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Mathematical modeling for factors estimation: A Study with reference to groundnut cultivation

Dr.T.Jagathesan[1]

Abstract

The price of raw materials are the key factors in determining the price structure. Variation in the prices of output limits utilization of resources for maximization of profit. Groundnut is cultivated in the States like Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh and Tamil Nadu in vast area of land. This study used primary data from a sample of 54 farmers of a village in Kanchipuram district who were groundnut cultivating farmers based on simple random sampling method. The regression result shows that if we increase labour by one hour the groundnut output reduces by 81.308 and hence it is labour intensive cultivation and for land if we increase it by one acre the output increases by 258.15 kg. An attempt is made in this study with a mathematical modelling for factors estimation for groundnut cultivation is attempted in a village at Kanchipuram which is highest producing district in Tamil Nadu.

Keywords: mathematical modelling, groundnut, regression result, utilization of resources.

Introduction

The price of agricultural commodities and agricultural raw materials are the key factors in determining the price structure. Lower or higher prices of output limits utilization of resources for maximization of profit. The decline in supply increases its prices. The rapid increase in population and economic development creates a strong pressure on demand which also leads to increase in food grain prices. This can be corrected only by a large and adequate supply of agricultural output and a greater attention is, therefore, required to be focused for matching the demand for food grains and agricultural commodities with the supply thereof. In this context, one needs detailed knowledge about the net effect of price and non-price factors like factor and product prices, technology, irrigation, capital use, acreage etc. so that required adjustment needed in price and non-price factors could be worked out to attain the specific goals of prices, production and crop income. In this paper, mathematical modelling for factors estimation for groundnut cultivation is

[1] Associate Professor and HOD of Mathematics, Ramakrishna Mission Vivekananda College (Autonomous), Chennai-600 004.

attempted in a village at Kanchipuram which is highest producing district in Tamil Nadu.

Review of literature

Ground nut is one of the important crops in India. Ground nut ranks fifth, among the world food crops (After Rice, Wheat, Maize, and Barley). The main states of India where the Ground nut is cultivated are Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh and Tamil Nadu. In India during 2017-18, the area under Groundnut was 7.70 million hectares with production of 7.30 million tonnes and productivity was 952 kg ha while in Maharashtra the area under Ground nut was 4.17 million hectares with production of 3.67 million tonnes and productivity was 877 kg ha^{-1} and the area in Vidarbha under Ground nut cultivation was 2.88 lakh hectares with production of 3.77 lakh tonnes and productivity was 1308 kg ha P.Kumar, P. Shinoj, S.S. Raju, A. Kumar, M.R. Karl, and S. Msangi, (2010).

F. Yakam-Simen, E. Nezry and F. Zagolski (1999) discriminated and estimated the cultivated area of winter wheat, spring barley, potato, sugar beets, maize, peas, rapeseed and other crops using the isodata cluster method applied with ERS SAR data. M. Bannayan and N.M.J. Crout, (1999) have analysed agricultural simulation models are a key component to test advances in agricultural technology and to predict crop responses to current and future climate forcing. Simulation models are strong tools to know the system responds to a given set of conditions. Crop simulation models are used in agriculture to estimate production potentials, design plant ideotypes, transfer agro technologies, assist strategic and tactical decisions, forecast real time yields and establish research priorities.

S.S.Jagtap and J.W. Jones. (2002) discussed about the crop simulation models and evaluated soil and environmental conditions across the world and have been successfully used in yield predictions. The use of crop growth models on large areas for diagnosing crop growing conditions or predicting crop production is hampered by the lack of sufficient spatial information about model inputs. A.M.Link, Panitzki and S. Reusch. (2005) discussed about ground based remote sensing for variable rate in management relies on real time, sensor-based spectral measurement of crop nitrogen assessment and management.

K.R.Thorp, K.C. DeJonge, A.L. Kaleita, W.D. Batchelor, and J.O.Paz (2008) articulated that DSSAT has modules allow the user to build model input files for spatial simulations across predefined management zones, calibrate the models to simulate historic spatial yield variability, validate the models for seasons not used for calibration and estimate the crop response and environmental impacts of nitrogen, plant population, cultivar, and irrigation prescriptions. A.K.L. Prasad, R.P. Chai, R.P. Singh, and M. Kafatos. (2006) considered parameters like soil moisture, NDVI, surface temperature, rainfall data of Iowa state for 19 years for crop yield assessment and prediction using piecewise linear regression method with breakpoint. A non-linear Quasi-Newton multi-variate optimization was utilized that minimizes inconsistency and errors in yield prediction. They suggested that crop yield prediction model would improve further with the use of long period dataset.

Sivarajan (2011) explained that crop models use mathematical function of various crop physiological factors like photosynthesis, respiration, growth rate to estimate crop growth changes under various climatic and environmental conditions. Such models provide assessment in small and homogenous fields with heterogeneous soil and different agro climatic zones. In this context model becomes complicated as it needs several inputs for simulation and calibration process difficult.

D. Bargiel, and S. Herrmann (2011) investigated the multi-temporal classification of agricultural land use based on high resolution spotlight Terra SAR-X images. A stack of l4 dual-polarized radar images acquired during the vegetation season have been used for two different study areas (North of Germany and South East Poland). The Maximum Likelihood classification was based on a high amount of ground truth samples. Overall accuracy for all classes was 61.78 per cent and 39.25 per cent for German and Polish region, respectively.

K.R.Thorp, J.W. White, C.H. Porter, G. Hoogenboom, G.S. Nearing, A.N. French, (2012) have analysed the use of crop growth models on large areas for diagnosing crop growing conditions or predicting crop production is hampered by the lack of sufficient spatial information about model inputs and focused on the integration of remote sensing and crop growth simulation models for crop growth monitoring and yield estimation. V. Mishra, J. F. Cruise, J.R. Mecikalski, C.R. Hain and M.C. Anderson (2013) have applied a two-source energy balance model v.z., Atmospheric Land Exchange Inverse (ALEXI) and the results indicated that the data were available at sufficient temporal resolution to drive the crop model in a realistic manner as compared to the rainfed model and observed corn yields with RMSE of 28 percent.

