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Modeling and Forecasting of Cocoa in India and its Sustainability

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Abstract: Keeping cocoa competitive in the export market is critical to India's economic well-being. This study project aims to examine cocoa farming's area, production, and productivity while also determining the industry's competitiveness and charting the various government policies that influence it. There is a mix of descriptive, qualitative, and quantitative methods. The data is analyzed using ARIMA (autoregressive integrated moving average) and an ETS state space model with level, trend, and seasonal components (T, S), as well as an error term (E). In this case, the best model was chosen because it had the lowest RMSE values both within and outside of the sample. In terms of area and output and productivity, the best models are ETS (M, M, N) and ARIMA (M, 0, M). The study predicted that area would increase from 119.61 in 2021 to 203.90 by 2027, production would increase from 28.98 to 43.78 by 2027, and productivity would increase from 0.279 to 0.2108 by 2027.We need to develop unique policies for cocoa areas, production, and productivity so that cocoa planting generates better net transfer values for farmers. The Sustainability index is increased ,from (period 1) to (period 2) in SI 1, SI 2 and SI 3 that means meeting our own needs without compromising the ability of future.

Keywords: Modelling, Forecasting, ARIMA, Exponential Smoothing, Area, Production, Productivity, and Cocoa.

1. Introduction

Cocoa is the dried and fully fermented fatty seed of the cacao tree that is used to make chocolate[1]. "Cocoa" can also refer to the drink known as hot chocolate; cocoa powder,

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the dry powder created by grinding cocoa seeds and separating the cocoa butter from the dark, bitter cocoa solids; or the combination of cocoa powder and cocoa butter[2]. The cocoa tree is a tiny (up to 6-8 m tall) evergreen tree[3]. It may be grown up to 300 m. (sea level). It requires a monthly rainfall of 90–100 mm and an annual rainfall of 1500–2000 mm. Plants require an egalitarian climate with evenly distributed rainfall[4]. Irrigation scheduling is required if dry spells last for an extended length of time[4]. The recommended temperature range is 15°–39°C, with a maximum of 25°C. Agriculture is playing a vital part in the development of our country's economic structure[5]. In India, it is mostly grown in the southern states of Karnataka, Kerala, and Tamil Nadu as an intercrop with Arecanut and coconut [6]. Many chocolate firms are gradually promoting contract farming as a way to increase the amount of land under cultivation[7]. More than two-thirds of cocoa is grown in coconut groves, a fifth in arecanut farms, and the balance in oil palm and rubber plantations[8]. Since the 1970s, cocoa has been grown commercially in India [9]. Cocoa, which is native to South America's Amazon region, is grown commercially in African, Latin American, and Asian countries under palm trees and partially disturbed forests for its dry beans, which is the primary ingredient in chocolate[10]. It is currently grown on over 65,500 hectares in India as a component crop in arecanut, coconut, and oil palm farms, yielding over 19,400 tonnes [11]. Karnataka had the highest production in India. Because of prevailing agro-climatic and socioeconomic variables, India's cocoa output, productivity, and quality are lower and not comparable to other major chocolate-producing countries[12]. Because of the high demand in the Indian chocolate sector and confectionaries, there is a huge opportunity for cocoa area expansion, which is projected to be 99,000 MT in 2027 [11]. The nursery should have at least 50% shade [14]. The land should be level and devoid of rodents and viruses [14]. Irrigation is provided by micro sprinklers, and vegetative propagation is used in cocoa to generate true-to-type trees [15]. Soft wood grafting is the most common method of vegetative proliferation[16]. An investigation into the production and productivity of cocoa in India was carried out with this in mind[16]. If there's ever going to be a big and massive demand for chocolates, cakes, and sweets as well as coffee in India in the near future, then it's important to know about cocoa production[17].

