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Modeling and forecasting of tea production in West Bengal

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ABSTRACT

Tea production in West Bengal is playing great role not only in world tea market but also in contributing substantially to Indian economy and in employment generation. Taking all these into consideration the present study attempts to analyze the growth and trend behavior of tea production scenario in West Bengal. Using time series data on tea production parameters and factors of production, the study attempts to model and forecast the future production behavior of tea in West Bengal. In this endeavour, a new method in formulating weather and other factor indices have been developed using direct effects from path coefficient analysis. Comparison of methods indicates that the newly developed method has outperformed some of the existing methods in literature. The study identified relative humidity and fertilizer consumption as the significant contributors in tea production. Using ARIMA models, in association with factors of production the study forecasts tea production of 318992 thousand kg from 120345 hectare of plantation with average productivity of around 2625 kg^{-1}/ha in West Bengal during 2020.

***Keywords*:** Factors of production, indices, modeling and forecasting

Tea serves as the most important and popular drink for two-thirds of the world population not only because of its attractive aroma and taste but also because of its many pharmacological effects, like suppressing tumor cell growth, reducing cardiovascular diseases, anti obesity and decrease the risk of atherosclerosis (Wang *et al*., 2010). Globally, tea is cultivated in 3.7 million hectares of land with an annual production of 4.07 million tones (Anon., 2010) thereby, resulting in average productivity of around 1100kg^{-1} ha. Amongst tea producing countries, the principal producers are China, India, Sri Lanka, Kenya and Indonesia. These five countries account for 77% of world production and 80% global exports. India is the largest tea producing country in the world and tea contributes 1% of the GDP of the country (Gupta and Dey, 2010). Major tea producing states in the country are Assam, West Bengal, Tamil Nadu and Kerala. West Bengal offers tea from Darjeeling, Dooars and Terai, contributing 24 percent of total production of India (Hazarika and Muraleedharan, 2011). Tea is grown on 115095 ha with production of 226.32 million kg in West Bengal in 2011 (Anon., 2012) Darjeeling is known as "The Champagne of Teas", cultivated on the slope of the Himalayas. None of tea in world has been able to match "the Darjeeling flavor". Darjeeling's Castleton tea held world record of Rs. 5001 per^{-1} kg due to its unique, delicate flavor and character (Arya, 2013). There are 309 tea estates in the State in the organized sector covering 103431 hectares. Besides, 8078 small growers are growing tea in 11094 hectare (Anon., 2011). Indian tea industry is one of the oldest agro-based well organized industries as it provides direct employment to more than a million workers mainly drawn from the backward and economically weaker section of the society of which a sizeable number are women (Jain, 2011). It is also a substantial foreign exchange earner and provides sizeable amount of revenue to the State and Central Exchequer. In 2003 West Bengal contributes 47 % of tea export of India (Anon., 2004).

But the production of tea in West Bengal was 221.57 million kg in 2009 as compared to 233.08 million kg in 2008. The over all production of tea declined by 4.9%, the production also declined by 6.2% during 2008 over the period 2007 (Anon., 2009). From 2001 to 2009 there is no considerable expansion in the land used for tea over a period of ten years in West Bengal (Rasaily, 2013). Tea production is influenced by various factors such as soil, climate, plant growth, pests and diseases. The seasonal effect on tea quality and production has long been known (Tang *et al*., 2011). A report of 2011 indicates that tea industry in West Bengal facing problems of low levels of productivity, high cost of production, decline in quality of production (Anon., 2011). So the study of growth, trends and production scenario of tea has got greater emphasis in research arena, not only in West Bengal but also in other states. Roy (2011) reviewed the growth in tea industry of Assam from 1970 to 2008 and revealed that growth of tea in Assam was stagnated. Ahammed (2012) analyzed the trends in Bangladesh tea using polynomial models. Borodoloi (2013) analyzed global tea production and export

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trend of India using linear regression analysis. Tea production in Sri Lanka was forecasted using ARIMA models (Rohana, 2005). Dutta *et al.* (2012) studied the linear relationship between rainfall and fertilizer with north east tea production. Study on above aspects and also on analysis of growth, trend, associationship of production with inputs, modeling and forecasting of tea production in West Bengal is very rare and almost nil. Hence there is a need to study production scenario of West Bengal tea thoroughly. As weather and technology factors affecting tea production, it is necessary to study what extent the climatic factors and other factors of production are associated. In this study attempt has been made not only to study trend, growth of tea in West Bengal but forecast production scenario considering various factors of production like weather and fertilizer.

