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Prediction of area, production and productivity of total fruit crops in Gujarat

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Abstract
Horticulture is the cardinal sector and contributes more towards economic growth in all over the world especially in developing countries. In India, horticulture is accelerating the economic growth and contributes 30.4 per cent of agricultural GDP. Gujarat gives prominent contribution to the Indian horticulture sector and contributes nearly 14 to 20 per cent share in major fruits and vegetables like sapota, papaya, onion, banana and lime. The state is the largest producer of cumin in the world and also has the highest productivity in custard apple and guava in India. The area, production and productivity of fruit crops in Gujarat from 1887-88 to 2015-16 has selected as variables for this forecasting study. Compound Growth Rate employed to find out the trends in area, production and productivity of total fruit crops which revealed the growth rate of area and production has been increasing and significant rather than productivity. Exponent Smoothing Model used to remove the random fluctuations in time series data and ARMIA model were employed to make the data into time series stationary. This research discovered that exponential smoothing model was found to be the best model for forecasting area and productivity, whereas the ARIMA model best described production.

Keywords: Fruit crops, time series, compound growth rate, exponential smoothing model, ARIMA

Introduction
Fruits are essential for balanced diet and good health as it is good sources of vitamins, minerals and fiber. It improves the socio-economic condition of farmers, and has become a means of improving livelihood for many unprivileged classes too. Being a country having varied climatic conditions, India has very immense potential for the production of different fruits. India ranks second in fruit production, after China. In India, Gujarat (9%) ranks third after Maharashtra (15%) followed by Andhra Pradesh (12%) (Horticultural Statistics at a Glance 2015). Gujarat, despite being third largest producing state, there still exist huge gap between per capita requirement and availability. It is therefore needed to reform policies in order to minimize the gap between two. Yield forecasting is an important way to support policy decisions for fruit crops in order to introduce confidence amongst the farming community for their socio-economic issues. In view of globalization, it is imperative to study trend of area, production and productivity of fruit crops by employing sound statistical modeling techniques. Thus, modeling and forecasting the area, production and productivity of total fruit crop over the years is of much practical importance. Hamjah (2014) [3] forecasted major fruit crops productions in Bangladesh using Box- Jenkins ARIMA model. Hossain and Abdulla (2015) [4] computed time series analysis for the pineapple production in Bangladesh. Hossain (2016) [5] forecasted banana production in Bangladesh by using different statistical models. Kumari *et al.*, (2016) [8] forecasted yield of pigeon pea in Vanaransi region by using different statistical models. Kumari *et al.*, (2017) [9] investigated forecasting models for predicting pod damage of pigeon pea in Varanasi region. Kumar and Kumari (2021) [7] forecasted area, production and productivity of sapota in Gujarat. Unjia *et al.*, (2021) [10] investigated trend analysis of area, production and productivity of maize in India. Kumar *et al.* (2022) [6] calculated trend analysis of area, production and productivity of minor millets in India. With respect to above literature the main purpose of the study was to evaluate the different statistical models for predicting area, production and productivity of fruit crops in Gujarat. The following goals were set for the current research:

1. To study compound growth rate for area, production and productivity of fruit crops.
2. To develop appropriate Exponential Smoothing (ES) models for forecasting area, production and productivity of fruit crops.
3. To develop appropriate Autoregressive Integrated Moving Average (ARIMA) models for forecasting area, production and productivity of fruit crops.

Methodology
Source of data
Time series secondary data on area, production and productivity of total fruit in Gujarat from 1987-88 to 2015-16 were collected from Directorate of Horticulture, Govt. of Gujarat.

Analytical framework
Compound Growth Rate (CGR)
Compound growth rates were worked out for studying the trends in area, production and productivity of total fruit crop in Gujarat. The log linear function was used to estimate compound growth rates.
Annual compound growth rates (CGR) of area, production and productivity were calculated by following log linear function:

$$Y_t = A\,(1 + r)^t \qquad \text{………… (1)}$$

Where Y_t= Area / Production / productivity at time t; r = Compound growth rate
Taking log on both sides of equation (1)

$$\text{Log } Y_t = \text{Log } A + t \text{ Log } (1 + r) \qquad \text{………… (2)}$$