The use of chemical pesticides, inorganic fertilisers, and growth regulators, which is a major component of current agricultural techniques, has greatly increased agricultural production, but at the expense of resource depletion, environmental degradation, and loss of crop diversity [18]. Examples of resilience are appearing on the ground in response to an increase in extreme climate events, emphasising the potential of sustainable agriculture [19]. Sustainable agriculture is the effective management of agricultural resources to meet changing human requirements while preserving or improving the environment's quality and protecting natural resources [20]. Such systems typically rely on crop rotations and organic wastes as opposed to the usage of chemical fertilisers, pesticides, growth regulators, and livestock feed additives [21]. Production of cocoa is one of the critical foundations of sustainable agriculture, which is becoming a key issue in economic development[22]. Production of cocoa is increasingly subject to sustainability criteria [23].

There are a number of strategies that outstanding statisticians are employing in the process of forecasting[25-29]. However, after learning about the various elements and facts related to cocoa production, such as its soil structure, spacing and planting technique, its management and propagation methods, etc., a study is undertaken to anticipate the area, production, and productivity of cocoa in India. There are a variety of methods for forecasting, including ARIMA and ETS. The Akaike Information Criteria, RMSE, and highest adjusted R2 are used to determine which forecasting model is the most accurate[30].Traditional non-stationary time series analysis techniques include ARIMA. As a contrast to regression models, an ARIMA model allows to be explained by its past, or lagged values, as well as its stochastic errors. It is common to refer to these models as “many models.” Despite the fact that this complicates the forecasting process, the structure may actually better imitate the series and result in a more accurate forecast. Using only AR or MA parameters, a pure model implies that the structure is incomplete. It’s common to refer to these models as ARIMA models because they combine autoregressive (AR), integration (I), and moving average (MA) processes. The ARIMA model is commonly referred to as simply ARIMA (p,d,q)[31]. The indicated models’ coefficients are estimated during the estimation stage. Typically, the least squares approach is used to estimate parameters based on the principle of minimizing the sum of squares due to residuals[30]. Stationarity and invertibility of the derived coefficient are tested during the estimation process, as is the model’s ability to fit the data well. The statistical significance of the coefficients determines their importance. To determine the standard error of each estimated coefficient, a sampling distribution is used. Automated ARIMA estimation routines automatically test for zero as a true coefficient. The quality of the estimates decreases if the coefficients are significantly linked. Calculating the Root Mean Square Error (RMSE) helps to ensure that the model fits the data as closely as possible[27]. It is required to do diagnostic testing after estimating the parameters of a tentatively identified ARIMA model to ensure that the model is adequate[32]. While conducting the research, all of these ideas are kept in mind. based on the results of this research, the most effective model for calculating Area is (1.1.0), the most effective model for calculating Production is (0.1.1). The second forecasting method used in this study is Exponential Smoothing. Time series data can be smoothed in order to remove chaotic patterns from its data set (unpredictable variations). One of the most prominent forecasting techniques, exponential smoothing (ES), results in a smoothed time series. The weights of older observations are reduced by an exponential factor due to exponential smoothing. The most recent data is more important in forecasting than the oldest. According to the time series data’s kind of trend and seasonality, many types of exponential smoothing can be applied to the data. There are 15 ways of smoothing the trend and sea-sonal components [33].Trend and Season are both denoted by two letters in each approach, which can be found in the uppercase or lowercase letters (T,S). Smoothed statistics or parameters such as Level, Trend, and Seasonality [34] are commonly used in exponential smoothing. The best area model is (M.M.N), the best production model is (A.M.N), and the best productivity model is (M.N.N). R program also calculates Root Mean Square Error for picking the best fit model for the study. Therefore, Cocoa prices and demand are expected to rise because of an increase in cocoa production and productivity in the forecasted area.

2. Materials and Methods

The area, production and productivity data series of Cocoa is collected from indiastat website (https://www.indiastat.com) for the period of 19993-2020.

Measures of Sustainability

Sustainability is a contentious, multifaceted, and variously defined (by different authors for different specialised objectives) phenomena. Despite its contentious character, there is general agreement that it is complicated and has to be evaluated in a variety of ways. It can be evaluated in its most basic form by looking at its economic, social, and biophysical characteristics. It's critical that major crops maintain their yield sustainability for guaranteed food and nutritional security. The study makes the assumption that sustainability entails perseverance and a crop's ability to produce steadily over an extended period of time. Therefore, under the current situation, a crop's ability to maintain productivity over an extended period of time denotes sustainability.Followings are the some of the measures found in literature, definitely these are not exclusive.