MATERIA AND METHODS

To study the production scenario of tea in West Bengal and influence of associated factors like weather and fertilizer on production, long term data on area, production and yield of tea from Tea board of India was collected for last 50 years. Data on ancillary variables like weather (Temperature, Rainfall, Relative humidity) and fertilizer consumption (Nitrogen, Phosphorus and Potassium) for West Bengal was also collected from India meteorological Department and Fertilizer Association of India respectively. Fertilizer consumption of a particular crop is not available, but the total consumption fertilizer is assumed to pursue a good indicator of tea production in state.

Time series data are very much susceptible to presence of outlier; as such present investigation started with test for outlier as per Grubb's statistic (www.graphpad.com). On rejection of outlier or replacement of extreme values (if any) by median, the data are subjected to test of randomness using turning point test. (Descriptive statistics provide simple summaries about the sample data) Descriptive statistics are used to describe the basic features of the data in any study. The most widely used descriptive measure of central tendency and dispersions like arithmetic mean, range, standard deviation along with simple and compound growth rates are used to explain each series. Procedure for simple and compound growth rate is as follows

Simple growth rate: This has been calculated using the formula $\frac{X_t - X_0}{X_0 \text{ x } n}$ x100,

where, X_t is the value of the series for the last period and X_0 is the value of the series for first period and n is the number of periods.

Compound growth rate: Procedures given by Prajneshu and Chandran (2005) was followed for computing compound growth rate. If Y denotes the area, production and productivity at a time X and r is the compound growth rate, model employed for estimating r is based on eq., (1) :

$$X_t = Y_t(1 + r)^t \quad (1)$$

The usual practice is to assume a multiplicative error-term in equation (1) so that the model may be linearized by means of logarithmic transformation, giving equation (2) :

$$\text{Ln}(Y_t) = \text{A} + \text{B.X} + e \quad (2)$$

where, A = Ln(Y_0), and B = Ln(1 + r). Equation (2) is then fitted to data using the "method of least squares" and goodness of fit is assessed by the co-efficient of determination R^2. Finally, the compound growth rate is estimated by equation (3) :

$$\hat{r} = \exp(\hat{B}) - 1 \quad (3)$$

Trend models

To trace the path of production process different parametric trend models as given in table below are used. Among the competitive trend models, the best models are selected based on their goodness of fit (measured in terms of R^2) value and significance of the coefficients.

Table 1: Linear and non-linear trend models

Model No.	Model	Name of the model
I.	$Y_t = b_0+b_1t$	Linear equation
II.	$Y_t = b_0+b_1t+b_2t^2$	Second Degree Polynomial
III.	$Y_t= b_0+ b_1 t + b_2t^2 + b_2t^3$	Third Degree Polynomial

where Y is the area/ production/ productivity and t is the time points

Association of the factors of production with yield

The production of tea is assumed to be influenced by climatic factors like rainfall, temperature and also use of several factors like fertilizer consumption and other resources. Hence these factors are needs to consider for forecasting. Monthly weather data on maximum and minimum temperature, rainfall and relative humidity for 8.30 and 5.30 hrs was used for whole crop season data. Two synthetic variables were developed *i.e.,* difference in maximum and minimum temperature and humidity. Also yearly state wise fertilizer consumption data of N, P and K was also incorporated.

For selection of effective variables influencing production methodology of weather indices proposed by Agarwal *et al.* (2001) was followed. In this method two variables are generated from original weather parameter. These indices are known as un-weighted indices and weighted indices. Un-weighted indices are totality of weather variable over crop season and weighted indices are weighted sum of weather variables over crop season. The weights are being the correlation coefficient between yearly (linear detrended) crop yield and weather parameters of respective months. Similarly indices were also generated for interactions of weather variables, using monthly product of weather variable taking two at time. Fertilizer indices (un-weighted and weighted) also developed from fertilizer parameters (N, P and K) using above procedure. Combinations of weather and fertilizer indices generated are presented in Table 1. Using this method total 36 variables are generated from weather and fertilizer data. Then These 36 variables were regressed with yield using stepwise regression (Draper and Smith 1981; Gomez and Gomez 1966) and significant variables were selected.

