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Study on hectareage response of cotton crop in the Amreli District of Gujarat

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Abstract
The present investigation was undertaken with a view to identify the models for predicting district wise crop hectareage of cotton crop in the Amreli district of Gujarat state. The investigation was carried out on the basis of secondary data covering the period of 21 years (2000-01 to 2020-21). The linear multiple regression technique adopting Nerlovian adjustment model was employed. Eight single equation and four simultaneous equation models were tried for the selected crop. The model selected on the basis of adjusted coefficient of multiple determination, RMSE, MAE and MAPE values is as $HECT = 68.460 + 0.229HECTL_1 - 19.481HECS + 0.595\ EYCT - 0.096EYCS + 0.623PCTL_1 - 0.091PCSL_1 - 0.0001RRSK$.

Keywords: Hectareage, cotton, Nerlovian adjustment model, Single equation model, Simultaneous equation model, adjusted coefficient of determination, RMSE, MAE, MAPE

Introduction
Gujarat is a significant state in India in terms of its contribution to agricultural growth. It covers 19.6 million hectares (19.6%) of the country's total land area. The state of Gujarat plays a prominent role in cotton production in India.
Among the crops grown in the Amreli district, cotton is one of the most dominant oilseed crops. The total area and production of cotton crop in the Amreli district in the year 2020-21 were 3313.35 "00" ha and 8114.58 "00" MT respectively (Directorate of Agriculture, Gujarat state, Gandhinagar).
According to Molua (2010) [5], expanding cultivated area is a feasible option for increasing -production. One of the most important issues in agricultural development economics is acreage response since the responsiveness of farmers to economic incentives largely determines agriculture's contribution to the economy where the sector is the largest employer of the labour force. Land is one of the most important and finite resource in agriculture. Thus, the optimum allocation of land to agricultural crops is of great importance. The allocation of land to different crops is affected by both price and non-price factors. An increase in a crop's own price is expected to have positive impact on the crop's acreage (Tahir, 2014). It is expected that farmers would allocate their limited land resources to that crop enterprise which the price tends to be encouraging. The non-price factors comprise of mainly competing crops, cost and availability of inputs, weather fluctuations, disease pest infestation, consumption needs, risk and uncertainity, marketing facilities, technological changes etc.
Nerlove's formulation of agricultural supply response is one of the most widely used econometric models in the empirical studies. The model developed incorporates one year as well as two year lagged dependent variable as an explanatory variable. The study of the factors considered by farmers in acreage allocation under cotton crop, will help to understand the decision making of farmers about the acreage allocation at micro level.
Considering the significance of the cotton crop in country's economy and lack of research work on comparison of different hectareage response models, particularly in Gujarat state, the present investigation on hectareage response of cotton crop was carried out.
Keeping the above-mentioned facts, the following specific objectives have been framed for the study.

Keeping the above-mentioned facts, the following specific objectives have been framed for the study

- To identify various price and non-price factors influencing the crop hectareage allocation under cotton crop.
- To compare simultaneous equation models with the single equation models for the predictability of crop hectareage of cotton crop.
- To suggest the models for prediction of hectareage for each of the selected crop.

Methodology

Source of data

The study was based on secondary data collected for the period of 21 years from 2000-01 to 2020-21. The annual data for related to hectareage and yield was collected from Directorate of Agriculture, Gujarat state, Gandhinagar (DAG). The data pertaining to farm harvest prices was collected from Directorate of Economics and Statistics, DAC & FW, Ministry of Agriculture and Farmers Welfare, GoI, New Delhi.The data related to rainfall was collected for the month of sowing and total annual rainfall.

Nerlovian adjustment lagged model

According to, Nerlove (1958) [6], the long run supply, A_t^*, is assumed in Nerlovian framework to be related to the price (P_{t-1}) in the simple linear manner:

$$A_t^* = a + bP_{t-1} + U_t \qquad (1)$$

The relationship between actual and the long run desired levels of acreage:

$$A_t - A_{t-1} = \delta(A_t^* - A_{t-1}), 0 \le \delta \le 1 \qquad (2)$$

Where, δ is known as the Nerlovian coefficient of adjustment and $(A_t - A_{t-1})$= actual change and $(A_t^* - A_{t-1})$= desired change.