Sustainability Index (SI)

(1) Singh *et. al.* (1990) has given the following measures of sustainability. Sustainability Index (SI) = $\frac{\bar{y}-s}{y_{\max}}$, where $\bar{y}$ is the average yield of a treatment, s is the standard deviation of yields over the years and $y_{max}$is the maximum yield of a treatment in any year.Higher the value of the index, higher is the sustainability status

$$SI = \frac{Y_{\max} - \bar{Y}}{\bar{Y}} \quad SI = \frac{Y_{\max} - \bar{Y}}{\bar{Y}}$$

(2) Sahu*et.al* (2005)a sustainability index value closer to zero is the most desirable value.

(3) Pal and Sahu (2007) $SI = \frac{s_i}{\bar{y}_i} \cdot \frac{1}{s_{\max}}$ lower the value of the sustainability index higher is the sustainability.

ARIMA (p, d, q) (Auto-Regressive Integrated Moving Average): We can represent ARIMA model as follows [36]:

$$Y_t = \varnothing_1 Y_{t-1} + \varnothing_2 Y_{t-2} + \cdots + \varnothing_p Y_{t-p} + a_1 - \theta_1 \alpha_{t-1} - a_2 - \theta_2 a_{t-2} - \ldots - a_q - \theta_q a_{t-q}$$

$\varnothing_p$: parameter values of AR operator, a_q: error term coefficient, θ_q: parameter values of MA operator, Y_t: variable with (d) difference from the original data.

ETS Model (Exponential Smoothing)

In our data, we ignore (S) because we have annual data [36].

To build the model, we had additive model $Y_t = T + E$, or multiplicative model like $Y_t = T.E$.

The individual component of the model is described below [36, 37]:

$$E[A,M]$$

$$T[N,A,M,AD,MD]$$

$$S[N,A,M]$$

Where: N: none; A: additive; M: multiplicative; AD: additive dampened; MD: multiplicative dampened.

The table 1 below describes the model that we are working on [36]:

Table 1: Probabilities of the Model Shape in State Space

Trend	*Additive Error Models*	*Trend*	*Multiplicative Error Models*
N	$y_t = l_{t-1} + \varepsilon_t$ $l_t = l_{t-1} + \alpha\varepsilon_t$	N	$y_t = l_{t-1} (1 + \varepsilon_t)$ $l_t = l_{t-1} (1 + \alpha\varepsilon_t)$
A	$y_t = l_{t-1} + b_{t-1} + \varepsilon t$ $l_t = l_{t-1} + b_{t-1} + \alpha\varepsilon_t$ $b_t = b_{t-1} + \beta\varepsilon_t$	M	$y_t = (l_{t-1} + b_{t-1}) (1 + \varepsilon_t)$ $l_t = (l_{t-1}) + b_{t-1}) (1 + \alpha\varepsilon_t)$ $b_t = b_{t-1} + \beta(l_{t-1} + b_{t-1}) \varepsilon_t$
AD	$y_t = l_{t-1} + \phi b_{t-q} + \beta\varepsilon_t$ $l_t = l_{t-1} + \phi b_{t-1} + \alpha\varepsilon_t$ $b_t = \phi b_{t-1} + \beta\varepsilon_t$	MD	$y_t = (l_{t-1} + \phi b_{t-1}) (1 + \varepsilon_t)$ $l_t = (l_{t-1} + \phi b_{t-1}) (1 + \alpha\varepsilon_t)$ $b_t = \phi b_{t-1} + \beta(l_{t-1} + \phi b_{t-1}) \varepsilon_t$

Where parameters: α: smoothing factor for the level, β: smoothing factor for the trend, ϕ: damping coefficient. And initial states: l: initial level components, b: initial growth components, which is estimated as part of the optimization problem.

