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Forecasting of Agricultural Scenario in Tamil Nadu — A Time Series Analysis

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SUMMARY

ARIMA models are built for the data related to the cultivable area, production and productivity of chosen crops in Tamil Nadu and forecast values are obtained. From this study it is inferred that the impact of green revolution enjoyed over these years may be revitalised.

Key Words: ARIMA, ARMA, Identification, Estimation, Diagnostic checking, Forecasting, Ordinary least-squares, Generalized least-squares.

1. Introduction

In this paper, ARIMA (autoregressive integrated moving-average) models are built for the agricultural data reported for some crops grown in Tamil Nadu and future values are predicted. In the present study, the identification process is carried over using the modified method of Hannan and Rissanen [4] (Balanagammal [1]). Estimation of the parameters and the white noise variance is carried out using generalised least-squares method (Balanagammal and Ranganathan [2]). McLeod and Li's test [5] is used for checking the adequacy of the fitted model. The difference equation method of Box and Jenkins [3] is applied in the forecasting stage.

2. Model Selection and Forecasting

If $\{z_t\}$, t = 1, . . ., n is a given set of observations, then any ARIMA (p, d, q) process is written in the form

$$\varphi(B)\, z_t = \Phi(B)\,(1-B)^d z_t = \alpha + \theta(B)\, a_t \tag{1}$$

where $\Phi(B) = 1 - \Phi_1 B - \ldots - \Phi_p B^p$ and

$$\theta(B) = 1 - \theta_1 B - \ldots - \Phi_q B^q \tag{2}$$

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The autoregressive (AR) operator $\Phi(B)$ is assumed to be stationary and $\theta(B)$, the moving-average (MA) operator is assumed to be invertible, $\{a_t\}$ is a sequence of independent and identically distributed random variables with mean zero and variance σ^2, B is the backshift operator such that $B^i z_t = z_{t-i}$ for any integer i, d is the degree of differencing necessary to induce stationarity in the data and α is a constant. The ARIMA (p, d, q) process becomes the autoregressive moving average-ARMA (p, q) process by a suitable transformation of the variables and is given by

$$\Phi(B)\, w_t = \theta(B)\, a_t \tag{3}$$

i.e.,

$$w_t = \sum_{i=1}^{p} \Phi_i\, w_{t-i} - \sum_{j=1}^{q} \theta_j\, a_{t-j} + a_t \tag{4}$$

where $\{w_t\}$ consists of N (i.e., n − d) observations.

In Tamil Nadu, food crops – rice, sorghum, pearl millet, maize, finger millet, black gram, green gram and red gram, cash crops – cotton, sugarcane, chilli and oil crop – groundnut are under active cultivation. The data obtained for the present study with regard to cultivable area, production and productivity of the above crops are from the Annual Report on 'Season and Crop Reports of Tamil Nadu' on Agricultural Statistics published by the Directorate of Statistics, Government of Tamil Nadu, India. The data pertaining to the agricultural years 1956-1957 to 1994-1995 are used for the model selection and forecasting.

In the present study, graphs of the data related to all crops with regard to area of cultivation, production and productivity show that the variances may not be constant in different parts of the series thus introducing non-stationarity in different time intervals. Hence, at first, the natural logarithmic transformation is carried over for all data i.e., if $\{z_t\}, t = 1, \ldots, n$ represents the original data $z_t = \log_e z_t$, $t = 1, \ldots, n$ represents the transformed data for all the crops. If the transformed data **(a)** exhibits no apparent deviations from stationarity and **(b)** has a rapidly decreasing autocorrelation function, a suitable ARMA process to represent the mean corrected data is sought. If not, a transformation of the data which generates a new series with the properties **(a)** and **(b)** is carried over. This can be frequently achieved by differencing which creates the class of ARIMA processes. Hence the graphs of the series for d = 0, d = 1 and d = 2 are drawn for each crop under each factor area, production and productivity where d stands for the order of differencing required to make the series stationary (Box and Jenkins [3]). The autocorrelation functions up to lag

20 for each crop in each factor are also found out for d = 0, 1, 2. The graphs of the autocorrelation functions of the corresponding series are also drawn. The transformed data and the graphs of the corresponding autocorrelation functions which satisfy the conditions **(a)** and **(b)** are selected for the modeling process. Thus the value of 'd' is identified.