Table 2: Weather indices developed by method using Agarwal *et al.*

	Un-weighted weather indices							
	Tmax	**Tmin**	**RF**	**RH_1**	**RH_2**	**Diff in temp**	**RH diff**	**Fertilizer**
Tmax	Z10							
Tmin	Z120	Z20						
RF	Z130	Z230	Z30					
RH_1	Z140	Z240	Z340	Z40				
RH_2	Z150	Z250	Z350	Z450	Z50			
Temp Diff temp						Z60		
RH Diff							Z70	
Fertilizer								Z70
	Weighted weather indices							
Tmax	Z11							
Tmin	Z121	Z21						
RF	Z131	Z231	Z31					
RH_1	Z141	Z241	Z341	Z41				
Rh_2	Z151	Z251	Z351	Z451	Z51			
Temp Diff temp						Z61		
RH Diff							Z71	
Fertilizer								Z71

Tmax=Maximum Temperature, Tmin=Minimum Temperature, RF=rainfall, RH_1= Morning relative humidity and RH_2 = Evening relative humidity, Temp Diff= Difference in temperature and RH Diff = Difference in humidity

Proposed method 1

In the above method it is assumed that technology impact is linear and hence yield was detrended using linear model. In this paper, modification to above method is made and one method is proposed. Instead of assuming linear trend, we have taken the best fitted trend model to de-trend the series before calculation of weather indices. Then correlation coefficients between best fitted detrended yield and weather variables are taken as weights during development of weather indices. In the same way correlation coefficients between best fitted detrended yield and fertilizer parameters is taken as weight during development of fertilizer indices. Un-weighted indices for weather and fertilizer are also developed. Both fertilizer and weather indices (36 variables) together regressed with yield using stepwise regression and significant parameters were selected.

Proposed Method 2

Agarwal *et al*. (2001) have used correlation coefficients as weight for developing weather indices. Simple correlation coefficient provides linear association of two variables and it doesn't consider presence of other variables. Direct effects of path coefficient analysis are the standardized partial regression coefficients which measures the effect of independent variable on dependent variable excluding the indirect effects of other variables via the independent variable concerned. Here we proposed second method for selection of associated variables using direct effect between the best fitted detrended yield and weather as weight during the development of weather indices. Fertilizer indices are also generated using weight from direct effects of path analysis and the best fitted detrended yield. Then un-weighted and weighed indices of fertilizer and weather together regressed with yield using stepwise regression and significant parameters were selected.

So, factors associated with production are selected using three methods *i.e.* weather indices method by Agarwal *et al.*, proposed method 1 and proposed method 2.

Modeling and forecasting of tea

ARIMA technique given by Box and Jenkins (1976) was used. Use of such models in forecasting purpose is also found in Mishra *et al.* (2013). Factors of production selected from above procedures also used in modeling. Modeling of tea production is done using ARIMA modeling without and with considering factors of production. Detailed procedure of ARIMA modeling is given below.

ARIMA model: ARIMA models, stands for Autoregressive Integrated Moving Average models. Integrated means the trends has been removed; if the series has no significant trend, the models are known as ARMA models.

Autoregressive Models (AR): The notation AR (p) refers to the autoregressive model of order p; the AR(p) model is written

$$X_t = c + \sum_{i=1}^{P} \alpha_i X_{t-i} + \mu_t$$

where, $\alpha_1, \alpha_2 ... \alpha_p$ are the parameters of the model, c is a constant and μ_t is white noise i.e. $\mu_t \sim WN(0, \sigma^2)$.

Moving Average model (MA): The notation MA (q) refers to the moving average model of order q:

$$X_t = \mu + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} + \varepsilon_t$$

where the $\theta_1, ..., \theta_q$ are the parameters of the model, μ is the expectation of X_t (often assumed to equal 0), and ε_t the is the error term.

Given a set of time series data, one can calculate the mean, variance, autocorrelation function (ACF), and partial autocorrelation function (PACF) of the time series. Based on the nature of ACF and PACF appropriate ARIMA models are worked out, but the final decision is made once the model is estimated and diagnosed. In this step one can see whether the chosen model fits the data reasonably well.

