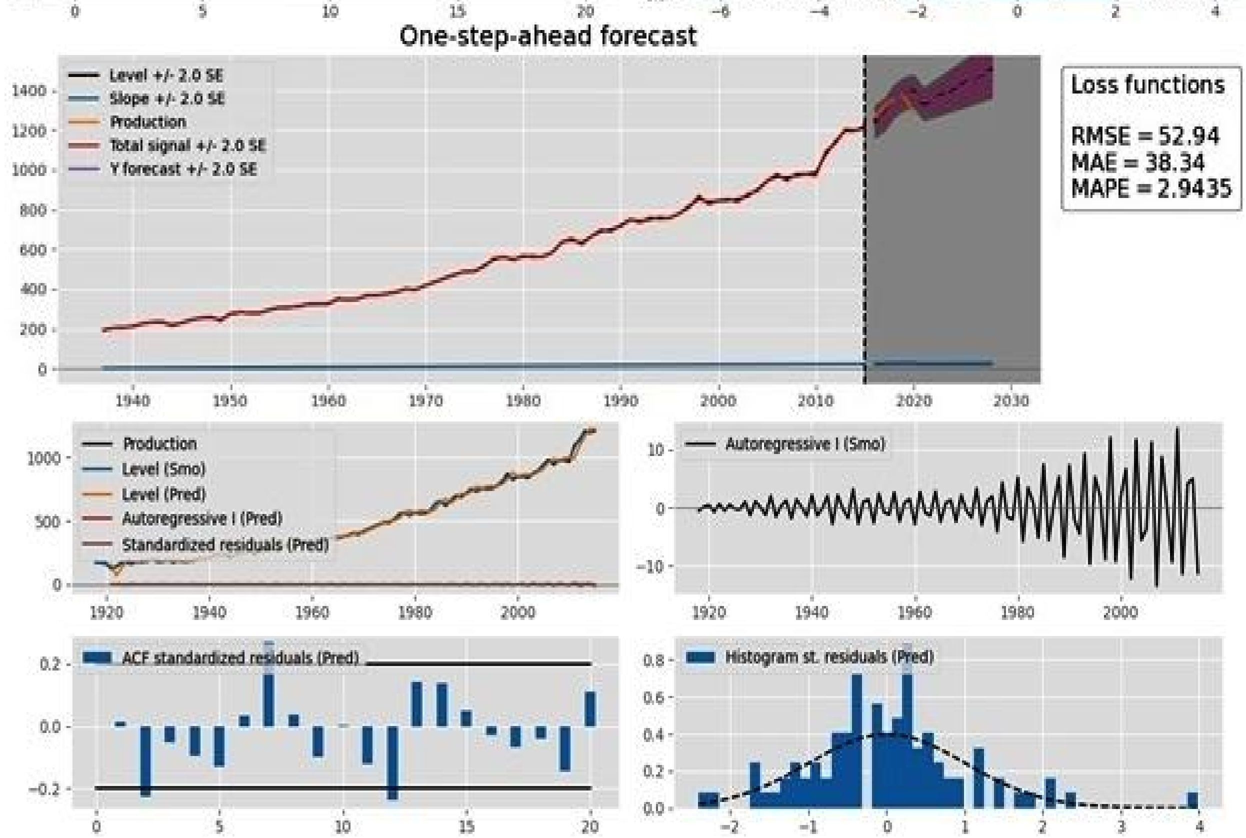
	RMSE	**MAE**	**MAPE**
Area	5.33	5.12	0.8863
Production	52.94	38.34	2.9435
Yield	50.14	38.42	1.6925

Table 5: Forecasting from 2021 to 2027 for Area, Production and Yield of tea in India using best models.

Year	Area	Production	Yield
2021	584	1344	2352
2022	587	1358	2365
2023	592	1375	2379
2024	595	1424	2392
2025	599	1422	2406
2026	603	1462	2420
2027	607	1486	2449

As shown in Table 5, the tea area in India is predicted to grow by 2027 to reach 607 thousand Hectares (about). During the decade 2021-2027, the economy will increase at a rate of 3.93 percent. The output of tea in India is predicted to reach 1486 thousand tonnes in 2027, representing a growth rate of 10.56 percent between 2021 and 2027. During the period 2021-2027, the tea yield in India is predicted to reach 2449 Kg. Hectare, representing a growth rate of 4.12 percent over the previous five-year period.


