Mysore J. Agric. Sci., 56 (1) : 335-340 (2022)

Co Integrated Movement of Food Grains Production and Agricultural Inputs in India - A Vector Auto Regression Approach

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Abstract

In the present study a novel attempt has been made to study the co integrated movement of food grains production and agricultural inputs in India. The data pertaining to food grains production and pattern of consumption of agricultural inputs like total cropped area, fertilizer consumption, pesticide consumption in India for the period 1950-1951 to 2019-2020 collected from official sources have been analysed. Coefficient of determination (R^2) has been used to evaluate the goodness-of-fit of linear, quadratic and cubic trend functions of the variables under study. Vector auto regression could be extensively used to examine the co integrated movement of each variable using the lagged values of itself as well as other variables. Findings of the study revealed that VAR models resulted in significantly high values of adjusted R^2 ranging from 0.95 - 0.99 for prediction models with respect to different variables showing the potential of the VAR approach to quantify the co integrated movement of the variables.

Keywords : Trend, VAR, Food grains production, Agricultural inputs, India

The production of food grains in India has been increased considerably from 50 MT in 1950-51 to 296 MT by 2019-20. Apart from providing food to nation, agriculture contributes labour, market of industrial goods and earns foreign exchange and provides savings (Singh, 2020). The performance of agriculture has an impact on the growth of other sectors also and the entire economy contributes to overall national income. Thus, agriculture continues to be a dominant sector in Indian Economy. The modernization of agriculture has supported the use of a wide range of agro chemicals in agricultural fields, including fertilizers, pesticides, micro nutrients and plant growth regulators (Yadav, 2019).

Sharma (2014) has opined that the options for increasing food production were limited by the availability of land, water and the increasing population, among other factors. Fertilizers can play an increasingly important role in agricultural production as the opportunity to bring new area under cultivation diminishes and the majority of Indian soil becomes deficient in many macro and micronutrients. The application of essential plant nutrients, particularly macro and micronutrients, in the optimum quantity and in the right proportion, by using the correct method and time of application and efficient and environmentally sound management, is the key to increased and sustained agricultural production. Therefore, it is important to understand fertilizer use behavior and efficiency over time and space, the changing structure of fertilizer markets, the policy environment, and the role of various factors influencing fertilizer consumption.

Material and Methods

The data used for the study have been collected from the sources like Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics and Statistics, Reserve Bank of India and www.indiaagristat.com. Basically, four variables such as total cropped area, fertiliser consumption, pesticide consumption and food grains production were taken for the study.

A trend is defined as the long-term behavior of a data over time. The trend analysis of data pertaining to total cropped area, fertilizer consumption, pesticide consumption and food grains production for the period from 1950-2020 in India were attempted. Functional forms like linear, quadratic, cubic were selected based on the highest coefficient of determination (R^2) for fitting the trend equations. The functional forms of trend were :

Linear function $Y = a + bt$

Quadratic function $Y = a + bt + ct^2$

Cubic function $Y = a + bt + ct^2 + dt^3$

Where,

Y = Total cropped area, fertilizer consumption, pesticide consumption and food grains production, t = time variable; a, b, c & d = Parameters

Vector Auto Regression

Vector Auto Regression (VAR) model is a multivariate forecasting algorithm. It is used in scenarios where forecasting with two or more time-series which influence each other has been considered. The term 'Autoregressive' stands because each time-series variable is modelled as a function of its own past values and also lags of the variables are used as predictors (Dissanayak, 2020).

