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Forecasting area, production and productivity of citrus in Gujarat by using GARCH, eGARCH and TAR models

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Abstract
In this study, the GARCH, eGARCH, and TAR models were used in order to forecast citrus area, production and productivity in Gujarat. Secondary statistics on sapota production, area and productivity were provided by the Directorate of Horticulture in Gujarat from 1991-1992 to 2016-17. Throughout the period 1958-1959 to 2016–2017, time series secondary data on citrus area, production and productivity were collected. Analysis of the data was carried out using the R Studio software (version 3.5.2). To predict citrus production, area and productivity in Gujarat, GARCH, eGARCH and TAR models were used. GARCH was found to be the most effective model for explaining citrus area for 2017-18, with a forecast value of 45.85 ('000' Ha). Citrus production and productivity were best described by the TAR model, with anticipated values of 615.32 ('000' MT) and 9.29 (MT/ha).

Keywords: Forecasting, area, production, productivity, citrus, autoregressive conditional heteroscedastic (ARCH) model, exponential generalized autoregressive conditional heteroscedastic (eGARCH) model and threshold autoregressive (TAR) model

Introduction
India is the world's second largest producer of fruits and vegetables, trailing only China. Horticultural crops account for a considerable share of India's total agricultural output. It has a large agriculture area and contributes around 28% of the Gross Domestic Product (GDP). It accounts for 37% of total agricultural commodity exports from India. India achieved its highest-ever horticultural production of 320.77 million tonnes from an area of 25.66 million hectares. Gujrat is the main producer of citrus in India, followed by Maharashtra, Madhya Pradesh, Tamil Nadu, Assam, Orissa, and West Bengal. Citrus farmed 81.0 ('000 Hectare) and produced 704 ('000 MT) with a productivity of 8.7 (MT/Hectare) in 2019-20. (National Horticulture Board, 2019-2020). Gujarat in India produced 6,00,000 tonnes (National Horticulture Board, 2017-2018).

Methodology
Source of data
Gujarat's Directorate of Horticulture, Government of Gujarat, provided secondary statistics on citrus area, production and productivity between 1991-1992 and 2016-17. Over the period of 1958-59 to 2016-17, secondary data has been collected on the citrus area, production and productivity over time.

Autoregressive Conditional Heteroscedastic (ARCH) Model
In ARCH models based on the variance of the error term at the time t, the squared error term values in previous time periods play an important role in determining the value of the error term at the time t. The model is specified as:

$$y_t = u_t$$

$$u_t \sim N(0, h_t)$$

$$h_t = \alpha_0 + \sum_{t=1}^{q} \alpha_j u_{t-i}^2$$

ARCH(q) refers to this model, where q denotes the order in which the lagged squared returns are included within the model. As a result of using ARCH (1) model,

$$h_t = \alpha_0 + \alpha_1 u_{t-1}^2$$

In order to be meaningful, h_t must always be strictly positive, since it is a conditional variance; a negative variance at any moment of time would be meaningless. It is usually required that all coefficients in the conditional variance be non-negative in order to obtain a positive estimate. Thus, coefficients must be satisfied $\alpha_0 > 0$ and $\alpha_1 \geq 0$.

Generalized Autoregressive Conditional Heteroscedastic (GARCH) Model

GARCH (p, q) is a model developed by Bollerslev (1986) and Taylor (1986). It is possible to use the conditional variance of variables as a regression model in which the conditional variance is dependent upon the past lags. The first lag is the squared residual from the mean equation, and the present lag represents the volatility from the last period, which is as follows:

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i}$$

GARCH (1,1) is the most widely used and simple model in literature, whose conditional variance is expressed as follows:

$$h_t = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 h_{t-1}$$

The unconditional variance h_t, as defined by the covariance stationarity hypothesis, can be estimated by taking the unconditional expectation of the above equation, as described below.

$$h = \alpha_0 + \alpha_1 h + \beta_1 h$$

$$h = \frac{\alpha_0}{1 - \alpha_1 - \beta_1}$$

For this unconditional variance to exist, it must be the case that $\alpha_1 + \beta_1 < 1$ and for it to be positive, we require that $\alpha_0 > 0$.