One-step-ahead forecast
Level +/- 2.0 SE
Slope +/- 2.0 SE
Autoregressive I +/- 2.0 SE
Area
Y forecast +/- 2.0 SE
Total signal +/- 2.0 SE
Loss functions
RMSE = 5.33
MAE = 5.12
MAPE = 0.8863
Area
Level (Smo)
Level (Pred)
Slope (Pred)
Autoregressive I (Pred)
Residuals (Pred)
Standardized residuals (Pred)
Autoregressive I (Smo)
ACF standardized residuals (Pred)
Histogram st. residuals (Pred)


One-step-ahead forecast
Level +/- 2.0 SE
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Level (Pred)
Autoregressive I (Pred)
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ACF standardized residuals (Pred)
Histogram st. residuals (Pred)

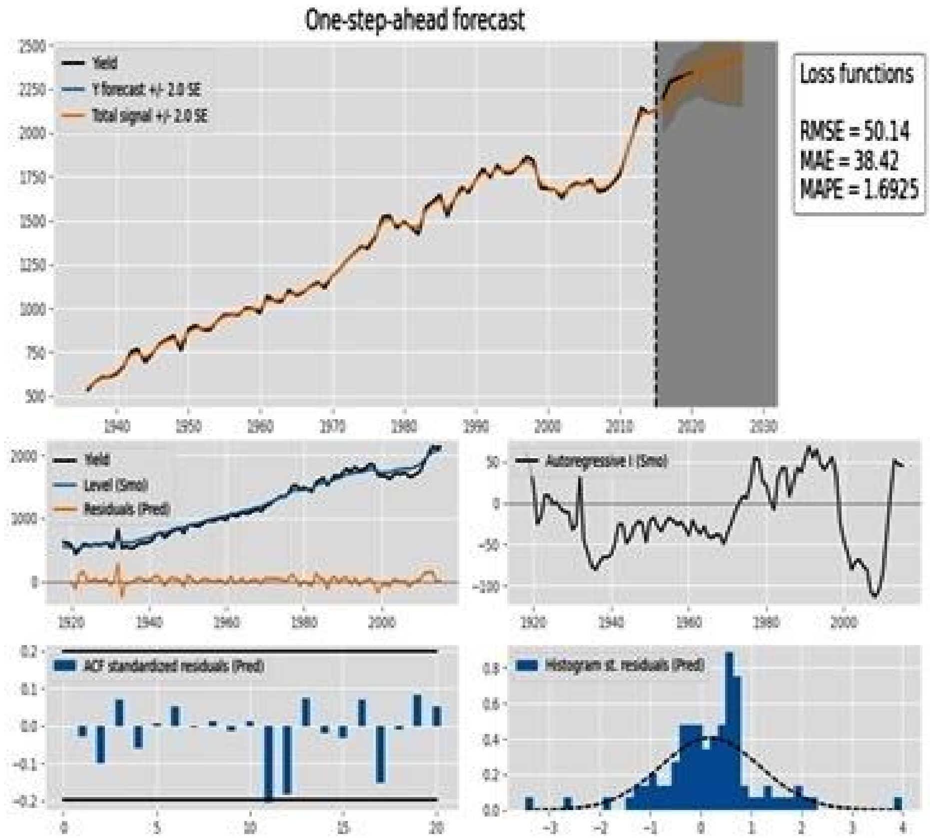

Figure 1: Actual and forecast values for Area, Production and Yield of tea in India with (Level -Total Signal-Slope -Autoregressive- Trend-Residuals) during the period 1937-2027 using State Space Models.

Forecasting: Following the development of the top models, forecasting for the area, production, and yield of tea in India is carried out. With respect to all time series, the residuals of the chosen models were determined to be stationary and white noise. Using the best-fitted models, the anticipated values for the years "2021" to "2027" are depicted in the figures. The figures displayed the anticipated values; all forecasted lines in the figures are within a few percentage points of the actual values, demonstrating the usefulness of the models chosen. From the forecast numbers, it can be seen that the tea growing area, tea production, and tea yield are all expected to increase in the future.

Conclusion: During the last 102 years (from 1918 to 2020), tea production has increased significantly in both land area and yield. Since 1918–1981, the rate of yield rise was much larger than in the period 1982–2020, whereas the rate of area expansion had the reverse tendency. Both when technology was more conventional and when it began to improve in 1918–2020, considerable output expansion was a result of increased yields, notably in that time period. With the expansion of "small-scale gardening" as an approach to tea cultivation, the industry's output is rising, bringing prosperity to many farmers and creating work for many people — primarily women. The long-term strategy for increasing tea production in the northern areas of India needs to be improved. Thus, India can continue to expand the area where tea can be grown as long as the region permits, but ultimately, she will have to rely on a strategy to boost yield. In order to take use of these possibilities, the administration of the Bangladesh tea plantations should look for suitable extra areas and put them under tea production. Redouble efforts to improve the tea plantation's yields and quality by bringing in higher yielding and better-quality vegetative clones and seeds from BTRI.

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