Akaike Information Criterion[35]:

$$-2\log L(\hat{\theta}) + 2k \tag{1}$$

$\hat{\theta}$: maximum value of the likelihood function, k: number of estimated parameter.

Root Mean Squared Error(RMSE)[38]:

$$\sqrt{\frac{\Sigma_{t=1}^{n}(\hat{y}_t - y_t)^2}{n}} \tag{2}$$

$\hat{y}_t$: predicted values, y_t : actual values, n: number of observations.

Where, we use Akaike criterion for comparison between models of the same type, while we use RMSE to compare between different models.

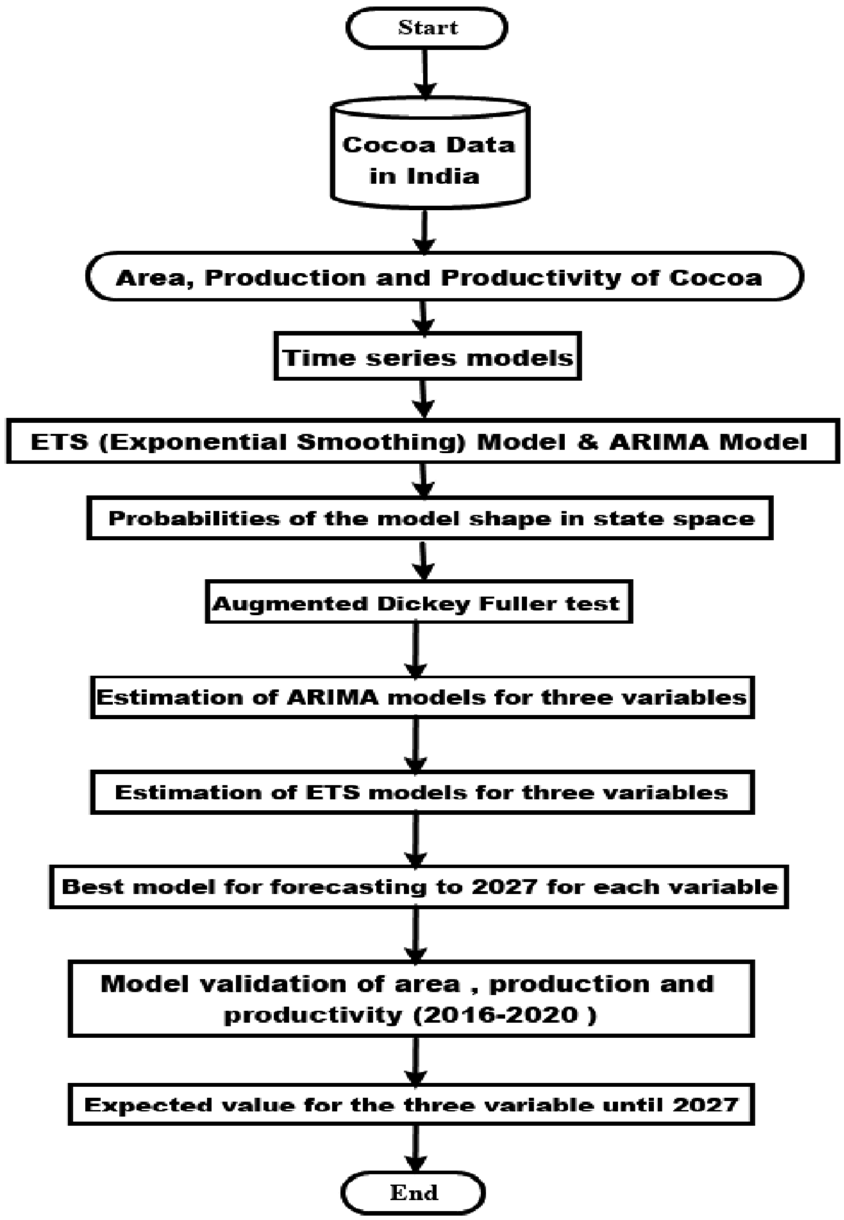


Figure 1: Represents the whole layout of our study

3. Results

Before developing the model, it is necessary to understand the nature of the data series. Descriptive statistics and data visualization make is easy to estimate the trends and patterns of the variables (Figure 1 & Table 2). The area and production of cocoa are followed as an increasing trend and productivity followed as decreasing trend.The linear increase in area and production during the studies time, punctuated by a slight decrease between 2010 and 2011. We also note a near-linear decrease in efficiency due to the area increasing more than production.