Definition of variables:

The following are the models used in farm management studies.

Profit function analysis:

$$Q = A\, N_H^{\alpha_1}\, B_N^{\alpha_2}\, X_P^{\alpha_3}\, F_M^{\alpha_4}\, S^{\alpha_5}\, K^{\beta_1}\, L^{\beta_2}\, U$$

$$\frac{\pi}{P} = A^*({w^1}/{P})^{\alpha_1^*}({b^2}/{P})^{\alpha_2^*}({r^3}/{P})^{\alpha_3^*}({m^4}/{P})^{\alpha_4^*}({s^5}/{P})^{\alpha_5^*}K^{\beta_1^*}L^{\beta_2^*}U$$

(or)

$$\pi^* = A^* w^{1\alpha_1^*} b^{2\alpha_2^*} r^{3\alpha_3^*} m^{4\alpha_4^*} s^{5\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*} U$$

Where
Q = The Physical output of ground nuts in the study area
N_H = Labour hours used per acre in the study area
B_N = Bullock labour is hours includes both hired and owned
X_P = Total quality of plant nutrients measured in kilogram per acre
F_M = Farm yard manure per acre
S = Total quantity of seed measured in kg per acre
K = Machinery charges
L = Land utilized for crop measure in acres
W.N = Total wage incurred per acre
b.B = Total wage incurred for bullock cost per acre

r.x = Total fertilizer cost incurred per acre
s.s = Total cost of seed per acre
m.F = Total cost of farm yard manure
w = Wage rate in rupees per man hour
b = Total Bullock labour rate per acre
r = Price of plant nutrients in rupees per kg
m = Price of FYM per kg in rupees.

Input demand function:

1. Human labour demand equation

$$-\frac{\partial \pi^*}{\partial w^*} = -\alpha_1^*\left(\pi^*/_{w^*}\right) = N_H \qquad \text{(a)}$$

2. Bullock labour demand equation

$$-\frac{\partial \pi^*}{\partial b^*} = -\alpha_2^*\left(\pi^*/_{b^*}\right) = B_N \qquad \text{(b)}$$

3. Fertilizer demand equation

$$-\frac{\partial \pi^*}{\partial r^*} = -\alpha_3^*\left(\pi^*/_{r^*}\right) = X_P \qquad \text{(c)}$$

4. Farm yard manure demand equation

$$-\frac{\partial \pi^*}{\partial f^*} = -\alpha_4^*\left(\pi^*/_{f^*}\right) = F_M \qquad \text{(d)}$$

5. Seed demand equation

$$-\frac{\partial \pi^*}{\partial s^*} = -\alpha_5^*\left(\pi^*/_{s^*}\right) = S \qquad \text{(e)}$$

Substituting π^* from **identify (i)** into ‘a’ to ‘e’ the demand equation can be written as:

Supply function:
Shephard’s lemmas (1953) shows that first order derivative of profit function with respect to output price gives output supply function.

$$\frac{\partial \pi}{\partial P} = \theta\left(\pi/_{P}\right)$$

The output supply function is the form of Cobb-Douglas function can be written as

$$Q = A\theta P^{\theta-1} w^{*\alpha_1^*} b^{*\alpha_2^*} r^{*\alpha_3^*} m^{*\alpha_4^*} s^{*\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*}$$

The equation represents the supply of factors with respect to output prices, wage rate, bullock labour price, fertilizer price, form yard manure price, seed price and price of capital input.

Estimation of Cobb-Douglas profit function and input demand function using Zellner's method (1962) the profit function and demand for factors like human labour, bullock labour, fertilizer, manure and seed were jointly estimated. The seemingly unrelated regression equation (SURE) was appeared by restricting $\alpha^{1*}, \alpha^{2*}, \alpha^{3*}, \alpha^{4*}$ and α^{5*} are equal in both the profit function and relevant factor demand equation.
The co-efficient of SURE methods as

$$\hat{\alpha}_{\text{SURE}} = (X^1 V^{-1} X)^{-1} X^{-1} V^{-1} Y$$

were, X is independent variable and Y is dependent variable.

$$V = \Sigma^{\emptyset} I_N$$

Were Σ representing the covariance of residual between the equations, Ø is the kronecker product and I_N is the identify matrix of number of observations.

Impact of observation:

The factor demand of ground nut for i^th variable as

$$X_i = X\,(PQ, w, b, r, m, s) \qquad i = 1, 2, 3, 4, 5$$

The factor supplies of groundnut as

$$Q = Q(P_Q, w, s, b, r, m\,, s)$$

Taking total differential of above equation and representing in terms of growth rate,

$$X_i = E_{X_i}^{PQ} P_*^* Q + E_{X_i}^{w} w_*^* + E_{X_i}^{b} b_*^* + E_{X_i}^{r} r_*^* + E_{X_i}^{f} f_*^* + E_{X_i}^{s} s_*^* + E_{X_i}^{K} K_*^* + E_{X_i}^{L} L_*^*$$
$$Q = E_{Q}^{PQ} P_*^* Q + E_{Q}^{w} w_*^* + E_{Q}^{b} b_*^* + E_{Q}^{r} r_*^* + E_{Q}^{f} f_*^* + E_{Q}^{s} s_*^* + E_{Q}^{K} K_*^* + E_{Q}^{L} L_*^*$$

E $\Rightarrow$ Elastisity of the parameters

$*$ $\Rightarrow$ indicates rate of change

Methodology and objective

The present study used a primary data of sample of 54 farmers were contacted in a village in Kanchipuram region from the Ground nut cultivating farmers. A simple random sampling method was adopted to collect the required information for the study. For the observation purpose a well-organized questionnaire was prepared. Simple statistical tools like Regression Equation were applied by using STATA application. This study attempts to estimate the use of inputs and level of output of groundnuts in the study area.