Putting Log Y_t= Y, Log A = a and Log (1 + r) = b, Eq(2) will become

$$Y = a + bt, \qquad \text{………… (3)}$$

Where, $r = (e^b - 1) \times 100$= CGR

There are two main approaches for forecasting i.e. explanatory (Causal model) and extrapolation method (Time series model). It is possible that both approaches will lead to the creation of accurate and useful forecasts but the former method is often more difficult to implement than the latter one because of various assumptions fulfilment requirement and data availability requirement.
Therefore, in the present study, two time series forecasting models were used to compare their ability for predicting future behavior of area, production and productivity of total fruit crops in Gujarat. Time series models used in the present investigation are:
1. Exponential Smoothing (ES) model
2. Autoregressive Integrated Moving Average (ARIMA) model

Exponential Smoothing (ES) model
Smoothing techniques are used to reduce irregularities (random fluctuations) in time series data. One of the most successful univariate time series forecasting technique is the exponential smoothing (ES) to produce a smoothed time series. In this technique, forecasts are weighted averages of past observations, with the weights decaying exponentially as the observations get older. In other words, recent observations are given relatively more weight in forecasting than the older observations. Exponential smoothing method is classified according to the type of component (trend and seasonality) presented in the time series data. In the present study, based on time series data, only two exponential smoothing methods are used i.e. simple exponential and double exponential smoothing technique.

1. Simple Exponential Smoothing (SES)
This method is suitable for forecasting data with no trend or seasonal pattern, although the mean of the data may be changing slowly over time. Forecasts are calculated by taking weighted averages of most recent observation and most recent forecast, where the weights decrease exponentially as observations come from further in the past.

Forecast equation $\hat{y}_{t+1/t} = l_t$
Level equation $l_t = \alpha y_t + (1 - \alpha) l_{t-1}$

Simple exponential smoothing has a flat forecast function, and therefore for longer forecast horizons,

$$\hat{y}_{t+h/t} = \hat{y}_{t+1/t} = l_t$$

2. Holt's linear trend(double) exponential smoothing method
Holt (1957) extended simple exponential smoothing to allow forecasting for those data which exhibit trend. This method involves a forecast equation and two smoothing equations (one for the level and one for the trend):

Forecast equation $\hat{y}_{t+1/t} = l_t + h b_t$
Level equation $l_t = \alpha y_t + (1 - \alpha)(l_{t-1} + b_{t-1})$
Trend equation $b_t = \beta(l_t - l_{t-1}) + (1 - \beta) b_{t-1}$

Where
y_t, $\hat{y}_t$ is observed and predicted value of series at time t
l_t and b_t are estimate of the level and trend (slope) of the series at time t
α, β are the smoothing parameter for the level and trend, $0 \le \alpha, \beta \le 1$

Initialisation
The application of every exponential smoothing method requires the initialisation of the smoothing process. For simple exponential smoothing we need to specify an initial value for the level, l_0. Similarly, double exponential smoothing involves initial value trend component b_0 also.

Model	Initial Values
Single	$L_0 = y_1$
Double	$L_0 = y_1, b_0 = y_2 - y_1$

In exponential smoothing, the method for obtaining the optimal values of smoothing parameters α and β is an iterative process which is chosen either by trial and error method or by some software like *MINITAB*, EViews, SPSS etc. which use an algorithm to select the value of the weights that minimizes mean square error for in-sample forecasts. In the present study, Expert Modeler option of SPSS 19.0 software is used to obtain appropriate values of all three parameters.

Autoregressive Integrated Moving Average (ARIMA) model
ARIMA models provide another approach to time series forecasting. Exponential smoothing and ARIMA models are the two most widely-used approaches to time series forecasting, and provide complementary approaches to the problem. While exponential smoothing models were based on

a description of trend and seasonality in the data, ARIMA models aim to describe the autocorrelations in the data.
ARIMA is one of the most traditional methods of non-stationary time series analysis. Usually time series, showing trend or seasonal patterns are non-stationary in nature. In such cases, differencing and power transformations are often used to remove the trend and to make the series stationary.
Box-Jenkins ARIMA, has been successfully applied in many time series forecasting and is a good tool to develop empirical model which is linear combination of its own past values, past errors (also called shocks or innovations).
ARIMA model allows Y_t to be explained by its past, or lagged values and stochastic error terms. The non-seasonal ARIMA (p,d,q) model can be written as:

If $w_t = \nabla^d y_t = (1-B)^d y_t$ then

$$w_t = \phi_1 w_{t-1} + \phi_2 w_{t-2} + ... + \phi_p \ w_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - ..... - \theta_q \varepsilon_{t-q}$$

Where
P: order of the autoregressive part;
d: degree of differencing involved;
q: order of the moving average part.
w_t & ε_t: Differenced data series and white noise
ϕ & θ: Autoregressive and moving average coefficient

The main stages in setting up a Box-Jenkins forecasting model are model identification, estimating the parameters, diagnostic checking of residual and forecasting.