Exponential Generalized Autoregressive Conditional Heteroscedastic (eGARCH) Model

Nelson (1991) proposed an exponential GARCH (EGARCH) equation with leverage effects. A conditional covariance specification for the EGARCH model looks as follows:

$$\log(h_t) = \alpha_0 + \sum_{j=1}^{q} \beta_j \log(h_{t-j}) + \sum_{i=1}^{p} \alpha_i \left| \frac{u_{t=i}}{\sqrt{h_{t=i}}} \right| + \sum_{k=1}^{r} \gamma_k \frac{u_{t-k}}{\sqrt{h_{t-k}}}$$

The EGARCH formulation has two advantages over the pure GARCH specification; those parameters will be positive even if they are negative, and asymmetries are acceptable.

In the equation γ_k represent leverage effects which accounts for the asymmetry of the model. While the basic GARCH model requires the restrictions the EGARCH model allows unrestricted estimation of the variance.

If $\gamma_k < 0$ it indicates leverage effect exist and if $\gamma_k \neq 0$ impact is asymmetric. The meaning of leverage effect bad news increase volatility.

It has been observed that GARCH residuals are often heavy tailed when applied to series resulting from GARCH models. Instead of using the normal distribution for students' t and GEDs, ARCH/GARCH models are employed to accommodate this.

Threshold Autoregressive (TAR) Model

It is generally understood that when a variable exceeds a particular threshold, the process may behave differently. In other words, for values above a threshold, a different model may apply than for values below. As defined by the dependent variable, TAR models are estimated separately in two or more intervals. There may or may not be a similarity in the order of these AR models.

In a threshold Autoregressive model, the parameters change according to the value of an exogenous threshold variable as a result of the value of a threshold variable. This can be considered an extension of autoregressive models. A Self-Exciting Threshold Autoregressive Model (SETAR) is a model where the past value of the time series itself is substituted for the threshold value.

TAR model:

$$y_t = \begin{cases} \beta_{10} + \beta_{11} y_{t-1} + u_{1t} & \text{if } s_{t-d} < r \\ \beta_{20} + \beta_{21} y_{t-1} + u_{2t} & \text{if } s_{t-d} \geq r \end{cases}$$

SETAR model:

$$y_t = \begin{cases} \beta_{10} + \beta_{11} y_{t-1} + u_{1t} & \text{if } y_{t-d} < r \\ \beta_{20} + \beta_{21} y_{t-1} + u_{2t} & \text{if } y_{t-d} \geq r \end{cases}$$

A delay parameter, d, is used to trigger the change from one regime to the other. It is possible to use these models to analyze time series data that exhibits regime switching behavior. However, there is a discontinuity in the threshold value of the model in this case. TAR can be generalized into Smooth Transition Autoregressive (STAR) model by replacing threshold value with smooth transition function.

Results and Discussion

Forecasting of area, production and productivity for Citrus

Forecasting of area for citrus

Figure 1 illustrates citrus area datasets from 1991-92 to 2016-17. In addition, Table 1 provides basic statistical information regarding the data set used.

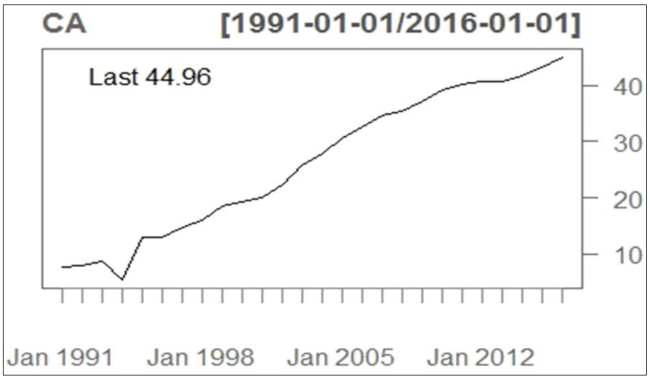

Fig 1: Area (In ' 000 Hectare) under citrus in Gujarat

Table 1: Summary statistics of citrus area

No. of observations	26
Minimum	5.5
Maximum	44.97
Mean	26.22
Median	26.92
Standard Deviation	12.93
Sem	2.54
Variance	166.82
Skewness	-0.11
Kurtosis	-1.53