Now, by substituting value of A_t^* in equation (2) from equation (1).

$$A_t = A_{t-1} + \delta(a + bP_{t-1} + U_t - A_{t-1}) \qquad (3)$$

$$A_t = \alpha + \beta_1 A_{t-1} + \beta_2 P_{t-1} + V_t \ (4)$$

Where,

$$\alpha = a\delta, V_t = \delta U_t,\ \beta_1 = 1 - \delta, \beta_2 = b\delta$$

This equation-4 acted as a basis for the eight single equation and for simultaneous equation model (SE model) for the crop under study. The parameters of single equation models and simultaneous equation models were estimated by the ordinary least square (OLS) method and two stage least square (2SLS) method, respectively.

Selection of competing crop

Selection of competing crops was done on the basis of its total area, sowing season and/or the magnitude as well as direction of correlation between the area of these crops. In Amreli, district castor was selected as competing crop.

Selection of independent variables

Out of all the variables effective explanatory variables for inclusion in different single equation models and simultaneous equation models were selected on the basis of magnitude of correlation coefficient and their interrelationships.

Specification of the variables

Specification of the variables included in the present investigation are as below.

Let X: Crop selected for the study
CS: Castor
CT: Cotton
C: Competing crop

Area variables

HEX: Current hectareage under 'X' crop in 00'ha.
$HEXL_1$: One year lagged hectareage of 'X' crop in 00'ha.
$HEXL_2$: Two year lagged hectareage of 'X' crop in 00'ha

Yield variables

YXL_1: One year lagged yield of 'X' crop in kg/ha
EYX: Expected yield of 'X' crop.

Price variables

PXL_1: One year lagged price of 'X' crop in rupees per quintal
PXL_2: Two year lagged price of 'X' crop in rupees per quintal
RPXL: Lagged relative price of 'X' crop calculated as.

$$\text{RPXL} = \frac{\text{PXL}}{\text{PCL}}$$

Where, PCL_1: One year lagged price of competing crop.
EPX: Expected price of 'X' crop.
REPX: Relative expected price of 'X' crop calculated as:

$$\text{REPX} = \frac{\text{EPX}}{\text{EPC}}$$

Where, EPC: Expected price of competing crop

Return variable

$GRXL_1$: One year lagged gross return of 'X' crop in rupees
RGRXL: Lagged relative gross return of 'X' crop calculated as.

$$\text{RGRXL} = \frac{\text{GRXL}}{\text{GRCL}}$$

EGRX: Expected gross return of 'X' crop
REGRX: Relative expected gross return of 'X' crop calculated as.

$$\text{REGRX} = \frac{\text{EGRX}}{\text{EGRC}}$$

Where, EGRC: Expected gross return of the competing crop

Rainfall variable

RFA: Total rainfall in the month of August in mm
RFT: Total annual rainfall in mm

Risk variable

PRSK, YRSK, RRSK: Risk due to price, yield and gross return, respectively.

Formation of different single equation models

While formation of single equation models, care was taken that the independent variables in a model form a logical set and also multicollinearity is absent between the pairs of independent variables. The multicollinearity was verified with the use of criteria known as Variance Inflation Factor (VIF) defined as.

The variance inflation factor for the j^{th} predictor is

$$VIF_j = \frac{1}{1 - R_j^2}$$

Where, R_j^2: R^2-value (coefficient of determination) obtained by regressing the j^{th} predictor on the remaining predictors.
If, 1 < VIF < 5, no multicollinearity, 5 < VIF < 10, predictors are moderately correlated, VIF > 10, serious multicollinearity requiring correction.
In time series data auto correlation is found more frequently. It was tested as (H_0) the absence of auto correlation ($\rho = 0$), against (H_1) the presence of auto correlation ($\rho \neq 0$) by using Durbin-Watson's (1970) 'd' statistic, which is given by

$$d = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{1}^{n} e_t^2}$$

Where, e_t = Error term of current year.
e_{t-1}= Error term of lagged year.
n = No. of observations.