In studies where several variables are involved with mutual dependence, the change in one variable can be forecasted based on the lagged values of the dependent variable as well as that of the independent variables. Such feedback relationships are allowed for in the Vector Auto Regressive (VAR) frame work. All variables are treated symmetrically and modelled as if they all influence each other. Formally all variables can be treated as 'endogenous. It comprises one equation per variable in the system. The right-hand side of each equation includes a constant and original or lags of all the variables in the system. For example, if we consider two variables VAR with one lag, the two-dimension VAR (1) can be written as,

$$y_{1,t} = C_1 + \emptyset_{11} y_{1,t-1} + \emptyset_{12,1} y_{2,t-1} + \varepsilon_{1,t}$$

$$y_{2,t} = C_2 + \emptyset_{21} y_{1,t-1} + \emptyset_{22,1} y_{2,t-1} + \varepsilon_{2,t}$$

Where $\varepsilon_{1,t}$ *and* $\varepsilon_{2,t}$ are white noise processors that may be correlated. The coefficient $\phi_{ii,l}$ captures the influence of the l^{th} lag of variable y_1 on itself, while the coefficient $\phi_{ij,l}$ l^{th} lag of variable y_j on y_i.

RESULTS AND DISCUSSION

Trend Analysis

The trend in total cropped area, fertilizer consumption, pesticide consumption and food grains production in India during the period from 1950 to 2020 were analysed and shown in Fig. 1.

The trend in total cropped area and food grains production in India could be quantified through a linear equation with R^2 equal to 0.94 and 0.96, respectively showing a positive trend. Regarding fertilizer consumption, variations were observed in rate of consumption and showed a decreasing tendency in the very recent periods. The reason might be that the people were becoming aware of the ill effects of higher consumption of chemical fertilizers and they were attracted towards bio fertilizers (Bansal, 2020). Second degree equation could represent the trend with R^2 equal to 0.98. During 1970's to 1990's the consumption rate in pesticide was comparatively high. After that there was a decline in the level of consumption. This decline might be due to the introduction of Integrated Pest Management, ban of some pesticides etc. Due to the up and downs in the consumption pattern of pesticides the trend could be expressed using a third-degree equation with R^2 equal to 0.81.

An idea about the progress of total cropped area, consumption of fertilizers and pesticides and food grains production could be visualized through trend analysis. In India overall trend was increasing with respect to all variables under study. So, to identify the co-integrated movement of food grains production with agricultural inputs such as total cropped area, fertiliser consumption and pesticide consumption, Vector Auto Regression model was used for all variables.