Table 2: ARIMA (1,1,0) model parameters for area of citrus

Model	Parameter estimation	
ARIMA (1,1,0) with drift	Estimate (S.E.)	Sig.
Drift	1.50 (0.24)	<0.01
AR1	-0.36 (0.18)	<0.05
Forecast Value 2017-18 (C.I.)	46.39 (43.06 to 49.72)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
101.55	0.92	
Lagrange-Multiplier test:		
order	LM test statistics	p. value
4	17.14	<0.01

Table 2 indicates that each parameter estimate was statistically significant. Additionally, Box-Ljungtest statistics indicate that residual autocorrelation is not significant, with a probability value of 0.92. For the year 2017-18, ARIMA (1,1,0) with drift forecasted citrus areas in Gujarat at 46.39 hectares (000 ha) with confidence intervals ranging from 43.06 to 49.72.

Testing of ARCH Effect

Based on the Box-Jenkins method, the residuals are assumed to remain constant over time. To test whether residuals remain constant during the fitting of the ARIMA model on all the series, the ARCH-Lagrange multiplier (LM) test was conducted. This test revealed that the present series is subject to ARCH effect. As shown in Table 2, Lagrange-Multiplier (LM) test statistics were significant up to lag 4 for autocorrelation of squared residual.

Autoregressive conditional heteroscedastic (ARCH) model/ Generalized ARCH (GARCH)

The most suitable parametric combination of GARCH (ARCH) model was arma (1,1) + garch (0, 1), out of several possible combinations. In Table 3, the results are presented.

Table 3: Arma (1,1) + garch (0, 1) model parameters for area of citrus

Model	Parameter estimation	
arma (1,1) + garch (0, 1)	Estimate (S.E.)	Sig.
Mu	57.06 (7.47)	<0.01
AR1	0.93 (0.02)	<0.01
MA1	0.13 (0.15)	NS
Omega	0.12 (0.06)	<0.05
beta1	0.61 (0.05)	<0.01
Forecast Value 2017-18 (C.I.)	45.85 (44.56 to 46.75)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
44.01	0.82	
Lagrange-Multiplier test:		
order	LM test statistics	p. value
6	0.08	NS

A significant difference was found in the estimates of all parameters, except MA1 of the weapon model, as shown in Table 3. According to the Box-Ljung test statistics probability value of 0.82, residual autocorrelation was also not statistically significant. As a result of arma (1,1) + garch (0,1), the forecasted citrus area in Gujarat for 2017-18 has been calculated to be 45.85 ('000' Hectares), with a confidence interval of 44.56 to 46.75. Also, Lagrange-Multiplier (LM) test statistics for autocorrelation of squared residual of this model was found to be non-significant up to the lag 6.

Exponential Generalized ARCH (eGARCH)

Among various parametric combinations of the eGARCH model, arma (1,1) + eGARCH (1, 1) was identified as the best combination for fitting eGARCH models. As shown in Table 4, the results were as follows.

Table 4: Arma (1,1) + egarch (1, 1) model parameters for area of citrus

Model	Parameter estimation	
arma (1,1) + egarch (1, 1)	Estimate (S.E.)	Sig.
Mu	68.67 (0.03)	<0.01
AR1	0.96 (0.002)	<0.01
MA1	0.03 (0.009)	<0.01
Omega	-0.08 (0.01)	<0.01
alpha1	-0.69 (0.03)	<0.01
beta1	0.89 (0.02)	<0.01
Forecast Value 2017-18 (C.I.)	45.83 (44.89 to 46.01)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
44.52	0.88	
Lagrange-Multiplier test:		
order	LM test statistics	p.value
7	0.84	NS

It can be seen from Table 4 that all parameters were significant at all levels. Based on the Box-Ljung test statistics probability value of 0.88, residual autocorrelation was also non-significant. Using arma (1,1) + egarch (1,1) as the forecasting method, the estimated citrus area in Gujarat for 2017-18 was 45.83 ('000' Hectares) with a confidence interval of 44.89 to 46.01. Also, Lagrange-Multiplier (LM) test statistics for autocorrelation of squared residual of this model was found to be non-significant up to the lag 7.

