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Original Research Article

Trend and Forecasting of Sri Lankan Tea Production

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ABSTRACT

Tea industry has a tremendous impact on the Sri Lankan economy. Total tea production in 2013 was 339 million kilograms and the total tea exports earned 164.9 billion rupees which accounts for 58.9% of total agricultural exports. Forecasting of tea production is one of the major important requirements to individual producers, agribusiness firms and policymakers for various purposes. There is a significant research need to update and develop models with present data for accurate forecasting in near future. With this background this study was undertaken to identify the trend and appropriate time series models to forecast elevation wise black tea production. Trend analysis revealed that, high grown and medium grown tea showed the decreasing trend during the early period while low grown tea showed increasing trend. But recent period production of all elevations showed a declining trend, which is a problem that should be addressed strategically. Exponential smoothing techniques and ARIMA methodology were employed to identify appropriate models for elevation wise tea production. MAPE was used as model selection criteria with residual analysis. Among the exponential smoothing models tested, Single exponential models were selected as good models and among the ARIMA models tested, ARIMA (1,0,1), ARIMA (1,1,1) and ARIMA (1,1,0) were selected for high, medium and low grown tea respectively.

Key-words: *ARIMA, Forecasting, MAPE, Residual analysis, Trend, Tea (Camellia sinensis).*

INTRODUCTION

Tea (*Camellia sinensis*) is one of the major plantation crops in Sri Lanka. Tea as a crop was first introduced to Sri Lanka when the coffee cultivation was in disarray with Leaf Rust disease. James Taylor started the first commercial tea plantation at Loolkandura estate in 1867. Over the years, Sri Lankan tea has earned a special name with good quality and specialty and distinctive flavor; the word "Ceylon" has become a synonymous with quality tea. Tea has become a basic human need and it is an essential product for peoples' day-today life as a beverage which is next to water. The entire economic base of the country was centered on the plantation sector at the time when Sri Lanka was gaining independence in 1948. The tea production in the country grew at annual rate of 10 percent over the decade 1990-2000 and favorable weather conditions, adoption of better management practices, proliferation of small holders and replacement of poor yielding seedling tea with high yielding VP varieties were the key contributors for that. There are three agro-climatic tea growing regions in Sri Lanka according to the three elevation zones; high grown, medium grown and low grown. Teas that are grown in higher elevation are above 1200 m from sea level. Teas grown in medium elevation are 600 m-1200 m from sea level, where teas are grown below 600 m from sea level are low grown.

Total tea production in the year 2013 was 339 million kilograms which was an all-time record surpassing the previous best of 318.6 million kilograms achieved in 2008. Tea exports earnings reached 164.9 billion rupees out of total agricultural exports of 279.5 billion rupees in 2011(Anon, 2011). Considering the above key performance indicators, the year 2010 was one of the best years for the industry where production, prices and exports recorded significant gains. Sri Lanka continues to retain its position as the largest orthodox black tea producer as well as the exporter who exports to over 140 destinations with the image of Ceylon tea enhanced by its unique specialty characters.

Colombo Tea Auction is the main mode of disposal of teas manufactured in factories. Almost 95 % of Sri Lanka's total tea production is sold at the Colombo Tea Auction, which is held twice a week. Colombo auction holds the record for the highest average auction price fetched for the last three years. The auction is conducted by Colombo Tea Traders Association and the Chamber of Commerce in Sri Lanka. However, tea industry can be introduced as "Green Gold" of Sri Lanka, which is a strong pillar of the country's economy in terms of foreign exchange earnings and employment. It is noteworthy to mention that as a labor intensive industry, it has a tremendous impact on rural economic development by empowering women and providing employment to huge rural surplus labor.

International tea market is compromised of China, India, Kenya, Sri Lanka and Vietnam as large producers. China, Sri Lanka and Kenya together account for more than 60 % of global exports. High cost of production and low productivity are the major constraints that Sri Lankan tea industry faces today. Adequate focus on replanting, fertilizing, adoption of good agricultural practices, increasing land productivity and taking remedial measures at alarming situations of production declines will enable Sri Lanka to produce excellent teas to cater the dynamic foreign markets with rapidly changing consumer preferences while accomplishing the cost competitiveness to exist in the global tea arena.