Formation of simultaneous equation models

Four simultaneous equation models were formed for the selected crop. In order to solve the simultaneous equation model, identification of the model is a mandatory condition. Therefore, to identify the equations of model order as well as rank conditions were applied. The rank condition tells us whether the equation under consideration is identified or not, whereas the order condition tells us if it is exactly identified or over identified.
All the equations included in the simultaneous equation models fulfilled both the conditions and hence, were exactly identified.

Result and Discussion

Correlation

In order to find out the degree of association between the hectareage under the crop and the variables affecting the current hectareage, correlation coefficients were worked out. The results suggested that the current hectareage of cotton was positively and highly significantly correlated with its lagged hectareage. There was a negative association between the current hectareage of cotton and current hectareage of its competing crop in the Amreli district. Lagged gross return of cotton and competing crop showed positive and highly significant correlation with current hectareage for Amreli district.

Single equation models

The results provided in Table 1 suggested that the highest values of coefficient of determination
(R^2) and adjusted coefficient of determination ($\bar{R}^2$) as well as minimum values of residual mean sum of square (RMSE), mean absolute error (MAE) corresponded to model-VII (R^2=0.918, $\bar{R}^2$=0.874, RMSE=334.65 & MAE=259.27) while, the minimum value of mean absolute percentage error (MAPE) *i.e.*, 11.19 corresponded to model-IV. Hence, model VII was found to be the best fitted for prediction of area under cotton hectareage in the Amreli district.
The perusal of results further indicated that the partial regression coefficient of lagged hectareage was positive and highly significant in all of the models. The coefficients of current hectareage of competing crop (castor) were negative and non-significant all the models. The lagged yield variables had positive and non-significant partial regression coefficients. Expected yield of castor had positive and non-significant coefficients in models V and VI. Coefficients of relative lagged price were positive and non-significant in all the models in which it was included. The partial regression coefficient of lagged gross return of cotton was positive and significant. The rainfall variable had positive and non-significant coefficients in all of the models. Price risk had negative and non-significant coefficients in models I, II, IV, VII and VIII while, positive and non-significant coefficients in models III, V and VI. The coefficients of yield risk were negative and non-significant coefficients in models I, II, III, IV and VII while, positive and non-significant coefficients in models V and VI.

Simultaneous equation models

The result corresponding to four different SE models are presented in Table 4. The perusal of results further indicated that the partial regression coefficient of lagged hectareage was positive and significant for SE model I and III and negative and non-significant for model II and IV (highly significant for model III). The coefficients of current hectareage of competing crop (castor) were negative and non-significant except for model IV for which coefficient was significant. The expected yield of cotton had positive and non-significant partial regression coefficients. Coefficients of lagged price and expected price of cotton were positive and significant. The partial regression coefficient of lagged gross return of cotton and castor were positive and non- significant. The expected gross return variables had positive and significant coefficients. The coefficients of return risk were positive and non-significant for all the models except for model I in which coefficient was negative.
The highest value of R^2 (0.950) and $\bar{R}^2$ (0.923) and least errors corresponded to SE model I, (RMSE= 261.78, MAE=195.36, MAPE=8.85). The results suggested that among the simultaneous equation models tried, SE model I was best for predicting area under cotton crop.

Table 1: Partial regression coefficients for different single equation models for cotton in Amreli District

Variable	Model							
	I	II	III	IV	V	VI	VII	VIII
Intercept	-1078.334	-391.73	-1065.00	-711.087	-1461.38	-576.976	460.50	44.782
$HECTL_1$	0.920^{**}	0.889^{**}	0.954^{**}	0.908^{**}	0.771^{**}	0.630^{**}	0.688^{**}	0.889^{**}
HECS	-1.709	-1.831	-0.939	-0.103	-20.423	-35.103	-2.874	-2.234
$YCTL_1$	0.406	0.678	-	-	-	-	-	-
$YCSL_1$	0.334	0.370	-	-	-	-	-	-
EYCT	-	-	-0.396	0.165	-	-	-	-
EYCS	-	-	-	-	0.971	1.538	-	-