Self-Exciting Threshold Auto Regressive (SETAR) models

SETAR model delay = 0 was found to be the best fit out of various parametric combinations when fitting SETAR model. In Table 5, the results are presented.

Table 5: SETAR (2, 3, 1) delay = 0model parameters for area of citrus

Model	Parameter estimation	
SETAR (2, 3, 1) delay = 0	Estimate (S.E.)	Sig.
Lower Regime estimate		
Intercept	6.47 (0.91)	<0.01
Lag1	0.13 (0.10)	NS
Lag2	0.38 (0.10)	<0.01
Lag3	0.27 (0.11)	<0.05
Upper Regime estimate		
Intercept	5.36 (0.97)	<0.01
Lag1	0.89 (0.02)	NS
Forecast Value 2017-18 (C.I.)	40.80 (39.33 to 42.10)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
50.97	0.36	

According to table 5, all parameters were significant with the exception of Lag1 for the lower and upper regimes. A probability value of 0.36 was also obtained for residual autocorrelation based on the Box-Ljung test statistics. As a result of SETAR (2, 3, 1) delay = 0, the forecasted value of citrus area in Gujarat for 2017-18 was 40.80 (000' Hectares) with a confidence interval of 39.33 to 42.10.

Also, Chow test was done in order to know the structural breakpoint in the data series. An obvious candidate for a breakpoint estimate is the year that yields the largest value of the Chow test sequence. In the present study, delay = 0 was found to be the best value with minimum AIC out of all.

Forecasting of production for Citrus

In Figure 2, a chart series has been presented which illustrates the production dataset for citrus from 1991-92 to 2016-17. Additionally, Table 6 provides a description of the characteristics (basic statistics) of the data set used.

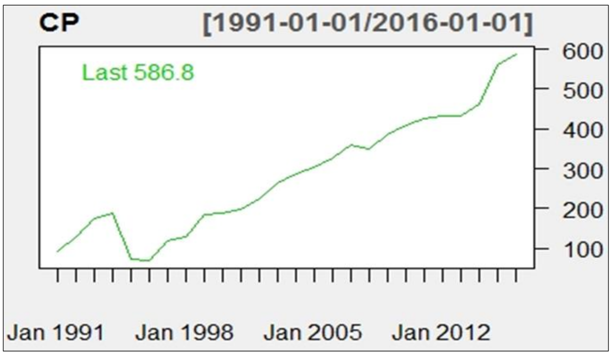

Fig 2: Production (In '000 MT) under citrus in Gujarat

Table 6: Summary statistics of citrus production

No. of observations	26
Minimum	68.8
Maximum	586.9
Mean	282.88
Median	274.16
Standard Deviation	149.52
Sem	29.33
Variance	22353.54
Skewness	-0.32
Kurtosis	-1.07

Table 7: ARIMA (0,1,0) with drift model parameters for production of citrus

Model	Parameter estimation	
ARIMA (0, 1, 0) with drift	Estimate (S.E.)	Sig.
Drift	19.75 (7.02)	<0.01
Forecast Value 2017-18 (C.I.)	606.55 (536.25 to 676.84)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
252.91	0.42	
Lagrange-Multiplier test:		
order	LM test statistics	p. value
4	9.57	0.02

There was a statistically significant difference in the estimate of alpha as shown in Table 7. As a result of the Box-Ljung test statistics, residual autocorrelation was not significant, with a probability value of 0.42. According to ARIMA (0,1,0) with drift, citrus production in Gujarat was predicted to be 606.55 (000 MT) in 2017-18, with a confidence interval of 536.25 to 676.84.

Testing of ARCH Effect

In the Box-Jenkins approach, it is assumed that the residuals remain constant over the duration of the study. To determine whether residuals remain constant following the fitting of the ARIMA model onto all series, the ARCH - Lagrange multiplier (LM) test was conducted. According to the results of the test, there is an ARCH effect in the present series. It is shown in Table 7 that the Lagrange-Multiplier (LM) test statistics for autocorrelation of squared residual are statistically significant with a p value less than 0.05 up to the lag four.

Autoregressive conditional heteroscedastic (ARCH) model/ Generalized ARCH (GARCH)

It was found that among various parametric combinations of GARCH (ARCH) model, arma (1, 1) + garch (1, 0) provided the best fit. Table 8 summarizes the results.