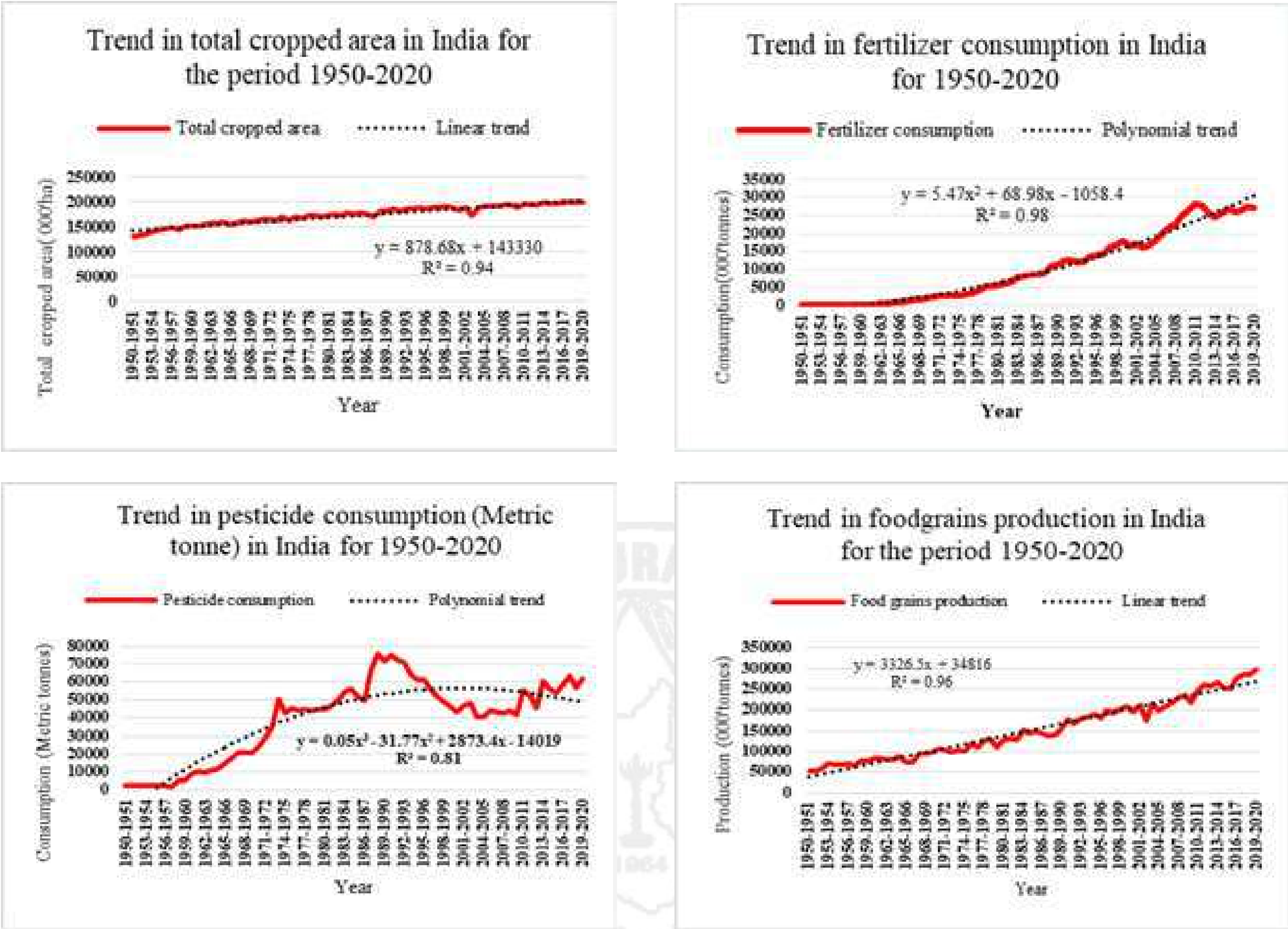

Fig. 1 : Trend in total cropped area, fertilizer consumption, pesticide consumption and food grains production in India

VAR Models using Lagged Values of Dependent and Independent Variables

If VAR models can be developed using lagged dependent and lagged independent variables, the same can be used to predict one variable well in advance say one year before the next food grain production etc. using the previous year's data on food grain production, total cropped area, fertiliser consumption and pesticide consumption. Similarly, each of the variables can be predicted using the lagged value of itself and lagged values of other independent variables.

VAR Model for Total Cropped Area in India

From Table 1 it is evident that, the total cropped area for the next year could be predicted using the current years' total cropped area, fertiliser consumption, pesticide consumption and food grains production.

TABLE 1

Estimated coefficients of VAR model for total cropped area in India

	Coefficient	Std.Error	t-ratio	p-value
Constant	49522.6	18457.7	2.68	0.009 ***
Total cropped Area: $V2_{-1}$	0.71	0.13	5.35	1.24e-06 ***
Fertilizer Consumption: $V3_{-1}$	0.78	0.30	2.65	0.01 **
Pesticide consumption: $V4_{-1}$	0.13	0.05	2.50	0.02 **
Food grains production: $V1_{-1}$	“0.08	0.05	“1.45	0.15 NS

*** significant at 1% level; ** significant at 5% level

The resulted vector auto regression equation for India with adjusted R^2 value equal to 0.95 was,

$V2 = 49522.6 + 0.71\ V3_{-1} – 0.78\ V4_{-1} + 0.13\ V2_{-1} - 0.08\ V1_{-1}$ ……….. (1)

Where V2 = total cropped area for the next year, $V2_{-1}$ is the total cropped area during the current year, $V3_{-1}$ is the fertiliser consumption during current year, $V4_{-1}$ is the pesticide consumption during current year and $V1_{-1}$ is the food grains production during current year.

In this case fertiliser consumption and pesticide consumption during current year were having significant influence on total cropped area during next year and the corresponding regression coefficients were significant at five per cent level of significance.