There are three agro climatic tea growing regions according to the different elevation zones; high grown, medium grown and low grown. Teas that are grown in Badulla and Nuwara Eliya are high grown teas where the elevation is above 1200 m from sea level. Teas grown in Kandy and Matale are medium grown teas, where the elevation is 600 m-1200 m and teas grown in Galle, Matara, Kalutara and Ratnapura are low grown teas, where the elevation is below 600 m. Tea industry is a strong pillar in Sri Lankan economy in terms of foreign exchange earnings and employment. Tea exports earnings reached 164.9 billion rupees out of total agricultural exports of 279.5 billion rupees in 2011(Anon, 2011).Two millions of people are employed directly and indirectly on the industry (Anon, 2011).

However forecasting of production of tea enable policymakers and planners to estimate the production requirement of tea in future and formulate appropriate strategies to meet the future demand.

There is a significant research need to update and develop models with present data for accurate forecasting in the near future. With this background this study was carried out with the objective of identifying trend and appropriate time series models for Tea production in Sri Lanka. Auto Regressive Integrated Moving Averages (ARIMA) and Smoothing techniques, in order to forecast elevation wise tea production and assess the trend of elevation wise tea production were carried out in this study.

MATERIALS AND METHODS

Data Collection

Time series data on elevation wise annual black tea production in kg from 1963 to 2011 were collected from statistical bulletin published by Sri Lankan tea board, which provided a total of 49 years production observations.

Analysis

Different trend models and time series models were tested for the data. Based on the Mean Absolute Percentage Error (MAPE) value, the best models were selected.

Statistical Methods

Trend Models

Linear, Exponential and Quadratic models were tested to find out the most suitable trend.

Exponential Smoothing Models

At the first phase of the analysis, Single exponential models were tested with different constant values.

The methods of single exponential forecasting take the forecast for the previous period and adjust it using the forecast error. [Forecast error = (Yt – Ft)]

$$F_{t+1} = F_t + \alpha (Y_t - F_t)$$

Where,

Yt= observed value for time period t

Ft= fitted value for time period t

α= weighting factor, which ranges from 0 to 1

t = current time period

At the second phase of analysis Holt's Linear Exponential Smoothing model (Double Exponential model) were fitted.

Holt, (1957) extended single exponential smoothing to linear exponential smoothing to allow forecasting of data with trends. The forecast for Holt's linear exponential smoothing is found using two smoothing constants, α and β (with values between 0 and 1), and three equations:

$$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + b_{t-1}) \qquad (1)$$

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1} \qquad (2)$$

$$F_{t+m} = L_t + b_t m \quad \ldots(c) \qquad (3)$$

Here, L_t denotes an estimate of the level of the series at time t and b_t denotes an estimate of the slope of the series at time t. Equation (1) adjusts (L_t) directly for the trend of the previous period, b_{t-1}, by adding it to the last smoothed value, L_{t-1}. This helps to eliminate the lag and brings L_t to the approximate level of the current data value. Equation (2) then updates the trend, which is expressed as the difference between the last two smoothed values. This is appropriate difference between the last two smoothed values. This is appropriate because if there is a trend in the data, new values should be higher or lower than previous ones. Since there may be some randomness remaining, the trend is modified by smoothing with β the trend in the last period (L_t-L_{t-1}), and adding that to the previous estimate of the trend multiplied by (1- β). Thus, equation (2) is similar to the basic form of single smoothing but applied to the updating of the trend. Finally equation (3) is used to forecast ahead. The trend, b_t, is multiplied by the number of periods ahead to be forecast, m, and added to the base value, L_t.

ARIMA Models

The general model introduced by Box and Jenkins (1976) includes autoregressive as well as moving average parameters, and explicitly includes differencing in the formulation of the model. Specifically, the three types of parameters in the model are: the autoregressive parameters (p), the number of differencing passes (d), and moving average parameters (q). In the notation introduced by Box and Jenkins, models are summarized as ARIMA (p, d, q); so, for example, a model described as (0, 1, 2) means that it contains 0 (zero) autoregressive and 2 moving average which were computed for the series after it was differenced once.

Model Selection and Validation

As the model selection criteria, Mean Absolute Percentage Error (MAPE) which is illustrated in equation (4) was used to select the best fitted model.

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}|PE_t| \quad (4)$$

Where, $PE_t = 100*(Yt - Ft)/Yt$

RESULTS

Time series plots of tea production for each tea growing areas are given in Figure 1, 2 and 3. It is very clear that, production behavior of the tea can be separated into two phases: 1963-1992 (Phase I) and 1993-2011 (Phase II).