Research Results
The trend in area, production and productivity of total fruit crop in Gujarat were investigated first, by estimating compound growth rate (CGR) [Table 1] and tested for their significance (by applying t-test).

Table 1: CGR of area, production and productivity of total fruit crop

Year	Compound Growth Rate (CGR)		
	Area	Production	Productivity
1987-88 to 1996-97	6.52**	2.60*	-3.68*
1997-98 to 2006-07	7.35**	10.80**	3.21**
2007-08 to 2015-16	2.41**	4.48**	2.02**
1987-88 to2015-16	6.24**	6.87**	0.59

Table 1 revealed thatgrowth in area, production and productivity of total fruit crop in Gujarat for the period 1987-88 to 1996-97, 1997-98 to 2006-07 and 2007-08 to 2015-16, appeared to be positive and highly significant. For the overall period, growth rate in area and production are also found to be increasing and highly significant while in case of productivity it is found to be non-significant. The results of the investigation were discussed below.

Forecasting total fruit crop area

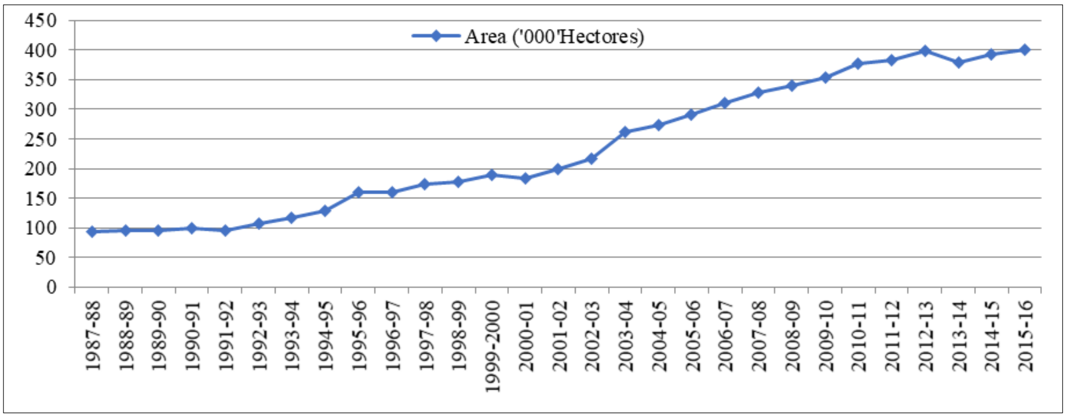

Fig 1: Area under total fruit crops in Gujarat during 1987-88 to 2015-16

It can be inferred from Fig. 1, that the series is not stationary because the mean of the time series is increasing with the increase in time.
In case of fitting exponential smoothing model, the performance of Brown's double exponential model was found to be the best out of various parametric combination. The results were shown in Table 2 and 3.
The Table 2 shows that the estimate of alpha (level and trend) 0.566 with standard error of 0.086 and was statistically significant also. The values of the fit statistics namely R^2, RMSE and normalized BIC were found as 0.98, 12.54 and 5.18 respectively at the model fitting phase (Table 3). Also, residual autocorrelations are non-significant as Q statistics is non-significant.

Table 2: Exponential smoothing model parameters for area

Model		Estimate	SE	T	Sig.
Area-Model_1	Alpha (Level and Trend)	.566	.084	6.716	.000

Table 3: Exponential smoothing model fit statistics for area

Model	Model Fit statistics				Ljung-Box Q(18)		
	Stationary R-squared	R-squared	RMSE	Normalized BIC	Statistics	DF	Sig.
Area-Model_1	.454	.987	12.549	5.175	16.626	17	.480

The forecasted value of total fruit crops area in Gujarat for the year 2016-17 was obtained as 406.30 ('000' Hectares) with confidence interval 432.00 to 380.59.
In case of fitting ARIMA model, out of various ARIMA models with different value of p, d and q, the performance of ARIMA (0,1,0) model was found to be the best. The results were given in Table 4 and 5.
The table 4 shows that the estimate of constant 10.950 and found to be statistically significant. The values of the fit statistics of ARIMA model namely R^2, RMSE and normalized BIC were found as 0.98, 12.22 and 5.12 respectively (Table 5). Also, residual autocorrelations were found to be non-significant.