RPCTL	624.575	-	1078.00	-	435.194	-	-	-
REPCT	-	-3.674	-	586.050	-	-807.482	-	-
$GRCTL_1$	-	-	-	-	-	-	0.0003*	-
$GRCSL_1$	-	-	-	-	-	-	0.0001	-
REGRCT	-	-	-	-	-	-	-	323.799
RFA	0.177	0.143	-	-	0.181	0.259	0.134	-
RFT	-	-	0.273	0.427	-	-	-	0.427
PRSK	-0.281	-0.425	0.062	-0.147	0.182	0.368	-0.638	-0.123
YRSK	-0.367	-0.107	-0.429	-0.010	0.221	0.894	-0.475	0.114
R^2	0.895	0.889	0.886	0.875	0.893	0.893	0.918	0.872
$\bar{R}^2$	0.825	0.815	0.825	0.817	0.836	0.836	0.874	0.807
RMSE	379.46	390.34	394.79	414.81	382.68	382.79	334.65	419.84
MAE	280.66	278.84	302.40	297.09	302.31	297.82	259.27	304.35
MAPE	12.65	12.59	11.99	11.52	14.12	15.28	11.19	11.67

Table 2: Partial regression coefficients for main equations corresponding to different simultaneous equation models for cotton crop in Amreli district

Variables	Model			
	I	II	III	IV
Intercept	68.460	-564.031	604.428	695.299
$HECTL_1$	0.229*	-0.203	0.602**	-0.017
HECS	-19.481	-12.000	-12.114	-22.709*
EYCT	0.595	1.751	-	-
EYCS	0.096	-0.026	-	-
$PCTL_1$	0.623*	-	-	-
$PCSL_1$	-0.091	-	-	-
EPCT	-	1.477	-	-
EPCS	-	-0.547	-	-
$GRCTL_1$	-	-	0.0002	-
$GRCSL_1$	-	-	0.0001	-
EGRCT	-	-	-	0.001*
EGRCS	-	-	-	0.0001**
RRSK	-0.0001	0.0002	0.0001	0.0001
R^2	0.950	0.940	0.908	0.936
$\bar{R}^2$	0.923	0.907	0.877	0.914
RMSE	261.78	288.45	355.06	297.99
MAE	195.36	222.49	276.33	230.75
MAPE	8.85	9.74	11.69	9.59

*, ** Significant at 5% and 1% levels, respectively

Recommended models

Table 3: Recommended model for cotton crop in Amreli district

Model No.	Recommended Model		R^2	$\bar{R}^2$	MAPE
SE Model I	HECT=	68.460+0.229*$HECTL_1$-19.481HECS +0.595EYCT-0.096EYCS+0.623*$PCTL_1$-0.091$PCSL_1$-0.0001RRSK	0.950	0.923	8.85

These results are in confirmation with Mohan *et al.* (2017) [4] who found non-significant effect of yield variables on area allocation under cotton crop in Andhra Pradesh state. Parmar (1991) [8] also observed similar results of positive and significant impact of lagged hectareage of cotton crop on its current year hectareage. He also found negative influence of yield and return risk on cotton area allocation. Similar to Amreli and Bhavnagar districts Nosheen and Iqbal (2008) [7], in their study on acreage response of major crops in Pakistan also pointed out the negative impact of area under competing crop on the area under cotton crop in the current year. The study by Duffy *et al*. (1994) [3], revealed positive impact of expected revenue of cotton crop on the acreage under cotton crop.

Conclusion

For cotton hectareage prediction in Amreli district, among the single equation models and the simultaneous equation models when taken together, along with the minimum values of error terms the highest value $\bar{R}^2$ was to the tune of 0.923 which corresponded to the SE model I. Thus, this model which explained around 95 per cent variation in cotton hectareage was recommended. The functional form of recommended model is as under:

$$HECT = f\ (HECTL_1, HECS, EYCT, EYCS, PCTL_1, PCSL_1, RRSK)$$

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