Table 8: Arma (1, 1) + garch (1, 0) model parameters for production of citrus

Model	Parameter estimation	
arma (1, 1) + garch (1, 0)	Estimate (S.E.)	Sig.
Mu	82.34 (34.47)	<0.01
AR1	1.00 (0.02)	<0.01
MA1	0.41 (0.46)	NS
Omega	1426.84 (473.60)	<0.01
alpha1	0.01(0.20)	NS
Forecast Value 2017-18 (C.I.)	581.61 (545.23 to 620.98)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
260.44	0.25	
Lagrange-Multiplier test:		
order	LM test statistics	p. value
6	0.30	NS

As can be seen from Table 8, all parameters have significant estimates with the exception of MA1 and alpha1. Additionally, the residual autocorrelation was not statistically significant according to the Box-Ljung test statistics probability value of 0.25. Based on arma (1,1) + garch (1,0), citrus production for Gujarat in 2017-18 was predicted to be 581.61('000' MT) with a confidence interval of 545.23 to 620.98. Also, Lagrange-Multiplier (LM) test statistics for autocorrelation of squared residual of this model was found to be non-significant upto the lag 6.

Exponential Generalized ARCH (eGARCH)

The best parameter combination of eGARCH model was arma (1, 1) + egarch (1, 1) when fitting eGARCH model. Table 9 provides the results.

Table 9: Arma (1, 1) + egarch (1, 1) model parameters for production of citrus

Model	Parameter estimation	
arma (1, 1) + egarch (1, 1)	Estimate (S.E.)	Sig.
Mu	140.81 (0.03)	<0.01
AR1	0.99 (0.004)	<0.01
MA1	0.26 (0.01)	<0.01
Omega	2.96 (0.008)	<0.01
alpha1	-0.45 (0.0001)	<0.01
beta1	0.61 (0.0001)	<0.01
Forecast Value 2017-18 (C.I.)	585.93 (553.69 to 620.02)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
264.10	0.24	
Lagrange-Multiplier test:		
order	LM test statistics	p. value
7	3.34	NS

The results of Table 9 indicate that all parameters were significantly estimated. As indicated by the Box-Ljung test statistics probability value of 0.24, residual autocorrelation was not significant. By arma (1, 1) + egarch (1, 1), the citrus production in Gujarat was estimated to be 585.93('000' MT), with a confidence interval of 553.69 to 620.02. Lagrange-Multiplier (LM) test statistics for autocorrelation of squared residual of this model was found to be non-significant up to the lag 7.

Self-Exciting Threshold Auto Regressive (SETAR) models

The SETAR (2, 0, 1) model delay = 0 was found to be the best out of various parametric combinations. Table 10 summarizes the results.

Table 10: SETAR (2, 0, 1) delay = 0 model parameters for production of citrus

Model	Parameter estimation	
SETAR (2,0,1) delay = 0	Estimate (S.E.)	Sig.
Lower Regime estimate		
intercept	86.66 (15.81)	<0.05
Upper Regime estimate		
intercept	18.52 (15.85)	NS
Lag1	1.01 (0.04)	<0.01
Forecast Value 2017-18 (C.I.)	615.32(565.46to 667.08)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
208.2	0.77	

The estimates of all parameters, with the exception of the intercept at the upper regime, were found to be significant in Table 10. According to the Box-Ljung test statistics probability value of 0.77, residual autocorrelation was also non-significant. Based on SETAR (2,0,1) delay = 0 for the year 2017-18, the forecast value for citrus production in Gujarat for the year was 615.32 ('000' MT) with a confidence interval of 565.46 to 667.08.
Also, Chow test was done in order to know the structural breakpoint in the data series. An obvious candidate for a breakpoint estimate is the year that yields the largest value of the Chow test sequence. In the present study, delay = 0 was found to be the best value with minimum AIC out of all.

Forecasting of productivity for citrus

The figure 3 shows a series of charts illustrating citrus productivity data from 1991-1992 through 2016-17. In addition, Table 11 presents the characteristics of the data set used (Basic statistics).