Applying the modified method of Hannan and Rissanen [4] (Balanagammal [1]), the parameters p and q are then identified. Knowing the values of p, d and q of the ARIMA model, the parameters Φ_i, $i = 1, \ldots, p$, θ_j, $j = 1, \ldots, q$ and the white noise variance σ^2 are calculated using the generalized least-squares (Balanagammal and Ranganathan [2]) if the model contains MA terms. If the model is pure autoregressive (AR) or autoregressive integrated (ARI) process then using ordinary least-squares method, the parameters are estimated using the transformed mean corrected data. Tables 1-3 exhibiting ARIMA order, the corresponding identified ARIMA model with the standard errors for the parameters given in parentheses, the white noise variance and the constant term (when 'd' is zero) are respectively given under each factor for all the crops.

For applying McLeod and Li's test [5], the residual autocorrelations up to lag 10 are calculated and are used in the diagnostic study. Chi-square test is applied at 95% level of significance with degrees of freedom 10. For all the ARIMA models obtained for each crop in each factor, the Chi-square test is insignificant. Hence the models identified and estimated are considered as the ARIMA models representing the data.

The last stage in the modeling process is forecasting. The residuals calculated during the estimation process, are considered as the one step ahead forecast errors. Following the steps of Box and Jenkins [3], the forecasts are obtained for the subsequent five agricultural years from 1995-1996 to 1999-2000 taking 1994-1995 as the base year for each crop in each head. 95% probability limits are also found out. The forecasts for the cultivable area, production and productivity for all the crops along with their probability limits (upper and lower limits) are given in the Tables 4A-4B to 6A-6B. The original values for the cultivable area, production and productivity for the crops rice, black gram and sugarcane for the years 1995-1996 and 1996-1997 are also given in the same Tables. The results for the other crops are available with the authors. Selected graphs (data graph and the corresponding autocorrelation graph) of particular crops namely rice, black gram and sugarcane relating to the area of cultivation, production and productivity are shown in Figures 1.1-1.3, 2.1-2.3 and 3.1-3.3. Line graphs of the forecasted values from 31(1986-1987) to 36(1991-1992) taking 30(1985-1986) as base year are also included in these graphs.

Table 1. ARIMA models developed to the cultivable area of various crops

No.	Crop	ARIMA order (p, d, q)	ARIMA model	σ^2
1	Rice	(1, 1, 0)	$w_t + 0.410\, w_{t-1} = a_t$ (± 0.148)	0.008
2	Sorghum	(0, 1, 0)	$w_t = a_t$	0.008
3	Pearl millet	(0, 1, 0)	$w_t = a_t$	0.005
4	Maize	(0, 1, 0)	$w_t = a_t$	0.105
5	Finger millet	(0, 1, 0)	$w_t = a_t$	0.005
6	Black gram	(0, 1, 0)	$w_t = a_t$	0.065
7	Green gram	(1, 0, 0)	$z'_t - 0.811\, z'_{t-1} = 2.10 + a_t$ (± 0.098)	0.060
8	Red gram	(1, 0, 0)	$z'_t - 0.855\, z'_{t-1} = 1.63 + a_t$ (± 0.086)	0.023
9	Sugarcane	(2, 1, 0)	$w_t + 0.001\, w_{t-1} + 0.734\, w_{t-2} = a_t$ (± 0.117) (± 0.116)	0.015
10	Cotton	(1, 0, 0)	$z'_t - 0.793\, z'_{t-1} = 2.6 + a_t$ (± 0.098)	0.021
11	Groundnut	(1, 0, 0)	$z'_t - 0.707\, z'_{t-1} = 4.04 + a_t$ (± 0.117)	0.006
12	Chilli	(0, 0, 1)	$z'_t = 11.139 + a_t + 0.574\, a_{t-1}$ (± 0.160)	0.026

Standard errors are given in parentheses.

