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Research Paper

Repercussions of climatic variabilities on tea production in Nilgiris district of Tamil Nadu, India

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ABSTRACT

The Nilgiris district of Tamil Nadu is one of the world's high-quality tea-producing region. This study focused on the changing climatic condition on tea production in Nilgiris, Tamil Nadu, India, utilising the data from 1991 to 2020 employing the ARDL-error correction model. Findings revealed that tea production is stable for past decades, positively influenced by minimum temperature, and relative humidity while negatively influenced by precipitation. Thus, understanding the intricate relationship between climate factors and tea production is crucial for sustainable agricultural practices in the region, with implications for adaptation strategies amidst changing climatic patterns.

***Keywords*: Tea production, Climate change, ARDL model, Diagnostic test, Nilgiris.**

India ranks second when it comes to tea production on a largescale, which accounts for around 24% of the global tea production (Shah and Pate, 2016). The north-eastern region, with its alternating wet and dry seasons, high humidity, and favourable temperatures, provides an ideal environment for tea cultivation (Mukherjee *et al.,* 2008). The states of Assam and West Bengal, India's two largest tea producing regions, account for approximately 75% of the country's total production (Kumar *et al.,* 2008). One significant producer of tea is Tamil Nadu with Nilgiris district accounting for 85% of the state's tea production (Sikka *et al.,* 2009). Nilgiris district is regarded as one of the world's best tea-growing regions due to moderate summers and rainfall influenced by south-west as well as north-east monsoon. Additionally, it also has lateritic loamy soil which is best suited for tea growth. However, climate change over the past three decades has brought about direct and indirect effects on tea crops, leading to various challenges and disruptions. The tea yield does not appear to be significantly impacted by the severity of the drought, while variabilities in the precipitation and temperature, particularly in its magnitude, exhibits a negative correlation (Mallik and Ghosh, 2023; Prasad and Rana, 2006).

Understanding this intricate relationship between climate and tea production is crucial for assessing the industry's vulnerability and developing effective adaptation strategies. This study examines how climate change is affecting tea production in the Nilgiris region of Tamil Nadu, India.

MATERIALS AND METHODS

The study used 30 years (1991 to 2020) data of tea production (TP, tons) obtained from Indiastat (https://www.indiastat.com/) and climatic parameters such as minimum temperature (Tmin, ^{0}C), maximum temperature (Tmax, ^{0}C), precipitation (P, mm) and relative humidity (RH, %) obtained from NASA POWER database (https://power.larc.nasa.gov/) with Latitude: 11.4916 and Longitude: 76.7337 for Nilgiris, Tamil Nadu. The Autoregressive Distributed Lag (ARDL) procedure (Pesaran *et al.,* 2001) was used in the analysis. The ARDL model is an econometric technique that is particularly useful when the primary variables are integrated of order I (1) or stationary at I (0), making it advantageous compared to other approaches. It is a better model than other to capture short- and long-term effect of response variable on the production of tea, according to the study's objectives. The ARDL approach follows the Ordinary Least Square (OLS) method for variables which falls under cointegration category between variables and is suitable for

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Table 1: Summary statistics (1991-2020)

Descriptive statistics	Tea production (TP, tons)	Maximum temp. (Tmax, ^{0}C)	Minimum temp. (Tmin, ^{0}C)	Precipitation (P, mm)	Relative humidity (RH, %)
Mean	131.1	38.2	11.4	883.7	72.7
Standard deviation	50.2	0.9	0.8	167.7	2.1
Minimum	42.2	36.1	9.4	464.1	66.8
Maximum	174.7	40.3	13.2	1186.5	76.1

simultaneously generating short run and long run elasticities for sample size (Duasa, 2007). Then order in which the variables are integrated is flexible with ARDL. When I (0), I (1), or conjointly integrated (Frimpong and Oteng, 2006) are the independent variable in the model, ARDL works well; however, it does not work when I (2) is present in any of the variables. The following model, which incorporates flexibility regarding the order of variable integration, was developed in order to ascertain how dependent and independent variables relate to one another.

$$TP_t = \propto_0 + \propto_1 Tmax + \propto_2 Tmin + \propto_3 P + \propto_4 RH + \epsilon_t \qquad (1)$$

By converting all variables of Equation (1) into the natural log, the model is designed below

$$lnTP_t = \propto_0 + \propto_1 lnTmax + \propto_2 lnTmin + \propto_3 lnP + \propto_4 lnRH + \epsilon_t \qquad (2)$$

Where TP represents Tea production, while *t* represents time period covering from 1991 to 2020. represents constant and are the coefficients of the variables. TMax, TMin, Precip and RH are maximum temperature, minimum temperature, precipitation and relative humidity, while fallacy is represented by . Equation (2) can be written in ARDL form as follows:

$$\Delta lnTP_t = \propto_0 + \sum_{k=1}^{n} \propto_1 \Delta\, lnTP_{t-k} + \sum_{k=1}^{n} \propto_2 \Delta\, lnTmax_{t-k} + \sum_{k=1}^{n} \propto_3 \Delta\, lnTmin_{t-k} + \sum_{k=1}^{n} \propto_4 \Delta\, lnP_{t-k} + \sum_{k=1}^{n} \propto_5 \Delta\, lnRH_{t-k} + \lambda_1 lnTP_{t-1} + \lambda_2 lnTmax_{t-1} + \lambda_3 lnTmin_{t-1} + \lambda_4 lnP_{t-1} + \lambda_5 lnRH_{t-1} + \epsilon_t \qquad (3)$$