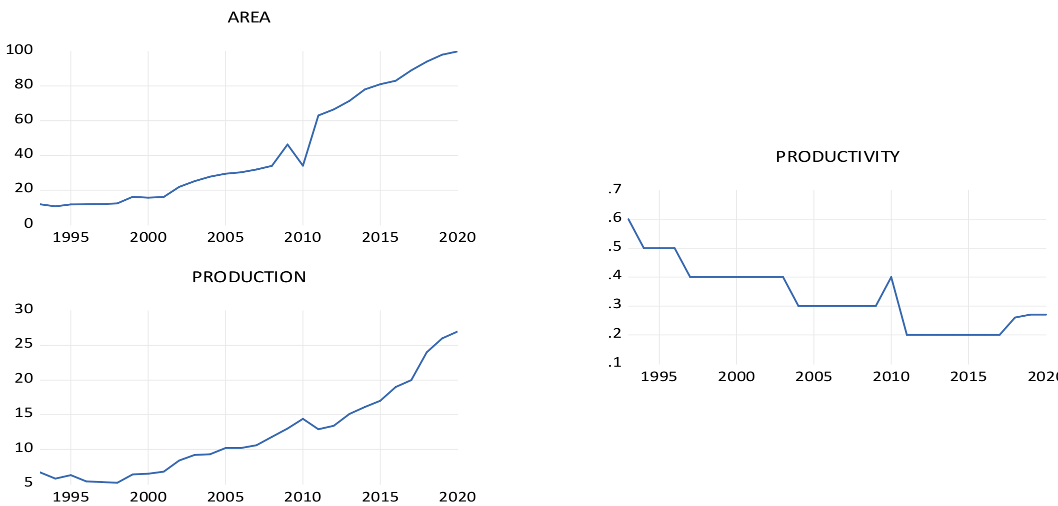


Figure 1: Plots of Area, Production and Productivity during the period 1993-2020

Table 2: Descriptive Statistics for Area, production and Productivity during the period 1993-2020

Variables	*Normality J-B (Prob)*	*Mean*	*Standard Deviation*	*Maximum*	*Minimum*	*Skewness*	*Kurtosis*
Area	0.193012	43.70	31.43	100.00	10.70	0.56	1.75
Production	0.149781	12.21	6.37	27.00	5.20	0.90	2.89
Productivity	0.462969	0.33	0.11	0.60	0.20	0.51	3.48

Note: Unit; Area- '000 Hectare; Production- '000MT; Productivity- MT/Hectare.

The Table 2 presents the most important descriptive statistics for the parameters. We note that the values of all variables are distributed normally, as p value obtained from JarqueBera test is greater than 0.05 (level of significance), so null hypothesis can not be rejected. Cocoa area under study registered from 10.70 to 100 ('000 Ha) with a higheraverage 43.70 and standard deviation 31.43, confirmed high scatterness than the production and productivity data series. Positive skewness (0.56) and kurtosis (1.75) gave an idea about the increase trending behavior observed from the study period. Cocoa production under study followed from 5.20 to 27.00 (‘000 MT) with an average and standard deviation are 12.21 and 6.37 respectively. Cocoa productivity under study registered from 0.20 to 0.60 (MT/ Ha), followed by 0.33 MT/ha average and 0.11 standard deviation. We note that the largest mean and standard deviation are for area with a large and stable development during the studied time.

The study period was divided into three sub periods for calculating sustainability index (i.e., Period I 1993-2006, Period II 2007-2020, and Period III 1993-2020 means overall period).The sustainability index of cocoa production from table 1 clearly showed that the Sustainability index is increased ,from (period 1) to (period 2) in SI 1, SI 2 and SI 3 that means meeting our own needs without compromising the ability of future generation to meet their own need (Table 3).