Table 2. ARIMA models developed to the production of various crops

No.	Crop	ARIMA order (p, d, q)	ARIMA model	σ^2
1	Rice	(0, 1, 1)	$w_t = a_t - 0.535\, a_{t-1}$ (± 0.163)	0.019
2	Sorghum	(1, 1, 0)	$w_t + 0.458\, w_{t-1} = a_t$ (± 0.144)	0.028
3	Pearl millet	(0, 1, 1)	$w_t = a_t - 0.490\, a_{t-1}$ (± 0.163)	0.032
4	Maize	(0, 1, 1)	$w_t = a_t - 0.442\, a_{t-1}$ (± 0.162)	0.108
5	Finger millet	(0, 1, 1)	$w_t = a_t - 0.524\, a_{t-1}$ (± 0.163)	0.020
6	Black gram	(0, 1, 2)	$w_t = a_t - 0.083\, a_{t-1} - 0.569\, a_{t-2}$ (± 0.166) (± 0.169)	0.058
7	Green gram	(0, 1, 0)	$w_t = a_t$	0.074
8	Red gram	(0, 1, 1)	$w_t = a_t - 0.489\, a_{t-1}$ (± 0.165)	0.049
9	Sugarcane	(0, 1, 1)	$w_t = a_t - 0.521\, a_{t-1}$ (± 0.166)	0.034
10	Cotton	(0, 0, 0)	$z'_t = 12.82 + a_t$	0.070
11	Groundnut	(2, 0, 0)	$z'_t - 0.427\, z'_{t-1} - 0.466\, z'_{t-2} = 1.5 + a_t$ (± 0.150) (± 0.166)	0.025
12	Chilli	(0, 1, 1)	$w_t = a_t - 0.502\, a_{t-1}$ (± 0.163)	0.067

Standard errors are given in parentheses.

Table 3. ARIMA models developed to the productivity of various crops

No.	Crop	ARIMA order (p, d, q)	ARIMA model	σ^2
1	Rice	(1, 1, 0)	$w_t + 0.438\, w_{t-1} = a_t$ (± 0.150)	0.007
2	Sorghum	(0, 1, 1)	$w_t = a_t - 0.434\, a_{t-1}$ (± 0.164)	0.018
3	Pearl millet	(0, 1, 1)	$w_t = a_t - 0.589\, a_{t-1}$ (± 0.162)	0.020
4	Maize	(1, 0, 0)	$z'_t - 0.664\, z'_{t-1} = 0.89 + a_t$ (± 0.123)	0.036
5	Finger millet	(0, 1, 1)	$w_t = a_t - 0.595\, a_{t-1}$ (± 0.163)	0.011
6	Black gram	(1, 0, 0)	$z'_t - 0.719\, z'_{t-1} = 1.67 + a_t$ (± 0.116)	0.040
7	Green gram	(1, 0, 0)	$z'_t - 0.732\, z'_{t-1} = 1.55 + a_t$ (± 0.113)	0.052
8	Red gram	(0, 1, 1)	$w_t = a_t - 0.431\, a_{t-1}$ (± 0.181)	0.028
9	Sugarcane	(0, 1, 1)	$w_t = a_t - 0.726\, a_{t-1}$ (± 0.162)	0.012
10	Cotton	(1, 0, 0)	$z'_t - 0.540\, z'_{t-1} = 2.48 + a_t$ (± 0.137)	0.064
11	Groundnut	(1, 1, 0)	$w_t + 0.594\, w_{t-1} = a_t$ (± 0.130)	0.014
12	Chilli	(1, 1, 0)	$w_t + 0.391\, w_{t-1} = a_t$ (± 0.151)	0.038

Standard errors are given in parentheses.
z'_t represents the transformed series and w_t represents the differenced series.

Table 4A. Comparative analysis of forecasts of cultivable area to selected crops with their original values (in hectares × 10^4)

Year	Rice		Black Gram		Sugarcane	
	Forecasted	Original	Forecasted	Original	Forecasted	Original
1995-1996	225.68 (270,189)	195.06	24.59 (40,15)	20.44	31.80 (40,25)	32.62
1996-1997	224.20 (276,182)	217.37	25.80 (52,13)	20.46	28.68 (40,21)	25.96
1997-1998	224.48 (287,175)		27.06 (64,11)		31.77 (45,23)	
1998-1999	224.04 (295,170)		28.38 (76,10)		37.44 (53,26)	
1999-2000	223.90 (304,165)		29.77 (91,10)		37.94 (56,26)	

Table 4B. Forecasts of cultivable area to various crops (in hectares × 10^4)