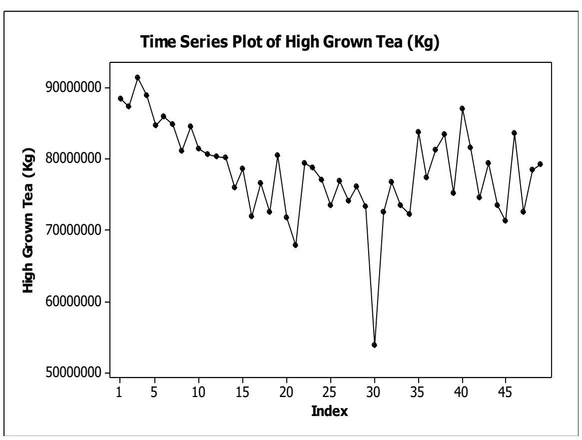

Fig. 1. Time series plot for high grown production

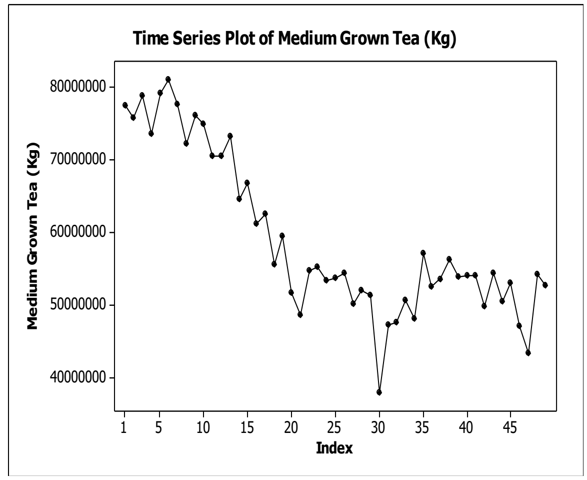

Fig. 2. Time series plot for medium grown production

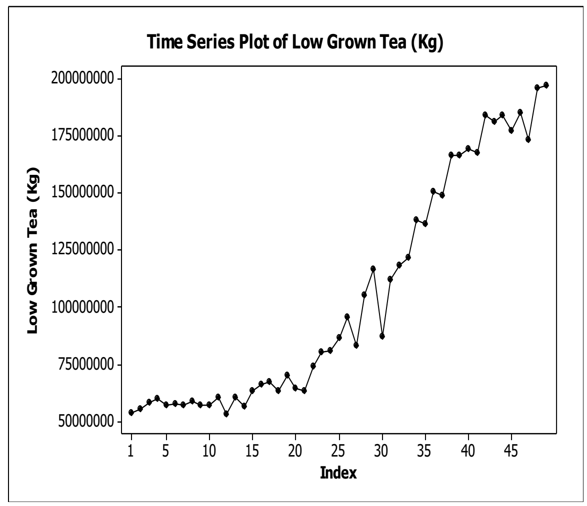

Fig. 3. Time series plot for low grown production

Trend Analysis

Due to the clear phases of the time series plot, trend analysis was performed separately for the two phases.

Trend analysis was carried out for selected three methods; Linear, Exponential and Quadratic.

The lowest MAPE was employed as the model selection criteria to select the best fitted general trend model. The MAPE values for the models tested are given in the Table 2. Selected models presented in the Table 1.

Figure 4-9 clearly show that the production trend of high, medium and low grown tea for the period 1963 to 1992 and

1994 to 2011separately. High grown and medium grown tea showed a declining trend during the early period while low grown tea showed increasing trend (Figure 4, 6 and 8). But production of all elevations showed declining trend for recent periods. (Figure 5, 7, and 8).

Exponential Smoothing Models

Table 3, 4 and 5 gives the MAPE values for Double and Single Exponential smoothing models and fitted values for the 2009, 2010, 2011and forecasted values for 2012, 2013 and 2014.

Table 1. Selected trend models

High Grown Tea (10^5)	
Phase I (1963-1992)	$Y_t = 923.9 – 14.3t + 0.2t^2$
Phase II (1993-2011)	Y_t= 729.4 + 12.4t –0.6t2
Medium Grown Tea (10^5)	
Phase I (1963-1992)	$Y_t = 826.0 – 11.9t$
Phase II (1993-2011)	$Y_t = 469.8 + 12.7t –0.6t^2$
Low Grown Tea (10^5)	
Phase I (1963-1992)	$Y_t = 625.6 – 18.5t + 1.1t^2$
Phase II (1993-2011)	$Y_t = 1020.3 + 88.9t – 2.3t^2$