Sustainability Index of Cocoa Production

Sustainability Index	*Period 1 (1993-2006)*	*Period 2 (2007-2020)*	*Period 3 (1993-2020)*	*Formula used*	*Reference*
SI 1	0.4340	0.4388	0.2163	$\frac{\bar{Y}-S}{Y_{max}}$	Singh et al., 1990
SI 2	0.4041	0.5730	1.2105	$\frac{Y_{max}-\bar{Y}}{\bar{Y}}$	Sahu et al.,2005
SI 3	0.0393	0.0486	0.0819	$\frac{S_i}{Y_i}\times\frac{1}{S_{max}}$	Pal and Sahu, 2007

After visualizing the data series, it is required to check the degree of stationarity of the variables before the model development. Stationarity is the degrees of moment, which doesnotdeal with time by differencing the past and present value [32].Augmented dickey fuller test [39] was applied for stationarity test of all data series (Table 4).

Table 4: Augmented Dickey Fuller Test Result

Variables	*ADF (t. statistics)*		*Order of integration*
	Level I(0)	*First difference I(1)*	
Area	0.6696	-8.820226***	I(1)
Production	5.0098	-5.247757***	I(1)
Productivity	-3.1791	-7.111437***	I(1)

* significant at 10%, ** significant at 5%, *** significant at 1%

The table (5) shows that all variables are stationary at the first differenceat 1% level of significance, and this is mainly due to the general linear random trend that is clear from the graph.So, it is clear that the difference *i.e.*d= 1 of all data seriesfor developing ARIMA (p, d, q) model. Other two order *i.e.*$p$and q are determined by using partial autocorrelation (PACF) and autocorrelation function (ACF) respectively. The best ARIMA model was found for area, production and productivity of cocoa represent in Table 4 (training data; 80%). From the table,ARIMA (1,1,0) model was performed as best model for area and production data series and ARIMA (0,1,1) followed as best for productivity data series. All best ARIMA model selected based on lower value of AIC, RMSE and ACF1 [40, 41].

Table 5: Estimation of ARIMA Models for three Variables

Variables	*Model*	*Parameters ARIMA*					
		Drift	*AR*	*MA*	*AIC*	*RMSE*	*ACF1*
Area	(1,1,0)	3.329***	-0.435***	-	186.2	14.305	0.0295
Production	(1.1.0)	0.734***	0.258	-	95.9	3.158	0.0769
Productivity	(0,1,1)	-	-	-0.367*	-74.3	0.127	0.0407

* significant at 10%, ** significant at 5%, *** significant at 1%

After finding the best ARIMA model, based on our objective, we were tried to fit ETS model [34], as we have an enough evidence of trending nature of the data series. The best ETS model with parameter estimation and goodness of fit details is depicted in Table 6 (training data; 80%). From the table, best model for Area is (M.M.N), and the best model for production is (A.M.N), the best model for Productivity is (M.N.N). We notice that the level parameter is the most influential for area*i.e.*l (9.366) and b (1.093), and the direction parameter has the most influence for production and productivity *i.e.*α (0.925 and 0.974 respectively). All three best ETS models was selected based on lower value of goodness of fit *i.e.* AIC and RMSE.The value of the Q-stat is low ,which means that there is no autocorrelation in the residuals of the ETS model. Therefore,the model is valid for prediction

Table 6: Estimation of ETS models for three variables

Variables	*Model*	*Parameters ETS*			*Initial stats*		*AIC*	*RMSE*	*Q-STAT*
		α	β	ϕ	l	b			
Area	(M,M,N)	0.346	0.000	-	9.366	1.093	6.554	0.1367	5.894
Production	(A,M,N)	0.925	0.000	-	6.152	1071	3.114	0.909	1.789
Productivity	(M,N,N)	0.974	-	-	0.586	-	-2.872	0.144	2.373

After developing the best ARIMA and ETS model of area, production and productivity data series, we compared both models and tried to select best time series model for cocoa variables. The model selection was based on lower value of AIC and RMSE for training data series (Table 5&6). The selected best model for area; ETS(M,M,N), production; ETS(A,M,N) and productivity; ARIMA(0,1,1) (Table 6).