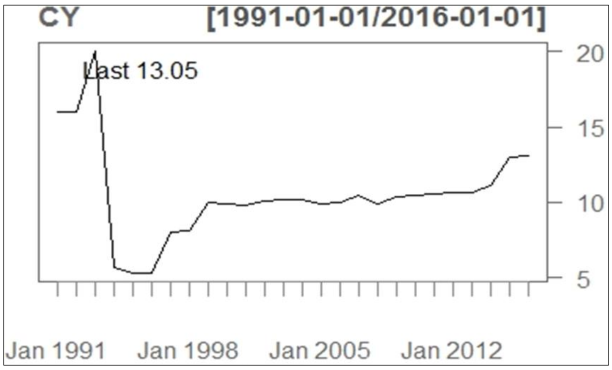

Fig 3: Productivity (In MT/Ha.) under citrus in Gujarat

Table 11: Summary statistics of citrus productivity

No. of observations	26
Minimum	5.4
Maximum	21
Mean	10.57
Median	10.19
Standard Deviation	3.18
Sem	0.64
Variance	10.22
Skewness	0.88
Kurtosis	1.41

Table 12: ARIMA (1, 0, 0) model parameters for productivity of citrus

Model	Parameter estimation	
ARIMA (1,0,0)	Estimate (S.E.)	Sig.
Intercept	10.86 (1.08)	<0.01
AR1	0.52 (0.17)	<0.01
Forecast Value 2017-18 (C.I.)	12.01(6.49 to 17.52)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
131.82	0.31	
Lagrange-Multiplier test:		
order	LM test statistics	p. value
4	0.01	<0.01

Statistical significance was found for both parameters in Table 12. A probability value of 0.31 was determined by Box-Ljung test statistics for residual autocorrelation. By using ARIMA (1,0,0) with constants, the citrus productivity for Gujarat for 2017-18 has been forecasted as 12.01 (MT/Ha) with a confidence interval of 6.49 to 17.52.

Testing of ARCH Effect

A basic assumption of the Box-Jenkins approach is that residuals will remain constant over time. Thus, in order to determine whether residuals remain constant after fitting the ARIMA model across all series, the ARCH - Lagrange multiplier test (LM) was conducted. A test of the present series revealed the presence of an ARCH effect. It is given in Table 12 where Lagrange-Multiplier (LM) test statistics for autocorrelation of squared residual was found to be significant upto the lag 4.

Autoregressive conditional heteroscedastic (ARCH) model/ Generalized ARCH (GARCH)

The best parametric combination of GARCH (ARCH) model was found to be arma (1, 1) + garch (1, 0) when fitting GARCH (ARCH) model. Table 13 presents the results.

Table 13: Arma (1, 1) + garch (1, 0) model parameters for productivity of citrus

Model	Parameter estimation	
arma (1,1) + garch (1,0)	Estimate (S.E.)	Sig.
Mu	10.21 (0.09)	<0.01
AR1	0.74 (0.06)	<0.01
MA1	-0.64 (0.07)	<0.01
Omega	0.017 (0.02)	NS
alpha1	0.99 (0.28)	<0.01
Forecast Value 2017-18 (C.I.)	10.70 (8.61 to 12.84)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
83.09	0.10	
Lagrange-Multiplier test:		
order	LM test statistics	p. value
6	0.17	NS

As can be seen in Table 13, all parameter estimates were significant except for the constant of the Garch model. According to Box-Ljung test statistics, residual autocorrelation was not significant (probability value of 0.10). Based on arma (1, 1) + garch (1, 0), citrus productivity for Gujarat for the year 2017-18 was expected to be 10.70 (MT/Ha.) with a confidence interval of 8.61 to 12.84. Also, Lagrange-Multiplier (LM) test statistics for autocorrelation of squared residual of this model was found to be non-significant upto the lag 6.

Exponential Generalized ARCH (eGARCH)

It was found that arma (1, 1) + egarch (1, 1) was the best parametric combination for fitting eGARCH model. Table 14 shows the results.