Year	Sor-ghum	Pearl millet	Maize	Finger millet	Green gram	Red gram	Cotton	Ground nut	Chilli
1995-1996	42.59 (51,36)	18.68 (21,16)	4.91 (9,3)	14.13 (16,12)	9.88 (16,6)	9.07 (12,7)	26.15 (35,20)	103.9 (122,89)	6.84 (9,5)
1996-1997	41.99 (54,33)	18.18 (22,15)	5.18 (13,2)	13.80 (17,11)	9.19 (17,5)	8.78 (13,6)	26.66 (38,19)	101.10 (123,83)	6.88 (10,5)
1997-1998	41.39 (56,31)	17.69 (22,14)	5.47 (16,2)	13.48 (17,10)	8.68 (17,4)	8.54 (13,5)	27.07 (40,18)	99.16 (122,81)	6.88 (10,5)
1998-1999	40.80 (58,29)	17.21 (23,13)	5.77 (21,2)	13.16 (18,10)	8.28 (17,4)	8 (14,5)	27.39 (42,18)	97.82 (121,79)	6.88 (10,5)
1999-2000	40.22 (59,27)	16.75 (23,12)	6.09 (25,1)	12.85 (18,9)	8 (17,4)	8.18 (14,5)	27.66 (43,18)	96.88 (121,78)	6.88 (10,5)

Upper and Lower limits are given in parentheses

Table 5A. Comparative analysis of forecasts of production to selected crops with their original values (in tons × 10^4)

Year	Rice		Black Gram		Sugarcane	
	Forecasted	Original	Forecasted	Original	Forecasted	Original
1995-1996	737.14 (969,561)	529.0	16.00 (26,10)	8.15	3409.86 (4895,2375)	3277.90
1996-1997	754.03 (1020,558)	580.53	15.92 (30,8)	7.5	3642.02 (5439,2439)	2591.88
1997-1998	771.31 (1070,556)		16.92 (33,9)		3889.97 (6021,2513)	
1998-1999	788.98 (1121,555)		17.98 (36,9)		4154.81 (6647,2597)	
1999-2000	807.05 (1173,555)		19.11 (39,9)		4437.69 (7323,2689)	

Table 5B. Forecasts of production to various crops (in tons × 10^4)

Year	Sorghum	Pearl millet	Maize	Finger millet	Green gram	Red gram	Cotton	Ground nut	Chilli
1995-1996	48.90 (68,35)	24.09 (34,17)	7.54 (15,4)	29.72 (39,22)	5.28 (9,3)	7.03 (11,5)	37.06 (63,22)	171.25 (234,125)	4.35 (7,3)
1996-1997	49.02 (71,34)	24.09 (36,16)	8.04 (17,4)	29.56 (40,22)	5.52 (12,3)	7.26 (12,4)	37.06 (63,22)	164.75 (231,117)	4.29 (8,2)
1997-1998	49.03 (77,31)	24.09 (37,16)	8.56 (19,4)	29.39 (41,21)	5.78 (15,3)	7.50 (13,4)	37.06 (63,22)	159.90 (237,108)	4.24 (8,2)
1998-1999	49.10 (81,30)	24.09 (38,15)	9.12 (22,4)	29.23 (42,20)	6.04 (18,2)	7.75 (14,4)	37.06 (63,22)	155.05 (236,102)	4.19 (8,2)
1999-2000	49.14 (85,28)	24.09 (40,15)	9.72 (26,4)	29.07 (43,20)	6.32 (21,2)	8 (15,4)	37.06 (63,22)	150.91 (237,96)	4.14 (8,2)

Upper and Lower limits are given in parentheses.

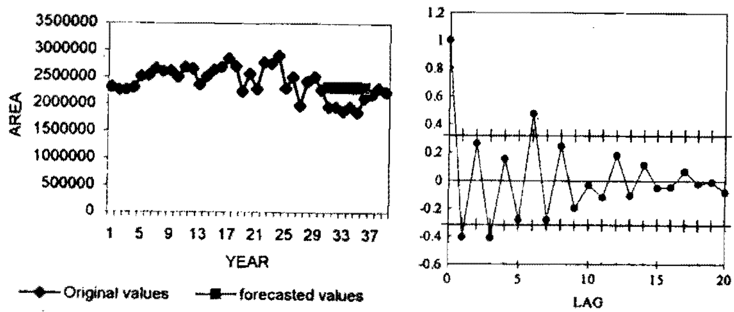
Table 6A. Comparative analysis of forecasts of productivity to selected crops with their original values (in kg/hectare) $\times 10^2$