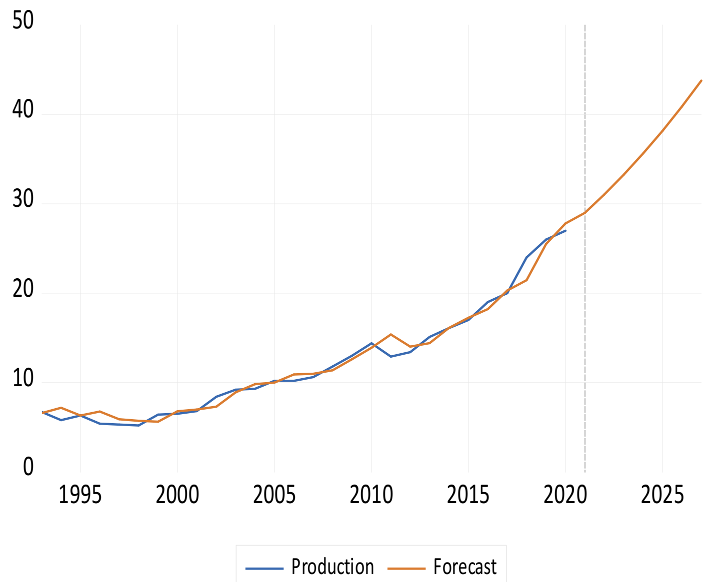
Table 7: The best model for forecasting to 2027 for each variable

Variables	*Area*	*Production*	*Productivity*
Model	ETS(M,M,N)	ETS(A,M,N)	ARIMA(0,1,1)

After selecting the best model, we tried to estimate the validation of the model by using the residuals obtained from the model of testing data series (Table 8). From the table, the RMSE value obtained for area, production and productivity are 0.1177, 0.584 and 0.1268 respectively. Also, we note that the best model achieves the least values for the RMSE,not only in of sample, but out of sampleand thus the true values approximate with the expected as shown in following Figure 2.

Table 8: Model Validations and Forecasting of Area, Production and Productivity 2016-2020

	2016		*2017*		*2018*		*2019*		*2020*		*RMSE*
States	*Obs.*	*Pred.*	*Obs.*	*Pred.*	*Obs.*	*Pred.*	*Obs.*	*Pred.*	*Obs.*	*Pred.*	
Area	83	89.37	89	95.26	94	101.75	98	108.27	100	114.45	0.1177
Production	19	18.23	20	20.29	24	21.45	26	25.50	27	27.81	0.584
Productivity	0.20	0.34	0.20	0.33	0.26	0.32	0.27	0.30	0.27	0.29	0.1268