From Table 5 adjusted R^2 value was significantly high and was equal to 0.95 and Durbin Watson equal to 2.75. Actually, the Durbin Watson (DW) Test is a measure of autocorrelation (also called serial correlation) in residuals from regression analysis. Here, with respect to total cropped area in India DW equal to 2.75. It shows the negative auto correlation.

VAR Model for Fertiliser Consumption in India

From Table 2 it is evident that fertiliser consumption for the next year could be predicted using its own lagged value during current year and lagged values of other variables. Lagged values of fertiliser consumption and total cropped area were found to be significant in the prediction equation developed. The resulted vector auto regression equation for India with significantly high value of adjusted R^2 value equal to 0.99 was, $V3 = -5858.66 + 1.03\ V3_{-1} – 0.02\ V1_{-1} - 0.002\ V2_{-1} + 0.05\ V2_{-1}$ ……. (2)

Where V3 is the fertiliser consumption for the next year, $V3_{-1}$ is the fertiliser consumption during the current year, $V1_{-1}$ is the food grains production during the current year, $V4_{-1}$ is the pesticide consumption during the current year and $V2_{-1}$ is the total cropped area during the current year.

TABLE 2

Estimated coefficients of VAR model for fertiliser consumption in India

	Coefficient	Std. Error	t-ratio	p-value	
Constant	-5858.66	3169.92	-1.85	0.07	*
Fertiliser consumption: V3-1	1.03	0.05	19.27	2.44e-028	***
Food grains production: V1-1	-0.02	0.01	-1.43	0.16	NS
Pesticide consumption: V4-1	-0.002	0.009	-0.25	0.80	NS
Total cropped area: V2-1	0.05	0.02	1.96	0.05	*

*** significant at 1% level; ** significant at 5% level; NS: Non-Significant

TABLE 3

Estimated coefficients ofVAR model for pesticide consumption in India

	Coefficient	Std. Error	t-ratio	p-value	
Constant	-8680.95	17246.1	-0.50	0.62	
Pesticide consumption: V4-1	0.94	0.06	16.89	2.83e-0.25	***
Food grains production: V1-1	-0.06	0.08	-0.70	0.48	NS
Total cropped area: V2-1	0.10	0.13	0.72	0.47	NS
Fertilizer consumption: V3-1	0.25	0.42	0.60	0.55	NS

*** significant at 1% level; ** significant at 5% level; NS: Non-Significant

TABLE 4

Estimated coefficients ofVAR model for food grains production in India

	Coefficient	Std. Error	t-ratio	p-value	
Constant	47983.8	43247.6	1.11	0.27	
Food grains production: V1-1	0.43	0.15	2.94	0.005	***
Total cropped area: V2-1	-0.05	0.33	-0.15	0.88	NS
Fertilizer consumption: V3-1	3.67	0.73	5.03	4.26E-06	***
Pesticide consumption: V4-1	0.3	0.12	2.56	0.01	**

*** significant at 1% level; ** significant at 5% level; NS: Non-Significant

TABLE 5

Estimated goodness of fit measures of VAR model for total cropped area in India

Mean dependent variable	175141.2	S.D. dependent variable	17833.02
Sum squared residual	1.05e+09	S.E. of regression	4042.74
R-squared	0.95	Adjusted R-squared	0.95
F (4, 64)	4.441.72	P-value(F)	7.87e-46
rho	-0.40	Durbin-Watson	2.75

From Table 6 adjusted R^2 value was significantly high and was equal to 0.99 and Durbin Watson equal to 2.75. It shows the negative auto correlation.

Pesticide Consumption - India

In the case of regressing pesticide consumption on all lagged variables including pesticide consumption, from Table 3 it is noticed that the significant regressor obtained was pesticide consumption during previous period.