Results and discussion

In this study, linear regression method of the following from has been used:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10}$$

Y is groundnut output in kg. per acre

A is intercept

X_{1is} Labour (in hours)

X_2 is Bullock labour (in hours)

X_3 is Seed (in kg. per Acre)

X_4 is Land (in Acre)

X_5 is Capital (in Rs)

X_6 is Wage (in Rs)

X_7 is Fertilizer (in Rs)

X_8 is Seed cost (in Rs)

X_9 is Bullock labour cost (in Rs)

X_{10} is Cost of farm yard manure (in Rs)

b_1 to b_{10} are regression coefficients

The results of the multiple linear regression are given in the following table and Charts.

Table 1: Regression results of groundnut cultivation

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.727276							
R Square	0.528931							
Adjusted R Square	0.416772							
Standard Error	779.3044							
Observations	53							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	10	28640328	2864033	4.71589	0.00016			
Residual	42	25507245	607315.4					
Total	52	54147573						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	5981.835	4896.007	1.221778	0.228605	-3898.71	15862.38	-3898.71	15862.38
Labour (in hours)	-81.308	308.1041	-0.2639	0.793149	-703.087	540.4711	-703.087	540.4711
Bullock labour (in hours)	-42.055	945.8593	-0.04446	0.964747	-1950.88	1866.766	-1950.88	1866.766
Seed (in kg. per Acre)	-62.7695	54.33428	-1.15525	0.25452	-172.421	46.8815	-172.421	46.8815
Land (in Acre)	258.1512	52.87499	4.882294	1.56E-05	151.4452	364.8572	151.4452	364.8572
Capital (in Rs)	0.13338	0.076726	1.73833	0.08948	0.28821	0.021464	0.28821	0.021464
Wage (in Rs)	0.02859	0.075592	0.37827	0.707132	0.18114	0.123956	0.18114	0.123956
Fertilizer (in Rs)	0.025605	0.149146	0.171677	0.864516	-0.27538	0.326593	-0.27538	0.326593
Seed cost (in Rs)	0.224059	0.179984	1.244883	0.220076	-0.13916	0.58728	-0.13916	0.58728
Bullock labour cost (in Rs)	2.282754	1.029131	2.218137	0.032007	0.205883	4.359624	0.205883	4.359624
Cost of farm yard manure (in Rs)	-0.216	0.250054	-0.86382	0.392594	-0.72063	0.288628	-0.72063	0.288628

Table 1 shows that if we increase labour by one hour the groundnut output reduces by 81.308 and hence it is labour intensive cultivation. Similar things are observed for Bullock labour, Seed in kg and Cost of farm yard manure. With regard to Land if we increase it by one acre the output increases by 258.15 kg.