Developed models are compared according to the minimum values of Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) and maximum value of Coefficient of determination (R^2) and of course the significance of the coefficients of the models. Best fitted models are put under diagnostic checks through auto correlation function (ACF) and partial autocorrelation function (PACF) of the residuals to verify to the residuals estimated from the models are white noise, if there are, one can accept particular fit otherwise discard it. Once the model satisfies the requirement, are used for forecasting purpose.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}\left(\frac{X_i - \hat{X}_i}{X_i}\right)^2}{n}} X100$$

$$\text{MAPE} = \frac{\sum_{i=1}^{n}\left|\frac{X_i - \hat{X}_i}{X_i}\right|}{n} \text{x}100$$

$$\text{MAE} = \frac{\sum_{i=1}^{n}\left|X_i - \hat{X}_i\right|}{n}, \quad R^2 = \frac{\sum_{i=1}^{n}\left(\hat{X}_i - \bar{X}\right)^2}{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}$$

where, $X_i, \bar{X}, \hat{X}_i$ are the value of the i[th] observation, mean and estimated value of the i[th] observation of the variable X.

Using above procedures, four types of models were developed considering with and without factors of production. First model was obtained without considering any factors of production known as univariate ARIMA. Second and third model was developed using ARIMA with associated factors selected from weather indices and proposed method 1. Fourth model was developed using ARIMA with associated factors from proposed method 2. These models are compared for maximum R square, minimum AIC, SBC, Log likelihood, RMSE, MAE etc. Best fitted ARIMA model is selected and used for forecasting tea production in West Bengal up to 2020.

RESULTS AND DISCUSSION

In consonance with the objectives of the study and as discussed in materials and method section are subjected to test of outlier and randomness. Table 3 presents the results of outlier and randomness test. It is also clear from the table that the series under consideration followed definite trends in all the selected parameters and no outlier is detected.

Area under tea in West Bengal has varied between 82705 hectare to 115100 hectare with an average of hectare (Table 4), registering a simple growth rate of almost 0.75 % per annum as against compound growth rate of 0.70%. The value of skewness (0.17) indicates that there has been shift of area in favour of tea during the early phase of study period. This is well supported by the findings of Rasaily, 2013, that in West Bengal during 2001 to 2009 estate sector area declined by 7.41% and may be used for non plantation purpose. So far about the productions of tea during study period is concerned, an average production of 154422.74 thousand kilogram associate with a simple growth rate of almost 4.69 % per annum. Skewness is positive (0.70) while kurtosis is negative (-0.06) indicates that that there has been increase in production during early half of the study period and it remains steady for a long duration. Average productivity of tea in West Bengal is 1524.33 kg^{-1} ha and ranges between *998* kg^{-1} *ha to 2426* kg^{-1} *ha*. By and large the productivity of tea has recorded a 1.40% compound growth rate during the whole period under study. Both skewness and kurtosis were positive indicating been increase in productivity during early half of the study period could not be sustained for longer period. Lower productivity of West Bengal may be attributed due to lower productivity in Darjeeling district around *545* kg^{-1} *ha* which in turn may be due to fact that tea plucking included collection of finest two leaves and bud to enhance the unique flavour and also due to old age tea bushes as opined by Kadavil, (2007).

Knowing the above overall performance, path of movement of the series was traced through parametric trends models (Table 5). A wide range of models has been explored, among the competitive models the best fitted models are selected based on the maximum Adj. R^2 along with significance of coefficients. Among the competitive parametric models, all cases cubic models are found best fitted; thereby indicating that the movement of all the series was uniform throughout the West Bengal. This may be due to the changes in policies and its execution at different point of times.

The most important factors affecting crop production are identified by using methods described (Table 6). Yield was detrended using cubic polynomial model and this detrended yield was used in analysis. In case of weather indices by Agarwal *et al*. and proposed method 1, it is found that F11 *i.e.* weighted fertilizer and Z41 *i.e.* weighted morning humidity was significant factors affecting crop yield. In case of proposed method 2, weighted fertilizer (F11) and un-weighted relative humidity (Z40) are found significant. Overall, fertilizer and relative humidity are main factors affecting tea production positively in West Bengal. Patra *et al.* (2013) found that variation in green leaf yield (81.9 %) of Darjeeling tea was due to relative humidity. Dutta *et al.* (2012) also opined that fertilizer application had positive impact on North eastern tea.