Year	Rice		Black Gram		Sugarcane	
	Forecasted	Original	Forecasted	Original	Forecasted	Original
1995-1996	32.9 (39,28)	27.12	4.8 (7,3)	4.0	1125 (1393,908)	1005
1996-1997	34.5 (42,28)	26.71	4.4 (7,3)	3.67	1141.5 (1425,914)	998.6
1997-1998	35 (44,28)		4.2 (7,3)		1158.5 (1457,921)	
1998-1999	36 (47,28)		4.1 (7,2)		1175.7 (1490,928)	
1999-2000	36.8 (49,28)		4.0 (7,2)		1193.2 (1523,935)	

Table 6B. Forecasts of productivity to various crops (in kg/hectare) $\times 10^2$

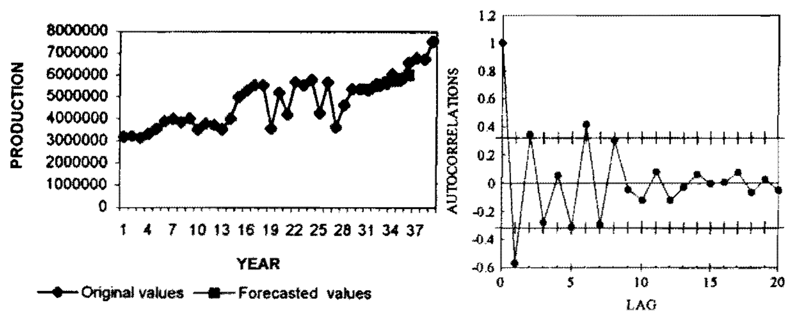
Year	Sor-ghum	Pearl millet	Maize	Finger millet	Green gram	Red gram	Cotton	Ground nut	Chilli
1995-1996	11 (14,8)	12.3 (16,9)	14.5 (21,10)	20.6 (25,17)	4.2 (7,3)	7 (10,5)	2.6 (4,2)	16.4 (21,13)	6.5 (10,4)
1996-1997	11.2 (15,8)	12.6 (17,9)	13.7 (21,9)	21.0 (26,17)	4 (7,2)	7 (10,5)	2.4 (4,1)	16.6 (21,13)	6.7 (10,4)
1997-1998	11.3 (16,8)	13 (18,9)	13.2 (21,8)	21.4 (27,14)	3.7 (7,2)	7 (11,5)	2.3 (4,1)	16.7 (23,12)	6.5 (11,4)
1998-1999	11.5 (17,8)	13.4 (19,10)	12.8 (21,8)	21.8 (28,17)	3.6 (7,2)	7 (11,5)	2.3 (4,1)	16.9 (23,12)	6.4 (12,4)
1999-2000	11.7 (17,8)	13.7 (20,10)	12.6 (21,8)	22.20 (29,17)	3.5 (7,2)	7.3 (12,4)	2.2 (4,1)	17.0 (24,12)	6.3 (12,3)

Upper and Lower limits are given in parentheses.



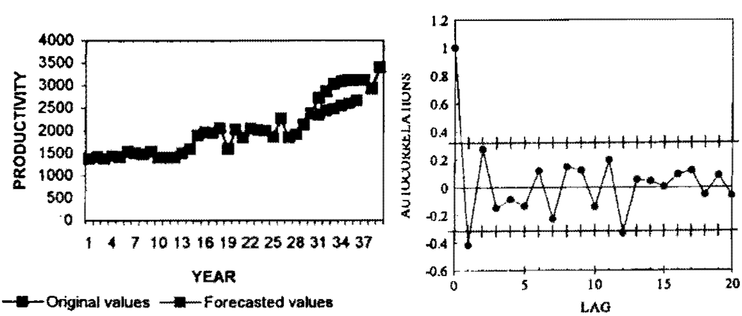
(a) (b)

Fig. 1.1 (a) The original series representing the cultivated area of the crop — rice along with the fitted values and (b) the autocorrelation function of its first differenced transformed series