Table 14: Arma (1, 1) + egarch (1, 1) model parameters for productivity of citrus

Model	Parameter estimation	
arma (1, 1) + egarch (1, 1)	Estimate (S.E.)	Sig.
Mu	10.75 (0.08)	<0.01
AR1	0.91 (0.003)	<0.01
MA1	-0.78 (0.0006)	<0.01
Omega	-0.31 (0.13)	<0.05
alpha1	0.82 (0.18)	<0.01
Beta 1	0.89 (0.06)	<0.01
Forecast Value 2017-18 (C.I.)	11.19 (8.96 to 14.06)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
82.87	0.12	
Lagrange-Multiplier test:		
order	LM test statistics	p. value
7	1.60	NS

The results of Table 14 indicate that all parameters were statistically significant. As per Box-Ljung test statistics probability value 0.12, residual autocorrelation was also non-significant. Based on arma (1, 1) + garch (1, 1) forecasts, the citrus productivity in Gujarat was estimated at 11.19 ('000' MT/Ha.) with a confidence interval of 8.96-41.6. Lagrange-Multiplier (LM) test statistics for autocorrelation of squared residual of this model was found to be non-significant up to the lag 7.

Self-Exciting Threshold Auto Regressive (SETAR) models

When fitting SETAR models, it was found that SETAR (2, 1, 2) model delay =2 was the best out of various parametric combinations. Table 15 provides the results.

Table 15: Setar (2, 1, 2) delay = 2model parameters for productivity of citrus

Model	Parameter estimation	
SETAR (2, 1, 2) delay=2	Estimate (S.E.)	Sig.
Lower Regime estimate		
Intercept	3.10 (0.99)	NS
Lag1	0.69 (0.11)	<0.01
Upper Regime estimate		
Intercept	20.71 (2.67)	<0.01
Lag1	-0.12 (0.14)	NS
Lag2	-0.74 (0.15)	<0.01
Forecast Value 2017-18 (C.I.)	9.29(6.55to 12.32)	
Fit Statistics		
AIC	Box-Ljungtestresid fit p value	
66.68	0.23	

It was found in Table 15 that all parameters except Lag1 of lower regime were significant. Based on the Box-Ljung test statistics probability value 0.23, residual autocorrelation was also non-significant. The forecasted value of Citrus productivity in Gujarat for 2017-18 was found to be 9.29 (MT/Ha.) with a confidence interval of 6.55 to 12.32 based on the SETAR (2,1,2) delay = 2 calculation.

Also, Chow test was done in order to know the structural breakpoint in the data series. An obvious candidate for a breakpoint estimate is the year that yields the largest value of the Chow test sequence. In the present study, delay = 2 was found to be the best value with minimum AIC out of all.

Table 16: Performance of different models for citrus

Forecasting model for Citrus		Area	Production	Productivity
GARCH (ARCH)	Model	**arma (1, 1) + garch (0, 1)**	arma (1,1) + garch (1, 0)	arma (1,1) + garch (0, 1)
	AIC	44.01	260.44	83.09
	Forecast	45.85	581.61	10.70
	C.I.	44.56 to 46.75	545.23 to 620.98	8.61 to 12.84
eGARCH	Model	arma (1, 1) + egarch (1, 1)	arma (1,1) + egarch (1, 1)	arma (1,1) + egarch (1, 1)
	AIC	44.52	264.10	82.87
	Forecast	45.83	585.93	11.19
	C.I.	44.89 to 46.01	553.69 to 620.02	8.96 to 14.06
TAR	Model	SETAR (2, 3, 1) delay = 0	SETAR (2, 0, 1) delay = 0	SETAR (2, 1, 2) delay = 2
	AIC	50.97	208.2	66.68
	Forecast	40.80	615.32	9.29
	C.I.	39.33 to 42.10	565.46 to 667.08	6.55 to 12.32

GARCH model was found to be best suited for explaining the area of sapota with a forecasted value of 45.85 ('000' Ha) for 2017-18. Also, production of this crop was appropriately modelled by TAR with forecasted value 615.32 (‘000’ MT) while TAR was best suited model for productivity with forecasted value 9.29 (MT/Ha).

Conclusion
Different statistical models like GARCH, eGARCH, and TAR performed quite well compared to classical time series models. A hybrid time series model was used to forecast citrus area, production and productivity in Gujarat. The GARCH model was most effective for forecasting areas while the TAR model performed the best for forecasting production and productivity. It therefore makes sense to forecast all crops in agriculture and horticulture using GARCH and TAR models, which would be useful to both farmers and policy makers.

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