After selection of significant associated variable with tea production, forecasting models are developed using ARIMA technique. ARIMA model are developed without and with inclusion of factors of production. Data for the period 1963-2010 is used for model building and 2011-12 for model validation. Each and every series is checked for stationarity before developing the model, if not, differencing or transformation technique is used to make these stationary. ARIMA models were developed for West Bengal tea area without considering factors of production and presented in table 7. For area, ARIMA (2,1,1) model was best fitted with R^2 (0.98) and lower values of AIC, SBC, Log likelihood etc criteria's. ACF and PACF of residuals are non significant. Tea area in West Bengal is forecasted using univariate ARIMA (2,1,1). In case of ARIMA with factors of production, the explanatory variables are forecasted using best fitted ARIMA models. Forecasted values of these explanatory variables are used in the ultimate ARIMA model for forecasting tea production. From Table 6, it is clear that R^2 value for production and productivity is higher in case of proposed method 2. In case of production, ARIMA (2,1,1) model with factors of production using proposed method 2 provides R^2 (0.97) and lower AIC, SBC and log likelihood values. For Productivity ARIMA with explanatory variables using proposed method 2 provide R^2 (0.94) and lower AIC, SBC and log likelihood values. Model validation is done for the year 2011 and 2012 and results are represented in table 8. From the table it was clear that minimum error is obtained from ARIMA with explanatory variables generated proposed method 2. Hence ARIMA with explanatory variables using proposed method 2 is used for forecasting of tea production and productivity.

Table 3: Test of outliers and randomness for area, production and yield of tea in West Bengal.

	No. of observation	No. of point (p)	E (P)	V(P)	ô-cal	Inference	Outlier
Area	50	8	32	8.57	8.20	Trend	No
Production	50	24	32	8.57	2.73	Trend	No
Yield	50	26	32	8.57	2.05	Trend	No

Table 4: Per se performance of tea production in West Bengal

	Area (hectare)	Production ('000 kg)	Yield(kg hectare^{-1})
Mean	99267.72	154422.74	1524.33
Maximum	115100.00	279300.00	2426.59
Minimum	82705.00	83456.00	998.10
SD	10577.20	49149.75	330.20
CV (%)	10.66	31.83	21.66
Kurtosis	-1.26	-0.06	0.49
Skewness	0.17	0.70	0.67
SGR (%)	0.75	4.69	2.86
CGR (%)	0.72	2.13	1.40

Table 5: Trends in area, production and yield of tea in West Bengal

	Model summary				Parameter estimates			
	R^2	Adj R^2	F	Sig.	Constant	b_1	b_2	b_3
Area (hectare)								
Linear	0.97	0.97	1380.06	0.00	81078.78	713.29		
Quadratic	0.97	0.97	771.59	0.00	82662.06	530.61	3.58	
Cubic	0.98	0.97	545.18	0.00	84127.39	201.98	19.53	-0.21
Logarithmic	0.75	0.74	140.61	0.00	68767.22	10271.07		
Compound	0.97	0.97	1526.65	0.00	82185.35	1.007		
Growth	0.97	0.97	1526.65	0.00	11.32	0.01		
Exponential	0.97	0.97	1526.65	0.00	82185.35	0.01		
Production ('000 kg)								
Linear	0.92	0.92	543.05	0.00	72010.87	3231.84		
Quadratic	0.95	0.95	471.53	0.00	93231.60	783.29	48.01	
Cubic	0.97	0.97	544.86	0.00	72651.85	5398.64	-176.01	2.93
Logarithmic	0.69	0.66	104.49	0.00	18543.61	45757.40		
Compound	0.96	0.96	1171.07	0.00	85980.78	1.021		
Growth	0.96	0.96	1171.07	0.00	11.36	0.02		
Exponential	0.96	0.96	1171.07	0.00	85980.78	0.02		
Yield (kg hectare^{-1})								
Linear	0.87	0.87	332.98	0.00	984.33	21.18		
Quadratic	0.89	0.89	199.18	0.00	1095.35	8.37	0.25	
Cubic	0.94	0.94	247.11	0.00	883.68	55.84	-2.05	0.03
Logarithmic	0.69	0.67	108.12	0.00	606.57	309.06		
Compound	0.90	0.90	444.23	0.00	1046.24	1.014		
Growth	0.90	0.90	444.23	0.00	6.95	0.01		
Exponential	0.90	0.90	444.23	0.00	1046.24	0.01		