The resulted vector auto regression equation was,

$V4 = -8680.95 + 0.94\ V4\text{-}_1{}^{***} - 0.06\ V1\text{-}_1 + 0.10\ V2\text{-}_1 + 0.25\ V3\text{-}_1$ …....….. (3)

Where V4 is the pesticide consumption for the next year, $V4_{-1}$ is the pesticide consumption during the current year, $V1_{-1}$ is the food grains production during the current year, $V2_{-1}$ is the total cropped area during the current year and $V3_{-1}$ is the fertiliser consumption during the current year. From Table 7 it could be noticed that the adjusted R^2 was equal to 0.95 and D.W was equal to 2.15.

TABLE 6

Estimated goodness of fit measures of VAR model for fertiliser consumption in India

Mean dependent variable	10672.18	S.D. dependent variable	9610.78
Sum squared residual	39563513	S.E. of regression	786.24
R-squared	0.99	Adjusted R-squared	0.99
F (4, 64)	2524.101	P-value(F)	1.24e-69
rho	0.14	Durbin-Watson	2.75

Food Grains Production - India

From Table 4, variables such as food grains production, fertiliser consumption and pesticide consumption were found to be significant. The resulted vector auto regression equation for India was

$V1 = 47983.8 + 0.43\ V1\text{-}_1{}^{***} - 0.05\ V2\text{-}_1 + 3.67\ V3\text{-}_1{}^{***} + 0.30\ V4\text{-}_1{}^{**}$…........…. (4)

Where V1 is the food grains production for the next year, $V1_{-1}$ is the food grains production during the current year, $V2_{-1}$ is the total cropped area during the current year, $V3_{-1}$ is the fertiliser consumption during the current year and $V4_{-1}$ is the pesticide consumption during the current year. In this case fertiliser consumption and pesticide consumption during past year were having significant influence on food grains production.

TABLE 7

Estimated goodness of fit measures of VAR model for pesticide consumption in India

Mean dependent variable	40015.45	S.D. dependent variable	21627.22
Sum squared residual	1.57E+09	S.E. of regression	4952.99
R-squared	0.95	Adjusted R-squared	0.95
F (4, 64)	786.54	P-value(F)	1.20E-53
rho	-0.09	Durbin-Watson	2.15

From Table 8 it was evident that the adjusted R^2 value was equal to 0.97 and DW was equal to 2.56 respectively.

The trend analysis for a period from 1950-2020 for the variables namely total cropped area, fertiliser consumption, pesticide consumption and food grains production in India depicted an overall growth movement in the upward direction except a decline in the very recent past for fertiliser consumption. The trend could be quantified through linear equations with R^2 equal to 0.94 and 0.96 with respect to total

TABLE 8

Estimated goodness of fit measures of VAR model for food grains consumption in India

Mean Dependent variable	154384.9	S.D. dependent variable	68284.72
Sum squared residual	7.56E+09	S.E. of regression	10871.23
R-squared	0.98	Adjusted R-squared	0.97
F (4, 64)	809.7	P-value(F)	5.06E-54
rho	-0.32	Durbin-Watson	2.56

cropped area and food grains production respectively. A second-degree trend equation could explain 0.98 percent of the variation in the data of fertiliser consumption in India showing a decline in the very recent past. In the case of pesticide consumption in India huge fluctuations were found to exist and a third-degree trend equation resulted in R^2 equal to 0.81. The trend analysis gave a rough idea about the movement of the variables under study. To express the interdependency among the variables under study, a vector auto regression approach was employed to examine co-integrated movement of variables. Results from VAR modelling showed that while regressing food grains production on lagged variable of itself and other lagged variables like fertiliser consumption, pesticide consumption and total cropped area, the adjusted R^2 was 0.98. Modelling fertiliser consumption on lagged value of itself, pesticide consumption and total cropped area resulted in an adjusted R^2 of 0.99. When pesticide consumption was regressed on all lagged variables, adjusted R^2 obtained was 0.95 and when total cropped area was regressed on all lagged variables, the adjusted R^2 was equal to 0.95 showing the potential of VAR modelling to assess the co integrated movement of variables in all cases.

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(*Received :* November 2021 *Accepted :* December 2021)