Chart 1: Regression standardised residual

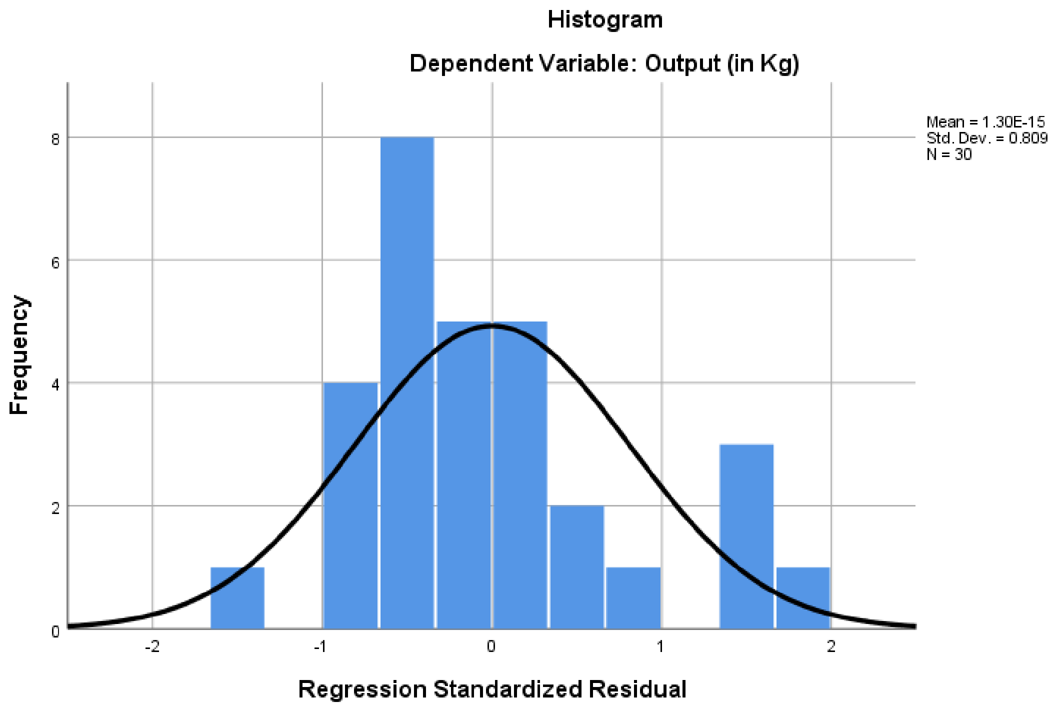

Chart 2: P-P Plot of Regression standardised for output

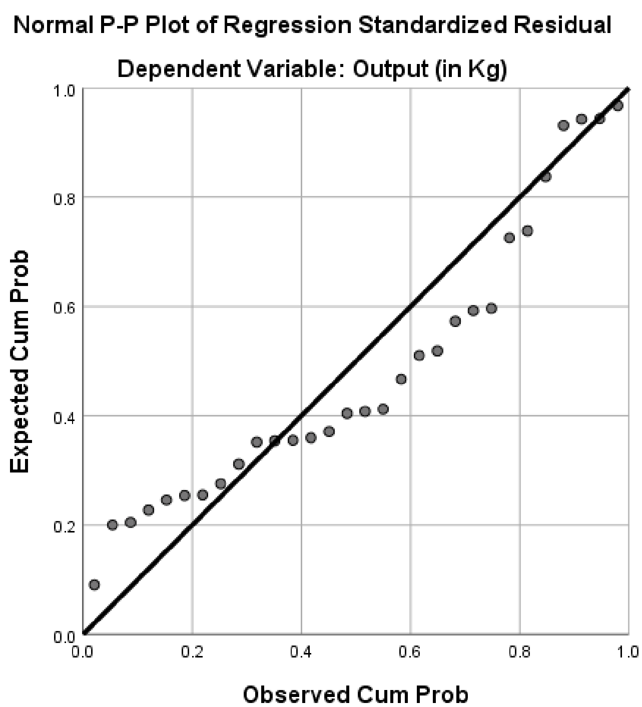

Chart 3: Partial Regression plot between output and labour

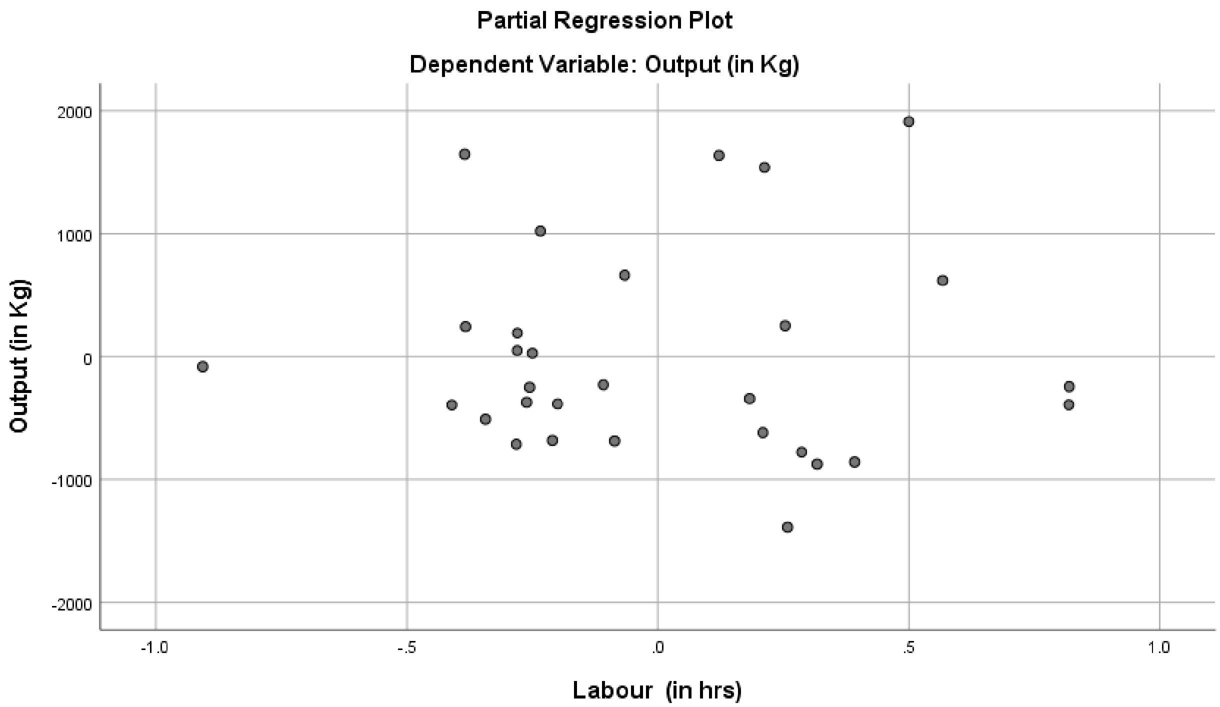

Chart 4: Partial Regression plot between output and bullock

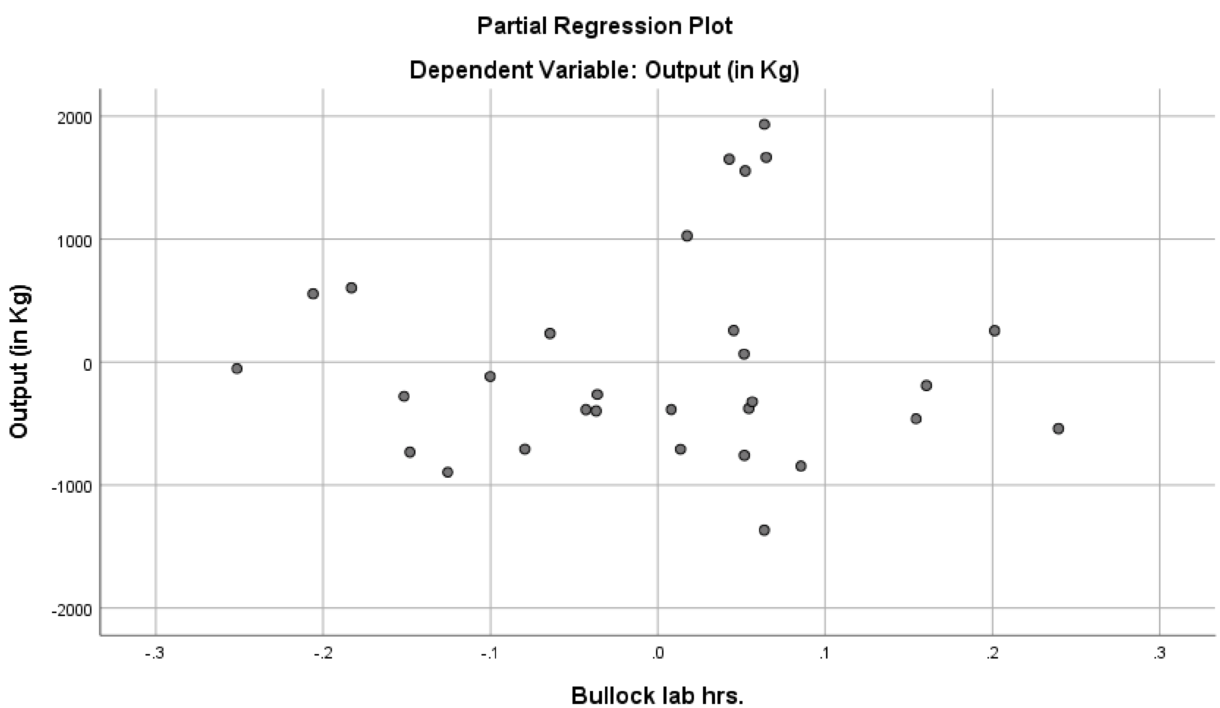

Chart 5: Partial Regression plot between output and seed

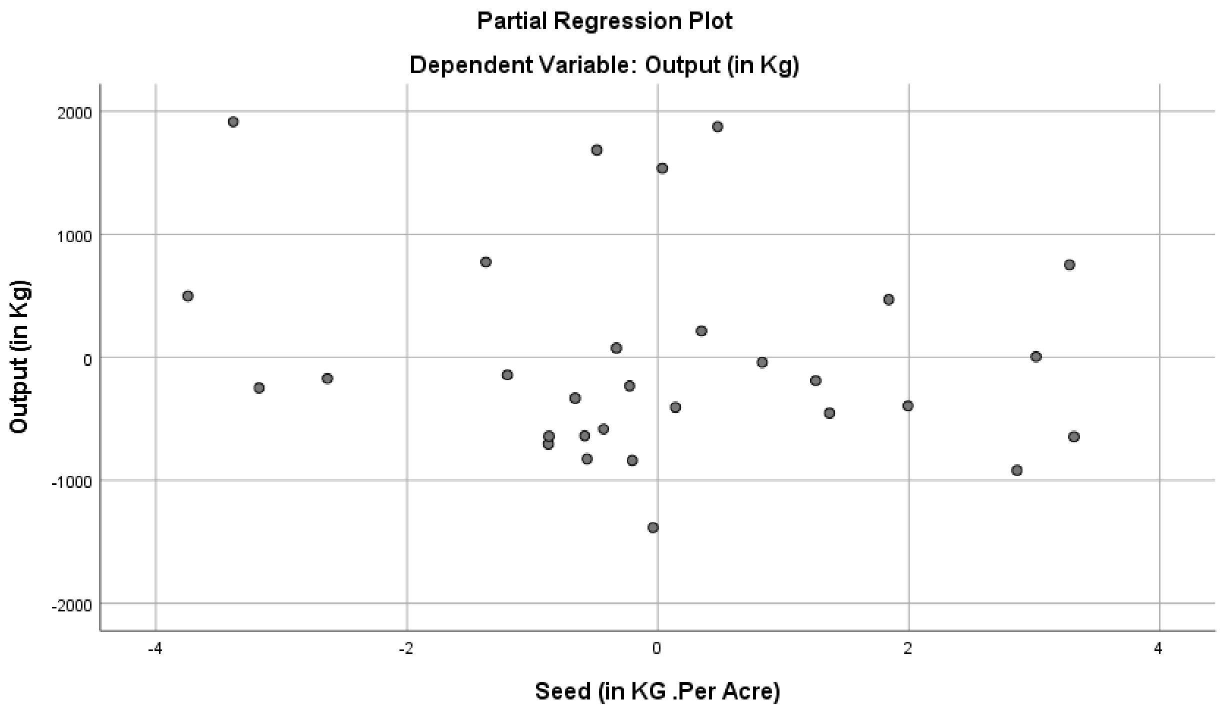

Chart 6: Partial Regression plot between output and land