Table 6: Regression analysis of factor influencing the productivity of tea in West Bengal

Model		Regression coefficients	Std. error	Sig.	R^2	Adj R^2	RMSE	MAE
Weather indices model by Agarwal *et al.*	Intercept	-803.88	617.70	0.20	0.88	0.88	113.31	94.63
	F11	0.58	0.04	0.00				
	Z41	9.06	2.85	0.00				
Proposed method 1	Intercept	-890.87	670.92	0.19	0.88	0.88	112.06	96.23
	F11	0.6	0.04	0.00				
	Z41	8.89	2.91	0.02				
Proposed method 2	Intercept	-675.72	672.73	0.32	0.9	0.89	111.5	95.81
	F11	1.41	0.09	0.04				
	Z40	1.89	0.7	0.01				

Note: F11 weighted fertilizer, Z41 weighted relative humidity and Z40 un-weighted relative humidity indices

Table 7: Best fitted ARIMA models for area, production and yield of tea in West Bengal.

Types		Model	R^2	Log Likelihood	AIC	SBC	RMSE	MAPE	MAE	MaxAPE	MaxAE
					Area						
Without Factors	Univariate	ARIMA (2,1,1)	0.89	-423.72	855.44	863.01	1435.95	0.92	902.19	6.76	5592.01
					Production						
Without Factors	Univariate	ARIMA (2,1,2)	0.92	-516.77	1043.53	1052.99	9570.70	4.40	6851.87	15.84	23585.20
With	Weather indices model by Agarwal *et al.*	ARIMA (4,1,0)	0.96	-518.73	1051.47	1064.71	9123.97	4.55	6990.68	14.20	18213.02
Factors	Proposed method 1	ARIMA (2,1,1)	0.97	-515.25	1042.50	1053.85	8769.31	4.26	6586.25	11.17	20363.44
	Proposed method 2	ARIMA (2,1,1)	0.97	-515.73	1043.46	1054.81	8842.98	4.24	6529.62	11.79	20242.37
					Yield						
Without Factors	Univariate	ARIMA (4,1,1)	0.90	-223.82	453.63	459.05	94.53	4.55	69.55	16.04	264.26
With Factors	Weather indices model by Agarwal *et al.*	ARIMA (4,1,1)	0.92	-289.32	594.65	609.783	80.74	4.00	58.63	13.86	188.80
	Proposed method 1	ARIMA (4,1,1)	0.94	-284.58	585.15	600.29	89.71	4.08	62.00	14.31	202.13
	Proposed method 2	ARIMA (2,1,1)	0.94	-285.43	582.85	594.20	84.17	4.18	63.62	12.14	180.10

Table 8: Model validation of area, production and yield of tea in West Bengal

Year	Actual	Predicted univariate	Predicted weather indices model by Agrawal *et al.*	Predicted proposed method 1	Predicted proposed method 2
			Area (hectare)		
2011	115100	115760			
2012	115100	116020			
			Production ('000kg)		
2011	271600	250755	255319	255147	255126
2012	279300	274179	272116	278358	278204
			Yield (kg ha^{-1})		
2011	2360	2096	2111	2158	2202
2012	2427	2311	2313	2388	2398

Table 9: Forecasting of area, production and yield of tea in West Bengal

Year	Area (ha)	Production (‘000kg)	Yield (kg ha^{-1})
2013	115778	269129	2310.95
2014	116534	270596	2299.23
2015	117028	281950	2380.26
2016	117810	292860	2463.85
2017	118319	299251	2507.6
2018	119076	304248	2534.62
2019	119612	310892	2573.41
2020	120345	318923	2625.19