Table 2. MAPE for fitted trend models

Tested Models	MAPE Value					
	High Grown Tea		Medium Grown Tea		Low Grown Tea	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
Linear	3.45	4.99	4.58	5.89	9.72	4.44
Exponential	3.34	5.92	4.60	5.92	7.94	5.32
Quadratic	2.96	4.89	4.59	4.72	5.63	2.82

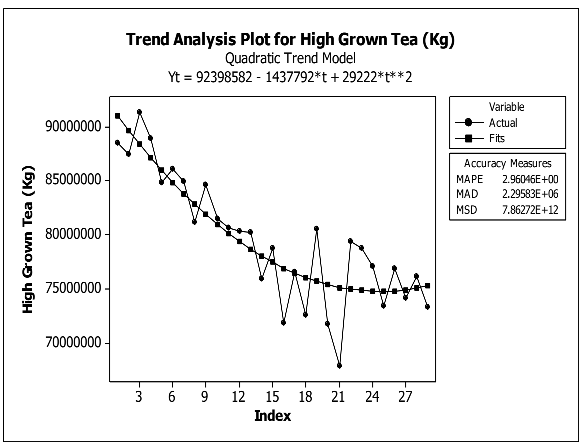

Fig. 4. Trend analysis plot for high grown tea-Phase I

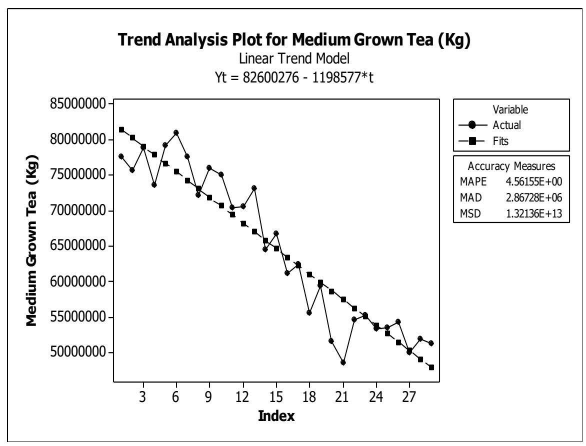

Fig. 6. Trend analysis plot for medium grown tea -Phase I

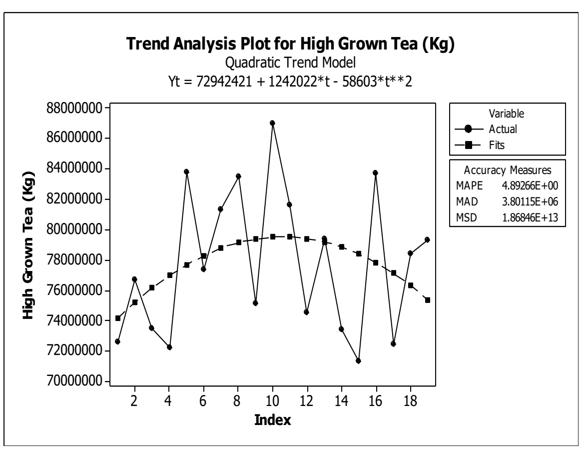

Fig. 5. Trend analysis plot for high grown tea - Phase II

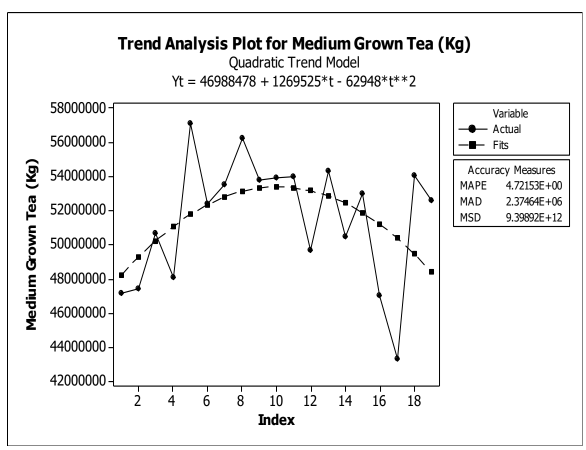

Fig. 7. Trend analysis plot for medium grown tea - Phase II

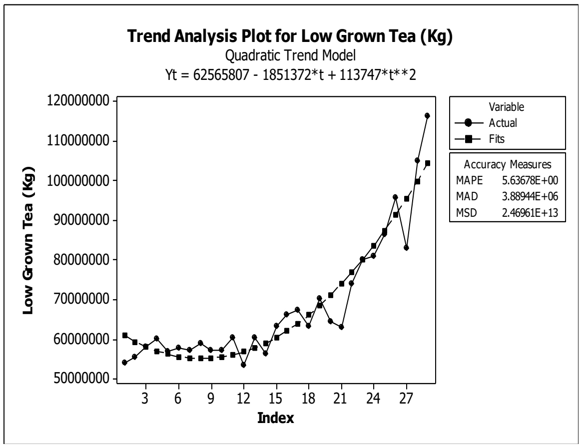

Fig. 8. Trend analysis plot for low grown tea - Phase I

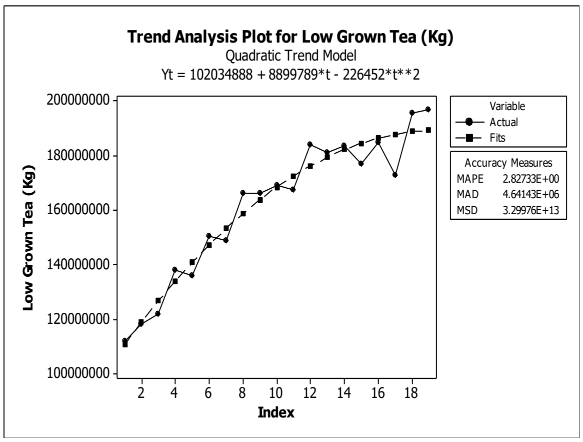

Fig. 9. Trend analysis plot for low grown tea - Phase II

Table 3. High grown tea production (Kg)

Year/ MAPE	Observed	Fitted /forecasted values	
		Single Exponential	Double Exponential
2009	72479739	78064795	78860644
2010	78387908	76221770	75213792
2011	79300000	76936579	76880332
2012		72479739	78226720
2013		78387908	78257487
2014		79300000	78288253
MAPE		5.3	5.5

Table 4. Medium grown tea production (Kg)

Year/ MAPE	Observed	Fitted /forecasted values	
		Single Exponential	Double Exponential
2009	43313234	49289859	48844672
2010	54060029	45824315	45306371
2011	52600000	50599791	49607336
2012		51759612	50952012
2013		51759612	50712082
2014		51759612	50472153
MAPE		5.8	6.1

Table 5. Low grown tea production (Kg)

Year/ MAPE	Observed	Fitted /forecasted values	
		Single Exponential	Double Exponential
2009	173033501	183149779	189143355
2010	195668124	175582006	183230866
2011	196700000	190608005	188883154
2012		195165297	193859533
2013		195165297	196083532
2014		195165297	198307531
MAPE		6.0	6.9

Table 6. Estimates of selected ARIMA models

Category	Selected Model	MAPE	Fitted values for 2009, 2010 and 2011 (in Mn kg)	Forecasted values for 2012, 2013 and 2014 (in Mn kg)
High Grown	ARIMA (1,0,1)	5.1012	78.4629 76.6387 77.4041	78.1678 78.2763 78.3780