Table 4: ARIMA model parameters

		Estimate	SE	T	Sig.
Area-Model_1	Constant	10.950	2.310	4.740	.000
	Difference	1			

Table 5: ARIMA model fit statistics for area

Model	Model Fit statistics				Ljung-Box Q(18)		
	Stationary R-squared	R-squared	RMSE	Normalized BIC	Statistics	DF	Sig.
Area-Model_1	.000	.988	12.225	5.126	18.157	18	.445

The forecasted value of total fruit crops area in Gujarat for the year 2016-17 was obtained as 412.88 ('000' Hectares) with confidence interval 437.82 to 387.95.

Forecasting of total fruit crop production

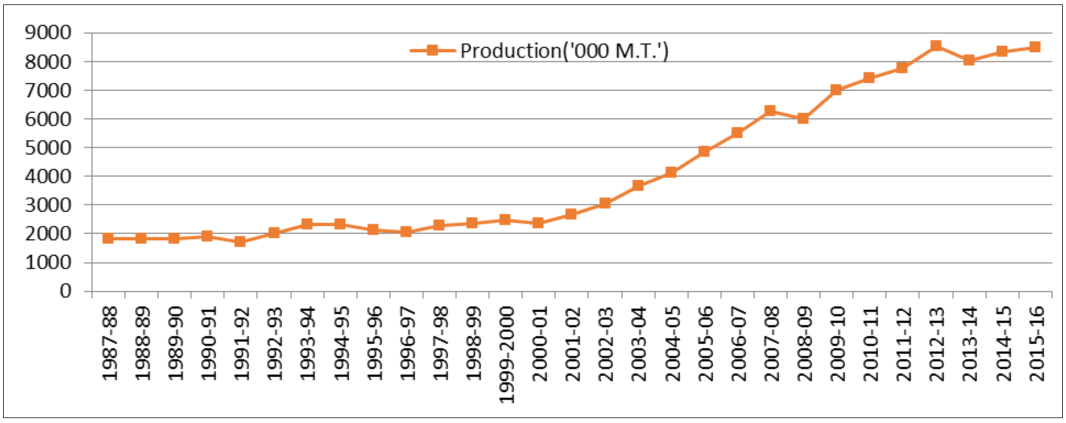

Fig 2: Production of total fruit crops in Gujarat during 1987-88 to 2015-16

It is clear from Fig. 2, that the time series is stationary up to 1999-2000 and showing an increasing trend since 2001-02. In exponential smoothing model, the performance of Brown's double exponential model was found to be the best out of all. The results were shown in Table 6 and 7.
The table 6 shows that the estimate of alpha (level and trend) 0.544 and also statistically significant. The values of the fit statistics namely R^2, RMSE and normalized BIC were found as 0.98, 336.46 and 11.75 respectively (Table 7). Residual autocorrelations were found to be non-significant as Q.

Table 6: Exponential smoothing model parameters for production

Model		Estimate	SE	T	Sig.
Prod-Model_1	Alpha (Level and Trend)	.544	.085	6.374	.000

Table 7: Exponential smoothing model fit statistics for production

Model	Model Fit statistics				Ljung-Box Q(18)		
	Stationary R-squared	R-squared	RMSE	Normalized BIC	Statistics	DF	Sig.
Production-Model_1	.498	.982	336.457	11.753	10.738	17	.870

The forecasted value of total fruit crop production in Gujarat for the year 2016-17 was obtained as 8703.98 ('000' M.T.) with confidence interval 9393.18 to 8014.78.
In case of fitting ARIMA model, out of various ARIMA models with different value of p, d and q, the performance of ARIMA (2,1,3) model was found to be the best where all lags of MA are found to be non-significant (table 8). The values of the fit statistics namely R^2, RMSE and normalized BIC were found as 0.987, 320.44 and 12.53 respectively (Table 9).

Table 8: ARIMA model parameters for production

			Estimate	SE	T	Sig.
Production-Model_1	Constant		248.178	27.211	9.121	.000
	AR	Lag 1	1.935	.068	28.301	.000
		Lag 2	-.993	.074	-13.451	.000
	Difference		1			
	MA	Lag 1	2.380	1.598	1.490	.150
		Lag 2	-1.812	2.146	-.844	.408
		Lag 3	.422	.635	.664	.513

Table 9: ARIMA model fit statistics for production

Model	Model Fit statistics				Ljung-Box Q(18)		
	Stationary R-squared	R-squared	RMSE	Normalized BIC	Statistics	DF	Sig.
Production-Model_1	.339	.987	320.44	12.253	11.177	13	.596

The forecasted value of total fruit crop production in Gujarat for the year 2016-17 was obtained as 8496.43 ('000' M.T.) with confidence interval 9107.46 to 7885.40.