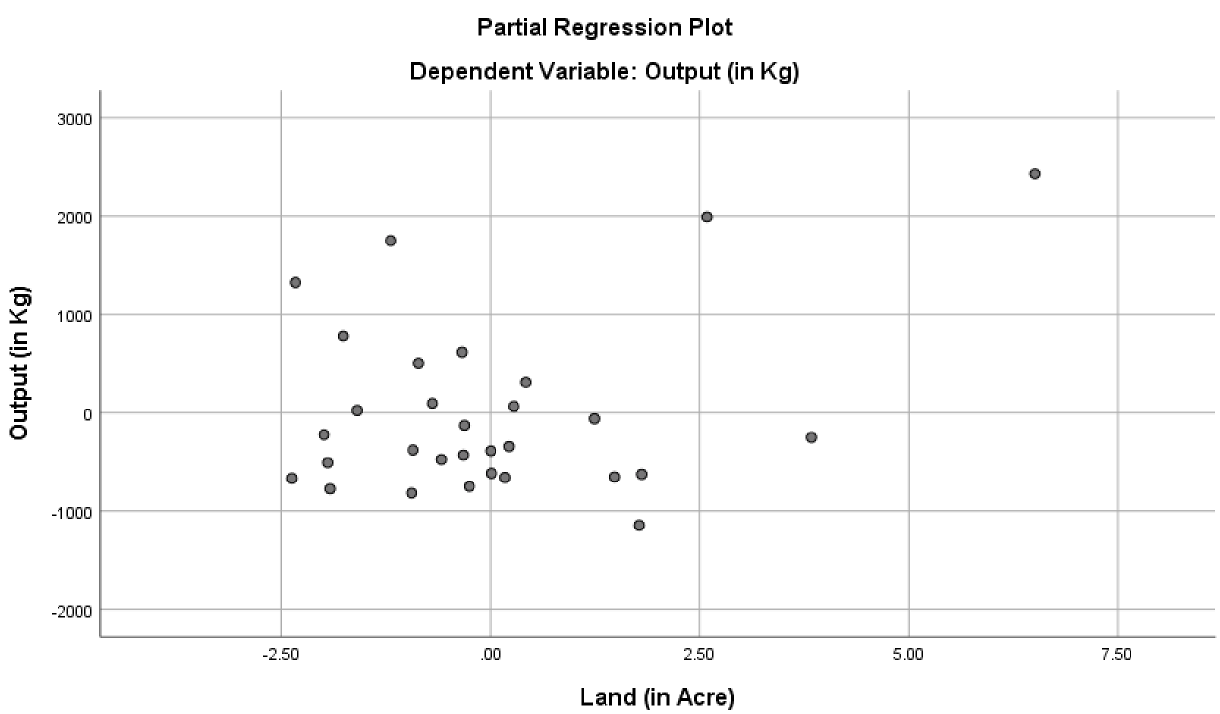

Chart 7: Partial Regression plot between output and capital

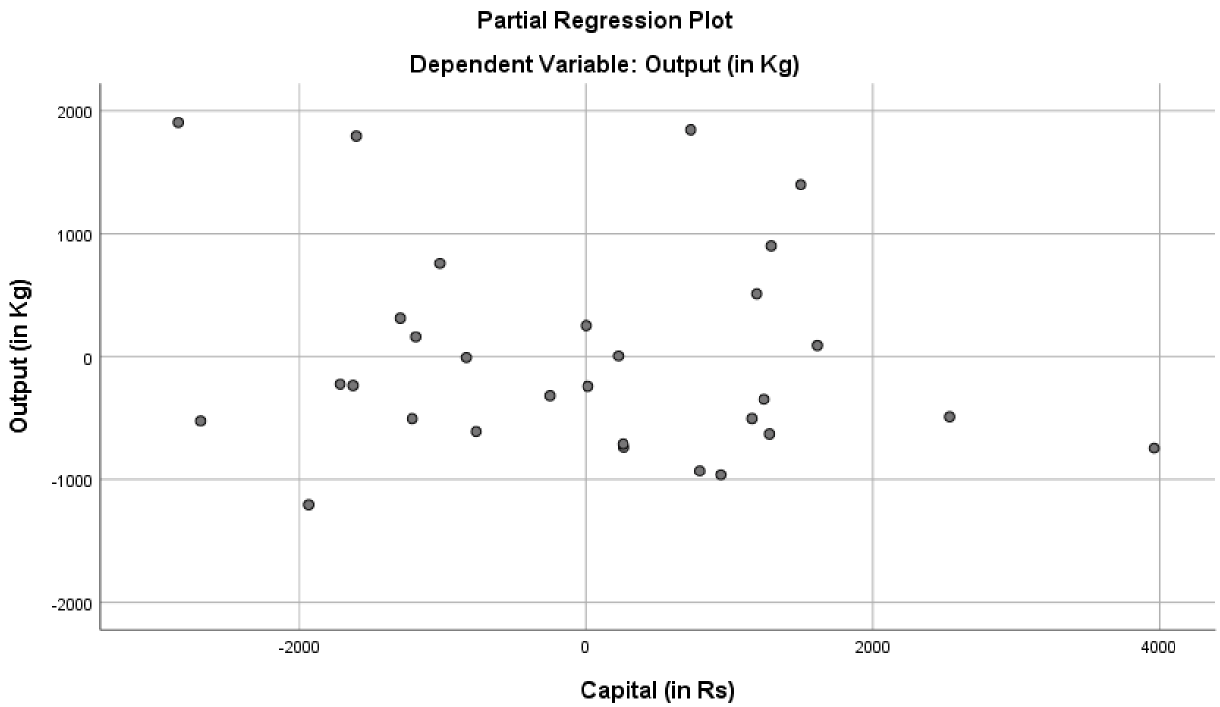

Chart 8: Partial Regression plot between output and wage

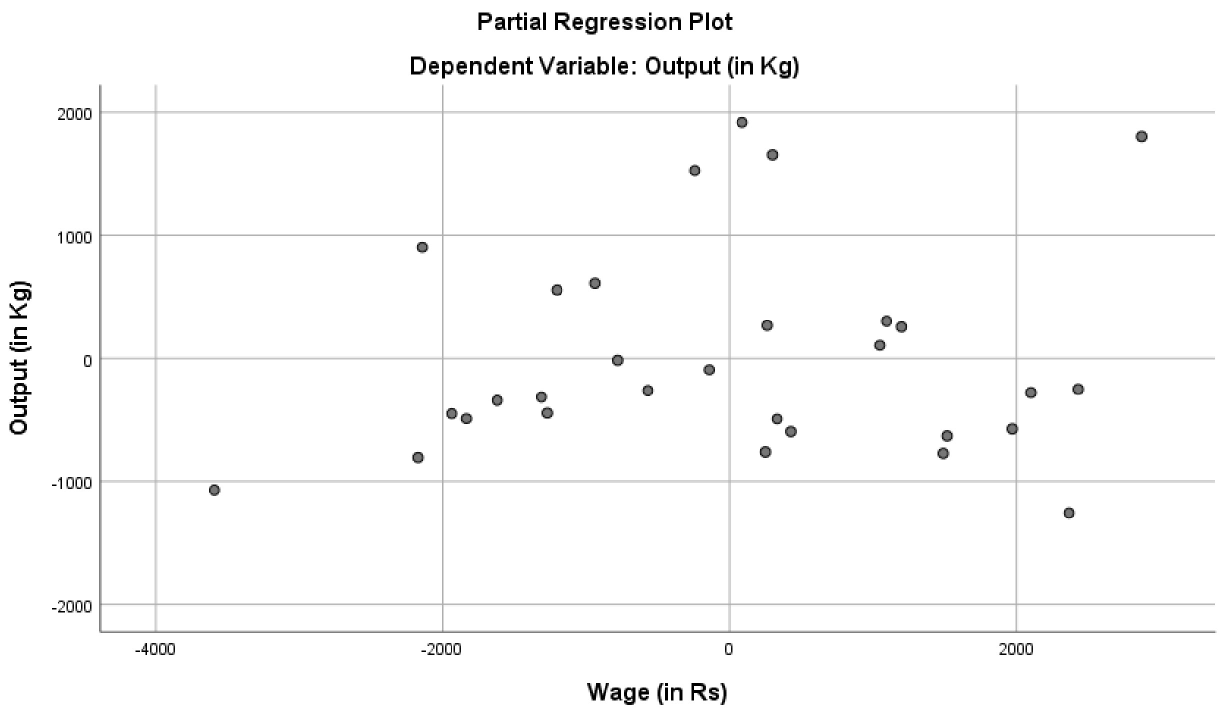

Chart 9: Partial Regression plot between output and fertilizer

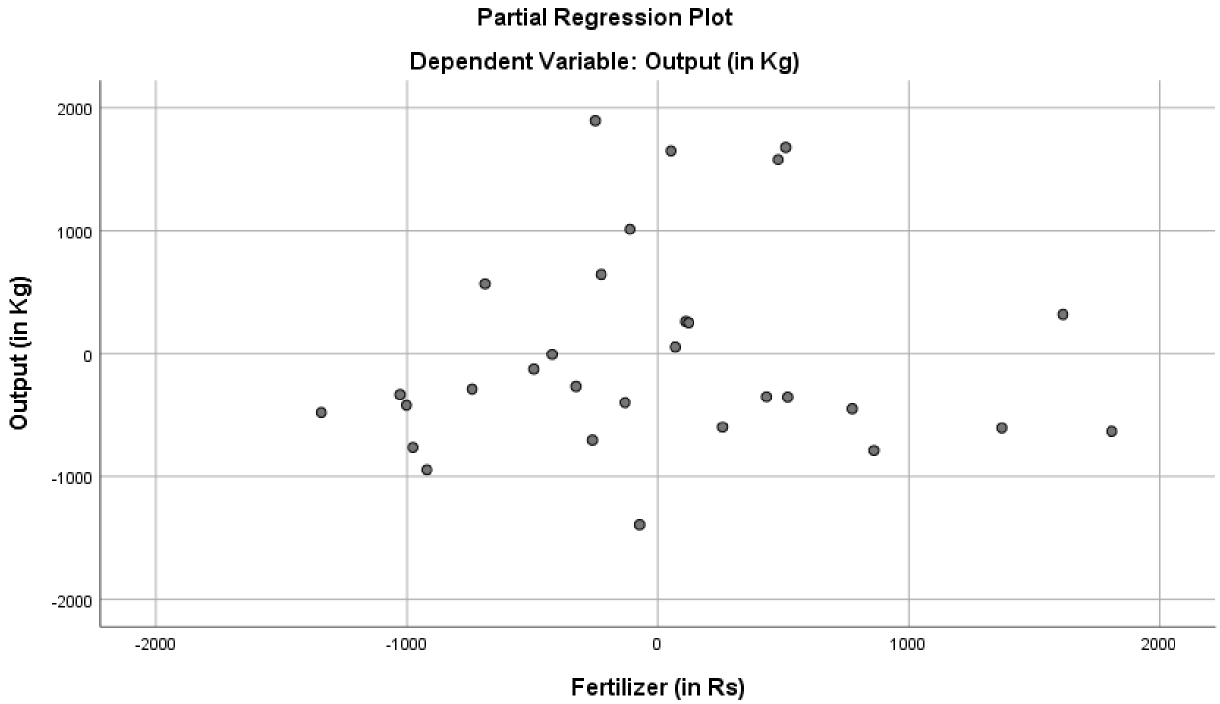

Chart 10: Partial Regression plot between output and seed cost

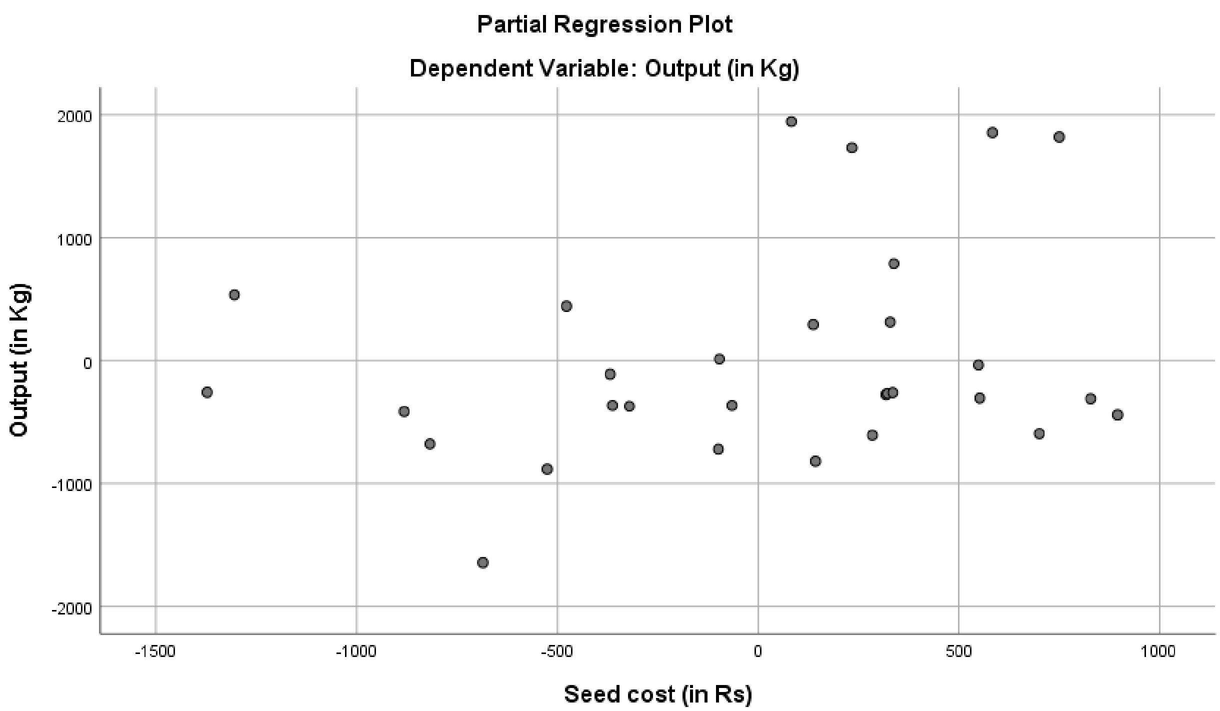

Chart 11: Partial Regression plot between output and bullock labour cost