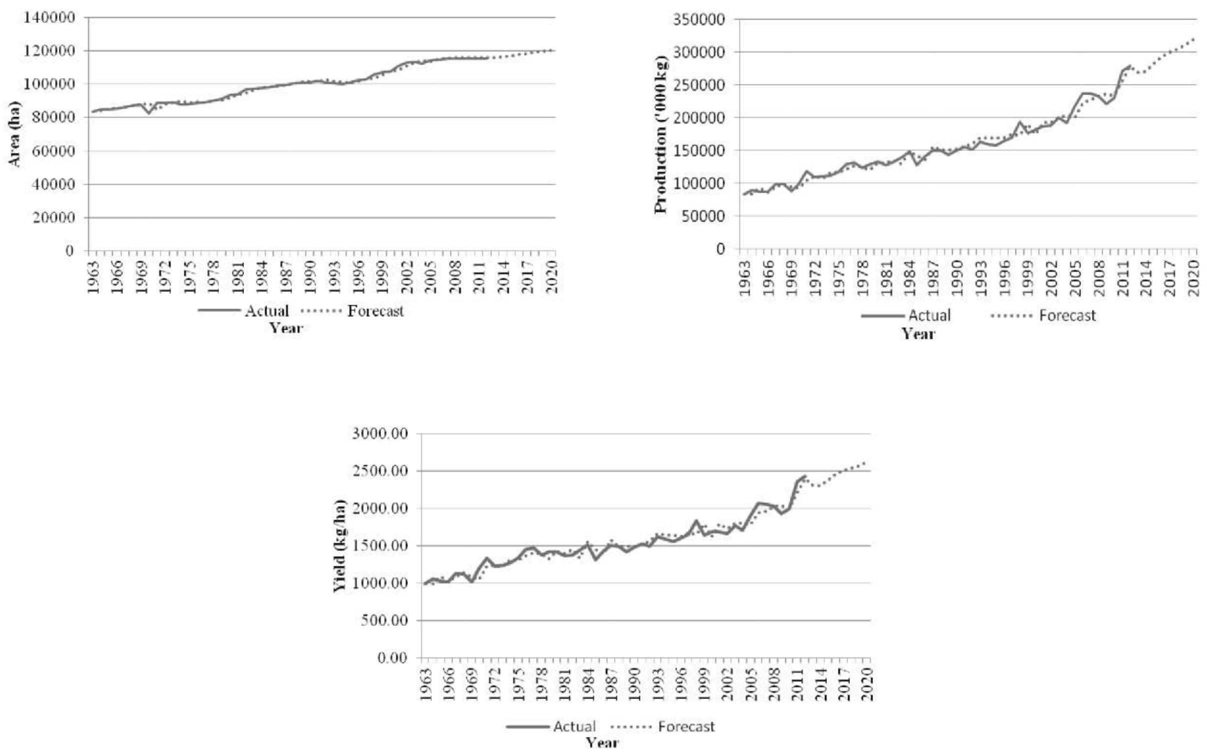

Fig. 1: Observed and forecasted area, production and yield of tea in West Bengal

Forecasting figures in table 9 indicate that there will be increase in area, production and yield of tea in West Bengal. It can be seen that forecasted production for the year 2013 is lower than 2012 but in later years the production increases. West Bengal is supposed to produce 318.92 million kg of tea from 121073 hectare of land with productivity of 2600 kg^{-1} *ha* (Figure 1). Though productivity of tea in West Bengal would increase (2600 kg^{-1} *ha*) in 2020 but still it will remain lower than many countries like Turkey (2900 $kgha^{-1}$) in 2011 (Anon., 2012). In world market, Kenya, Vietnam and Turkey are competitive markets of Indian tea. Though reasons for low productivity are not taken up in this study, Arya in 2013 reported that the reasons for low productivity were high production cost, aged tea gardens, pest and weather. More over against suggested rate of replanting (2% per annum) of tea garden the actual being less than 0.3% which is surely disturbing (Anon., 2011). As Darjeeling tea fetching more price in global market, production of tea in Darjeeling should be taken in to with ultimate sincerity.

Thus the above critical review of tea production scenario in West Bengal indicate that

1) Expansion/growth in tea production parameters has taken place mostly during early phase of tea industry in West Bengal.
2) Growth in production parameters for last fifty years is very low.
3) Inspite of definite trend (cubic) in production parameters, the tea industry in West Bengal is far away from either of the production potential or from the highest productivity.
4) RH and fertilizer are the two major factors of production are identified.
5) Among the indices based model for tea production in West Bengal, model proposed in method 2 based on path indices are found to be superior over other models in literature.
6) Inspite of marginally increased forecasted values of area, production and yield, the tea industry in West Bengal will be far away from highest productive countries in the world with respect to quantum of produce. Thus, the study strongly advocates for immediate break in tea industry of West Bengal.

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