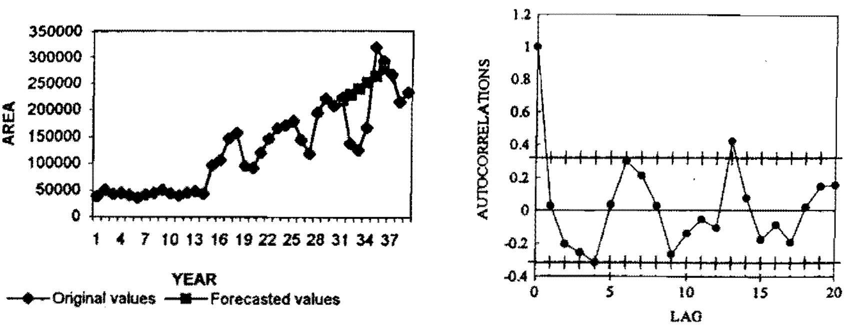
(a) (b)

Fig. 1.2 (a) The original series representing the production of the crop — rice along with the fitted values and (b) the autocorrelation function of its first differenced transformed series



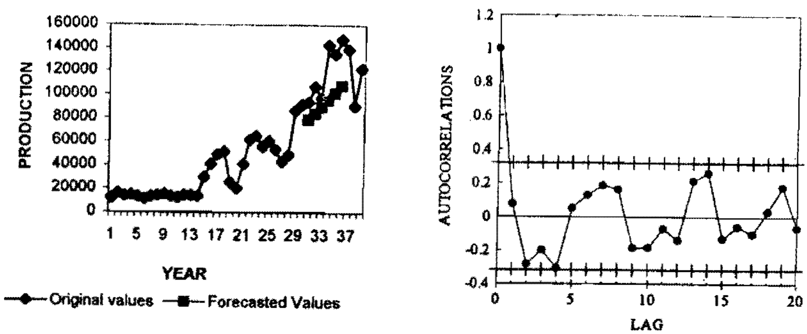
(a) (b)

Fig. 1.3 (a) The original series representing the productivity of the crop — rice along with the fitted values and (b) the autocorrelation function of its first differenced transformed series



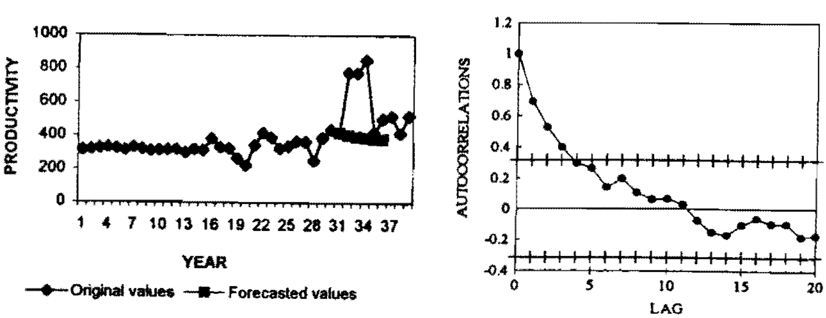
(a) (b)

Fig. 2.1 (a) The original series representing the cultivated area of the crop — blackgram along with the fitted values and (b) the autocorrelation function of its first differenced transformed series



(a) (b)

Fig. 2.2 (a) The original series representing the production of the crop — blackgram along with the fitted values and (b) the autocorrelation function of its first differenced transformed series



(a) (b)

Fig. 2.3 (a) The original series representing the productivity of the crop — blackgram along with the fitted values and (b) the autocorrelation function of its first differenced transformed series

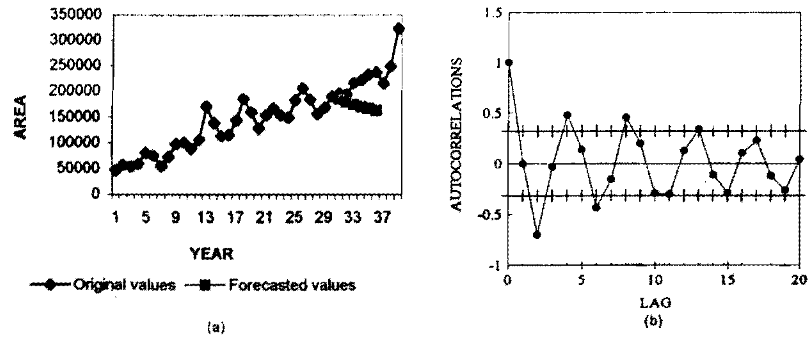


Fig. 3.1 (a) The original series representing the cultivated area of the crop — sugarcane along with the fitted values and (b) the autocorrelation function of its first differenced transformed series