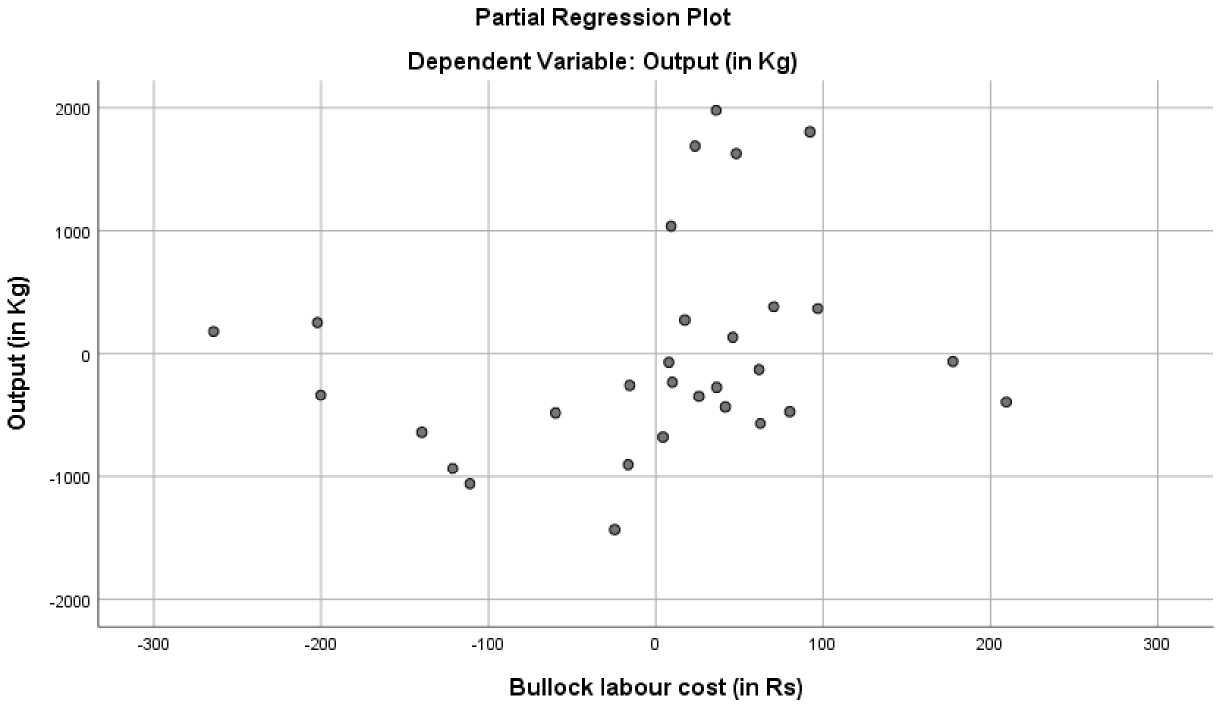

Chart 12: Partial Regression plot between output and cost of farm yard manure

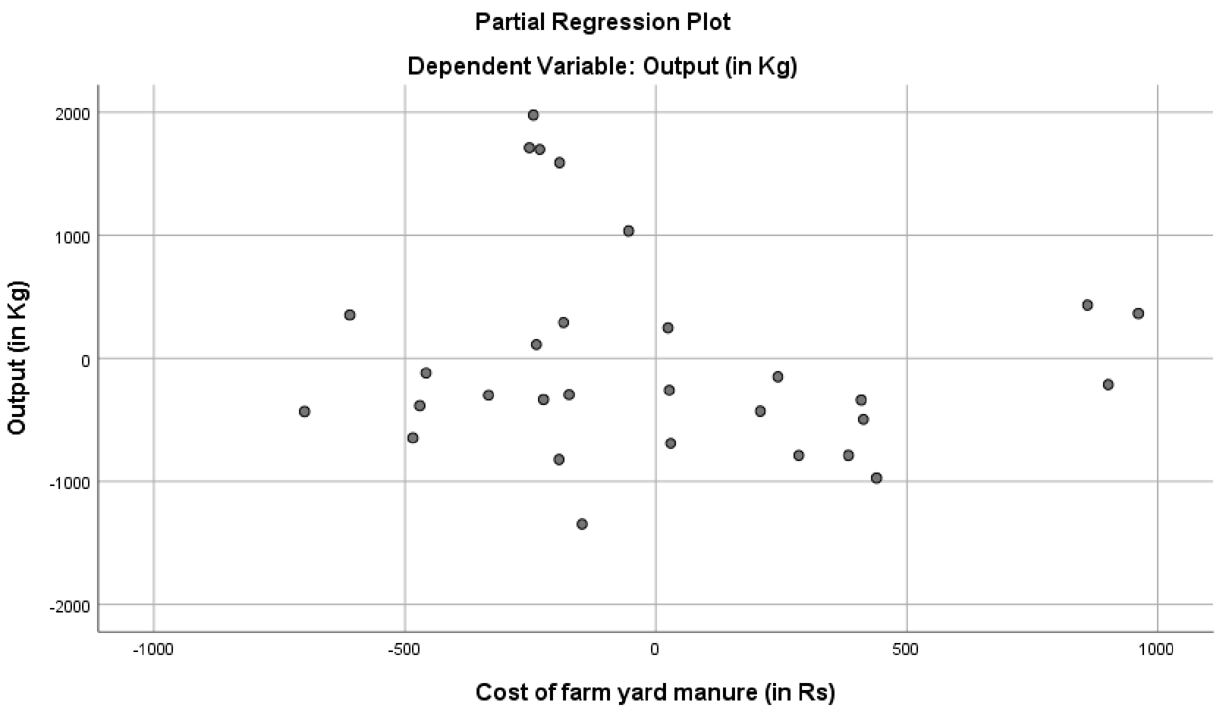

Chart 1 to Chart 12 provides the histogram and partial regression plot between output and 10 different inputs which show the relationship and distribution. They provide a specific probability distribution that compared the empirical distribution functions of the primary data. The P-P plot gives the skewed distribution of data in weird patterns in comparing probability distribution that has equal location found in the Charts. The partial regression plots given in the above charts have identified the leverage points, linearity and the most influential data points explaining the relationship between the independent and dependent variables of the model.

Conclusion

Mathematical model ensures accurate inside interpolation and initialization for parameters in such 10 inputs analysed with groundnut output. However, assimilation through comparison and optimization of reflectance simulated in this crop model has brought desired result. In addition, agricultural simulation models are a key to test advances in agricultural technology and to predict crop responses in future climate forcing situation. Input and output analysis, Cobb-Douglas production function, linear programming, differential calculus, general equilibrium is some of the models used in mathematical economics to accentuate authenticity.

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