Medium Grown	ARIMA (1,1,1)	5.8842	43.3132 54.0600 52.6000	50.7370 50.4475 49.8618
Low Grown	ARIMA (1,1,0)	6.5508	185.372 183.136 189.192	200.648 203.189 206.408

DISCUSSION

According to the MAPE values, Single Exponential models were better for the forecasting purposes of all elevation with compare to Double Exponential models.

ARIMA procedure was carried out for the same data set and three ARIMA models were identified for three elevations by following Box-Jenkins ARIMA methodology. Selected ARIMA models, relevant MAPE, fitted values and forecasted values were summarized in Table 6. Residual analysis was carried out separately for three selected models and it revealed that non randomness and non-autocorrelation between lags for residuals.

CONCLUSION

Trend analysis for tea production revealed that the latter period (1993 to 2011) has a decreasing trend for tea production in all elevation. Mostly it may be an adverse repercussion of increasing cost of production and recent climate changes.

According to the models fitted by Single Exponential models and Double Exponential models, Single Exponential models were better than double exponential models for forecasting of production of tea for the all elevations.

ARIMA models selected for high, medium and low grown tea are ARIMA (1, 0, 1), ARIMA (1, 1, 1) and ARIMA (1, 1, 0) respectively.

By increasing production, producer can increase the profitability and reduce the cost of production which is high in Sri Lanka. This high production cost may be a reason for the slipping of Ceylon tea from some competitive markets in the global tea arena where the major competitors like Kenya, who has a higher productivity and gain the competitive advantage in production and export performances. Adequate focus on replanting, fertilizing and other field operations will heighten the production and simultaneously strategic implementation of solutions for labor disputes will be another rigorous fact for enhancing the production of black tea in all elevations.

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