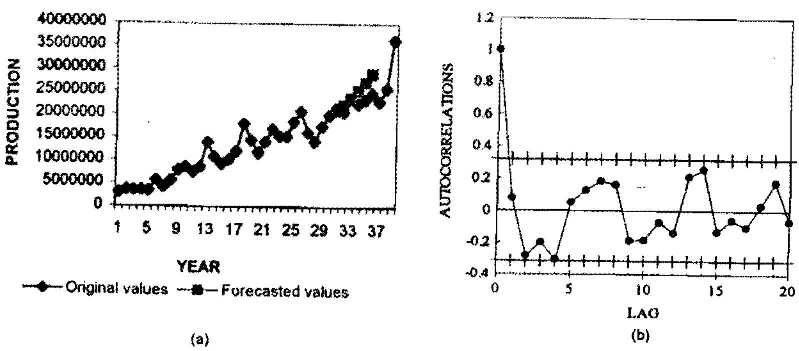


Fig. 3.2 (a) The original series representing the production of the crop — sugarcane along with the fitted values and (b) the autocorrelation function of its first differenced transformed series

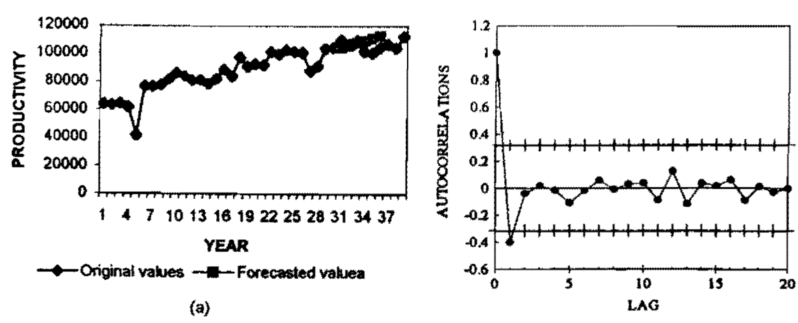


Fig. 3.3 (a) The original series representing the productivity of the crop — sugarcane along with the fitted values and (b) the autocorrelation function of its first differenced transformed series

Programs are developed in FORTRAN language for all the stages by the authors themselves (Balanagammal [1]).

3. Suggestions to Improve Crop Yield

Based on the season and crop data available from the year 1956-1957 to 1994-1995 in Tamil Nadu, ARIMA models have been developed to forecast the cultivable area, production and productivity for the next five years i.e., 1995-1996 to 1999-2000 considering 1994-1995 as base year.

From the forecast analysis, the following results are observed. The area of cultivation for the crops rice, sorghum, pearl millet, finger millet, green gram, red gram and groundnut may be decreased whereas an increase in the area is noticed in the crops maize, black gram and cotton. The crop sugarcane seems to have an oscillating trend in the area of cultivation during the forecasting period, while the crop chilli has the same area of cultivation.

With regard to production, finger millet and groundnut have a decreasing level of production with a decrease in the area of cultivation whereas, both the area of cultivation and production level increase in the crop maize. In rice, sorghum, green gram and red gram the cultivable area decreases though production level increases. In black gram, the production level oscillates though the cultivable area increases. Though there is an oscillating trend in the area of cultivation in sugarcane, production level is increasing. In the crop pearl millet, the production level is constant though the cultivable area decreases. In case of cotton, the production level remains the same though there is an increase in the area of cultivation. The production level decreases in the crop chilli, inspite of the fact that the cultivable area remains the same.

With regard to productivity of the crops, maize, black gram, green gram and cotton show a decreasing trend during the forecasting period while the other crops such as rice, sorghum, pearl millet, finger millet, red gram, sugarcane and groundnut show smaller increasing trend. The productivity of chilli seems to oscillate. The original values available for all the crops for the period 1995-1996 and 1996-1997 with regard to area, production and productivity do not show higher increasing trend.

From the analysis on forecasting, it is revealed that nearly all the crops taken in the present study do not show higher increasing trend in the area of cultivation and production. In this circumstance based on the present findings, one has to seriously view the various courses of action to be implemented to increase the production by taking appropriate positive measures in the Green Revolution.

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