Forecasting of total fruit crop productivity

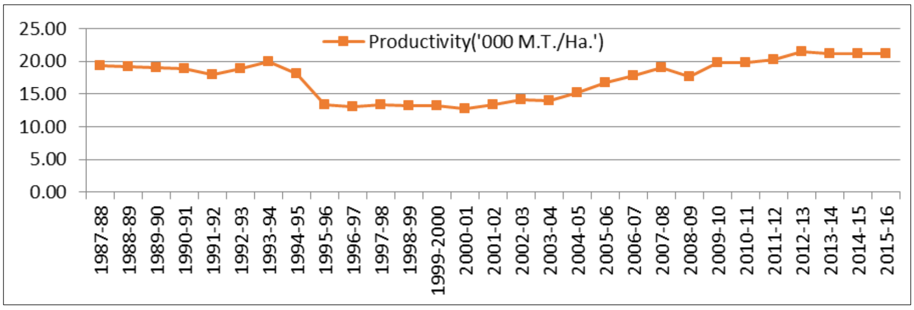

Fig 3: Productivity of total fruit crops in Gujarat 1987-88 to 2015-16

Fig. 3, indicates that the time series is stationary over long period of time. In exponential smoothing model, the performance of simple exponential model was found to be the best out of all where the estimate of alpha 1.00 and also statistically significant. The values of the fit statistics namely R^2, RMSE and normalized BIC were found as 0.82, 1.26 and 0.578 respectively (Table 10 & 11). Residual autocorrelations were found to be non-significant as Q.

Table 10: Exponential smoothing model parameters for productivity

Model		Estimate	SE	t	Sig.
productivity -Model_1	Alpha (Level)	1.00	.189	5.292	.000

Table 11: Exponential smoothing model fit statistics for productivity

Model	Model Fit statistics				Ljung-Box Q(18)		
	Stationary R-squared	R-squared	RMSE	Normalized BIC	Statistics	DF	Sig.
productivity-Model_1	-.003	.826	1.260	.578	13.083	17	.731

The forecasted value of total fruit crop yield in Gujarat during the year 2016-17 was obtained as21.21 with confidence interval 23.79 to 18.63 (M.T./ha.).

In case of fitting ARIMA model, out of various ARIMA models with different value of p, d and q, the performance of ARIMA (1,0,0) model was found to be the best. The estimate of constant and AR at lag 1 are 4,28 and 0.91 were found to be significant (table 12). The values of the fit statistics namely R^2, RMSE and normalized BIC were found as 0.82, 1.275 and 0.718 respectively (Table 13). Residual autocorrelations were found to be non-significant as Q.

Table 12: ARIMA model parameters for productivity

			Estimate	SE	T	Sig.
productivity-Model_1	Constant		4.288	.249	17.242	.000
	AR	Lag 1	.907	.077	11.773	.000

Table 13: ARIMA model fit statistics for productivity

Model	Model Fit statistics				Ljung-Box Q(18)		
	Stationary R-squared	R-squared	RMSE	Normalized BIC	Statistics	DF	Sig.
productivity-Model_1	.826	.828	1.275	.718	15.926	17	.529

The forecasted value of total fruit crop productivity in Gujarat for the year 2016-17 was obtained as 20.96 with confidence interval 23.97 to 18.12(M.T./ha.).

Comparison of performance of model

Table 14: Comparison of model performance

Results	Model Accuracy and forecasted value	Exponential	ARIMA
Area	Model description	Brown	ARIMA (0,1,0)
	Forecast	406.30	412.88
	RMSE	12.54	12.25
Production	Model description	Brown	ARIMA (2,1,3)
	Forecast	8703.98	8496.43
	RMSE	336.45	320.44

Yield	Model description	Simple	ARIMA (1,0,0)
	Forecast	21.21	20.96
	RMSE	1.26	1.275

Conclusion

The present investigation aimed to forecast area, production and productivity of total fruit crop in Gujarat with the help of Exponential Smoothing Model and Autoregressive Moving Integrated Moving Average Model (ARIMA). On the basis of result obtained, it is concluded that Exponential Smoothing Model was found to be the best suitable model predicting area and productivity of total fruit crop while production was best explained by ARIMA model.

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