The component of drift is depicted by ∝_0, the first difference by Δ, and the white noise by ∈_t. The lag length was determined by the study using the Akaike Information Criterion (AIC). The study used the Error Correction Model (ECM) to analyse how the variables interact in the short term, after first establishing their long-term relationships. Equation (4) below formulates Equation (3) in its ECM general form:

$$\Delta lnTP_t = \propto_0 + \sum_{k=1}^{n} \propto_1 \Delta\, lnTP_{t-k} + \sum_{k=1}^{n} \propto_2 \Delta\, lnTMax_{t-k} + \sum_{k=1}^{n} \propto_3 \Delta\, lnTMin_{t-k} + \sum_{k=1}^{n} \propto_4 \Delta\, lnPrecip_{t-k} + \sum_{k=1}^{n} \propto_5 \Delta\, lnRH_{t-k} + \emptyset ECM_{t-1} + \epsilon_t \qquad (4)$$

where $\emptyset$ represents the ECM coefficients for short-run dynamics and Δ represents the first difference. ECM displays the rate of long-term equilibrium adjustment after a shock of short-term.

RESULTS AND DISCUSSION

The condensed statistics of the variables are displayed in Table 1. During 30 years (1991-2020) period, the average production of tea was 131.1 tons with standard deviation of 50.2 tons, the mean maximum temperature was 38.2 ^{0}C, minimum temperature was 11.4 ^{0}C, precipitation was 888.6 mm and relative humidity was 72.7%.

Correlation coefficient

Table 2 shows the correlation between production of tea and climate parameters. It reveals that, minimum temperature and tea production in the study area has positive high correlation with the value of 0.68 which indicates the strong association between temperature and tea production i.e., the climate has an impact on the tea output.

Unit root test

The unit root test results (with trend) are shown in Table 3. The study variables' stationarity was examined using the Augmented Dickey-Fuller (ADF) test. Values below the critical value are indicated by the unit root test statistic. While the minimum temperature for tea production is statistically significant at the 5% level, other variables, including maximum temperature, precipitation, and relative humidity, are statistically significant at the 1% level. The chosen variables are therefore stationary, indicating that the analysis should continue.

Table 2: Correlation between tea production and climate parameters

Parameters	Correlation coefficient
Maximum temp.	-0.28
Minimum temp.	0.68^{+}
Precipitation	-0.04
Relative humidity	0.13

Note: + represents positive high correlation

Table 3: Unit root test (with trend)

Variables	ADF Test	
	t - statistic	P – Value
LnTP	-2.875	0.0439**
LnTmax	-5.710	0.0000***
LnTmin	-2.835	0.0535**
LnP	-4.441	0.0003***
LnRH	-4.244	0.0006***

*Note: *** and ** represents 1% and 5% level of significance*

Table 4: Diagnostic test

Tests	Statistic value	P - Value
Breusch-Godfrey serial correlation LM test	2.03	0.6879
Heteroskedasticity test	2.05	0.4076

Table 5: ARDL-Error correction model (ECM) estimates

Independent variables	Coefficient	t statistic	P value
Adjusted			
LnTP (L1)	-0.5039	-2.93	0.010**
LR			
LnTmax	0.9112	0.21	0.837
LnTmin	5.6983	3.24	0.005***
LnP	-1.3577	-1.99	0.064*
LnRH	13.2352	2.37	0.031**
Constant	-30.1403	-1.88	0.078

R - Square - 0.61

*Note: ***, ** and * represents 1%, 5% and 10% level of significance*

Diagnostic test

The regression models are validated using the econometric diagnostic test. The heteroskedasticity test has been applied to assess the variance of errors in the model, and the Breusch-Godfrey (BG) analysis is frequently utilised to test for autocorrelation in the time series models. The Breusch-Godfrey Serial Correlation LM test value, as shown in Table 4, is 2.03, above the significance level of 0.05. It suggests that the serial correlation is absent from the model, but the heteroskedasticity test value of 2.05, which is higher than 0.05, shows homoscedasticity.

Error correction model

The outcome of ARDL error correction model is presented in Table 5. The R^2 reveals that independent variable in the model accounts for the 61% of the variance in the dependent variable. The variables such as LnTP (5%), LnTmin (1%), LnP (10%), and LnRH (5%) are statistically significant and determine the production of tea in Nilgiris of Tamil Nadu. Furthermore, it indicates that a one percent increase in LnP and precipitation leads to decreases of -0.50 and -1.35 percent in tea production, respectively. Similarly, a one percent increase in minimum temperature and relative humidity leads to an increase of 5.69 and 13.23 percent in the production of tea in the study area. The warmer temperature will have a harmful effect on the production of tea (Gunathilaka *et al.,* 2017).

Increased temperature in the summer and monsoon seasons have an impact on tea yields; conversely, higher temperature during winter and heavy rainfall during the summer and winter months have a positive effect on tea yields (Muoki *et al.,* 2020; Mallik and Ghosh, 2023). It is also known that, monsoon months will have maximum rainfall and winter months have lowest temperatures (Jayasinghe and Kumar, 2020; Sahu *et al.,* 2024). The findings were detrimental to the growth of tea yield. There was seasonal variation in the rainfall, despite the fact the results indicated that it was increasing. Both climatic factors had negative impact on tea yield because the study area did not receive the necessary rainfall or temperature during the necessary months. As a result, the tea yield decreased over time.

CONCLUSION

The outcome of the research shows observable changes after the year 2015, with increased maximum temperature, precipitation, and relative humidity. However, in the case of the tea production, a decline was observed, which can be ascribed to the fluctuation in the climatic factors. Increased temperature has led to drying of the tea leaves, whereas humidity increase has some benefit upon the production, but excessive increase can cause damage to tea plantations. Increased rainfall may create favourable circumstances for the proliferation of pests and diseases that can hamper production and output.

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