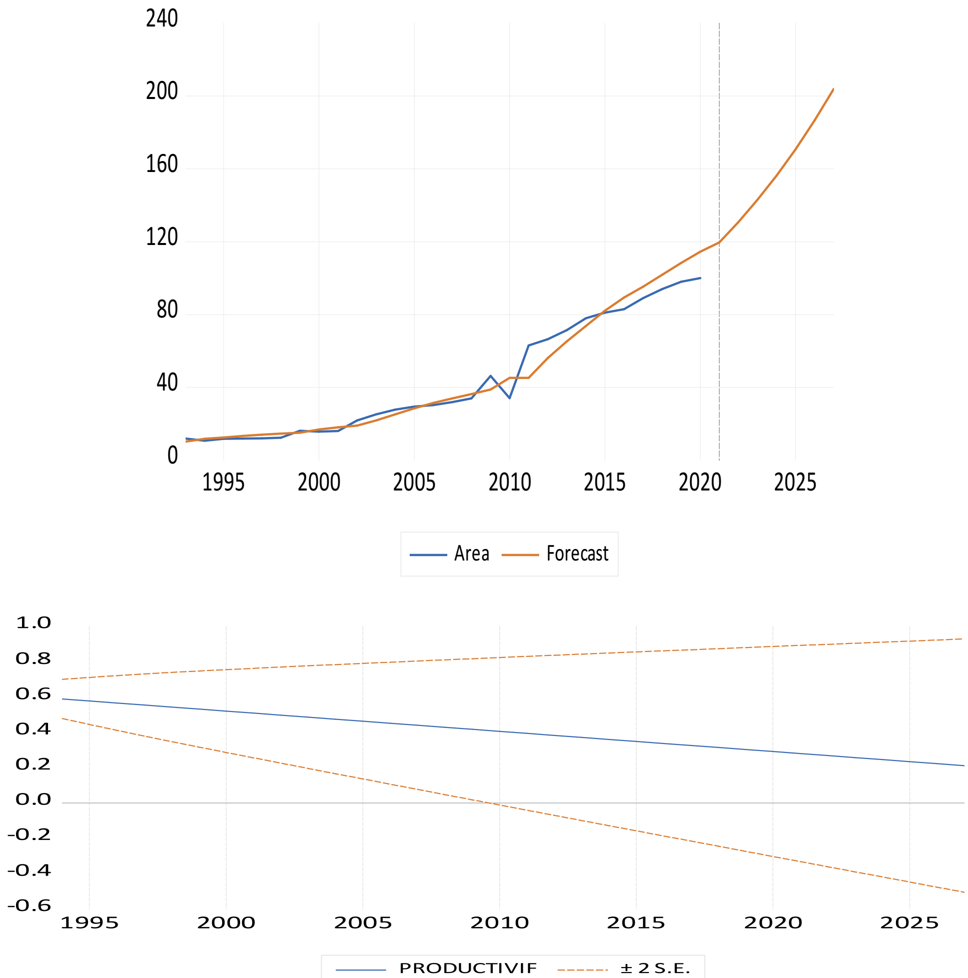


Figure 2: Area – Production - Productivity forecast by ETS to 2027

The figure 2 shows us that the calculated values using the model are close to the actual data and go in the same trend. Thus, we find the increasing trend of area and production and the decreasing trend in each of (productivity), which can be obtained from the following Table 8.We note from the table that the area is expected to develop from 119.61 in 2021 to 203.90 and production from 28.98 to 43.78. and productivity from 0.279 to 0.2108 in 2027.We also note from the table 8, the future simple growth rate for area expected to be increased as 10.06% and for production 7.29%. But for productivity data series, it has expected as decreasing growth rate -3.51% from 2021 to 2027 of cocoa. So, it is required to make an attention of productivity of cocoa. The main challenges of cocoa production such as sustainable livelihoods for farmers, climatic changes should be minimized to overcome the declining productivity problem.

Table 8: The expected value for the three variables until 2027

	AREA	*Production*	*Productivity*
		Forecast	
2021	119.6176	28.98659	0.279506
2022	130.7377	31.04978	0.26806
2023	142.8916	33.25983	0.256614
2024	156.1754	35.62719	0.245168
2025	170.6941	38.16305	0.233722
2026	186.5625	40.8794	0.222275
2027	203.9061	43.7891	0.210829

4. Conclusions

Taking into account the increasing demand for cacao around the world, the quest to obtain models and forecasts for cocoa's land area, production, and productivity as well as the debate over which model to use for cocoa's land area, production, and productivity may be useful in providing some of the information required to address these issues and to guide the cocoa research agenda. After much deliberation, we found that the best models for area, production, and productivity are ETS (M, M, N), ETS (A,M,N) and ARIMA (0,1,1), respectively, and that these models may provide answers and direction on these topics pertaining to cocoa output, area, and productivity in India.We also conclude that, the forecast estimation obtained from the best model; area and production of cocoa is expected to an increasing trend, whereas for the productivity of cocoa is expected as decreasing trend. So, it is more concern to look into this problem of cocoa productivity. We strongly estimated that, this study will bring the literature of adaptation of time series model in agricultural commodities. Also, this research will provide a strong decision-making criterion of cocoa production for researchers and policy makers.

Conflicts of Interest

The authors declare no conflict of interest.

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