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Statistical analysis of area and production of groundnut & sunflower oil seed crops in Tamil Nadu: A non-linear model approach

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Abstract
This study aim to identify the best model for area & production of Oil seed crops in Tamil Nadu. A secondary data was collected over a period from 1990 to 2017 (27 years). The main Oilseed crops considered for the study are Ground nut and Sunflower. There are four nonlinear models such as Exponential, Logistic Sinusoidal, and Hoerl models are used. The best model is selected based on R^2, RMSE and MAE values. According to area of Ground nut and Sunflower, Hoerl model is found to be the best since it has highest R^2(76%), Lowest Root Mean Square Error (55990.44) for Groundnut and highest R^2(78%), Lowest Root Mean Square Error (9418.802) for Sunflower. According to Production, Sinusoidal model is found to be the best for both Groundnut and Sunflower oilseed crops based on R^2 and RMSE value. Hence, Hoerl & Sinusoidal model is the most suitable fitted model for Area & production of Ground nut and Sunflower crops in Tamil Nadu respectively.

Keywords: Area, groundnut, nonlinear models, R^2, RMSE, sunflower

Introduction
India regarded as a paradise of oilseed crops having 19.0 per cent of the total world's oilseeds area and 10.0 per cent of world's oilseeds production. India is the fourth largest producer in the world in terms of output and occupying second place in area under oilseeds.

Groundnut (*Arachis hypogaea*) is the second most important annual oilseed crop after soybean. The groundnut seed oil content varies from 44 to 50% depending upon the varieties and conditions. In India, Tamil Nadu has the highest productivity compared to all other states in the country. Tamil Nadu is one of the top four groundnut-producing states in the country, accounting for around 20% of total production. Rainfall irrigates about two-thirds of the land, while irrigation irrigates the remaining one-third. In Tamil Nadu, the area under groundnut is about 3.38 lakh hectares. The soils in the entire Tamil Nadu are sandy loam. The major groundnut growing areas are Vellore, Cuddalore, Tiruvannamalai, Villupuram, Dharmapuri, Salem, Erode, Trichy, Madurai, Perambalur, Ariyalur, Pudukottai and Kancheepuram districts.

Sunflower (*Helianthus annus*) is a third important oilseed crop after soybean and groundnut. It has grown in popularity in India as a result of the government's emphasis on vegetable oil production. In India the sunflower is traditionally cultivated in Karnataka, Maharastra and Andhra Pradesh. In recent years its cultivation has also been taken up in non-traditional states like Haryana, Punjab, UP, Gujarat, Tamil Nadu, Orissa, MP, and Rajasthan, Karur, Tiruchirapalli, Thoothukudi, Dharmapuri, Virudhunagar, Dindigul, Tirunelveli, Thiruvannamalai and Namakkal are the major sunflower producing districts in the state.

In 2020-21 total Kharif oil seeds production in the country was 23.39 million tonnes which is 14.5% higher than the average of last five years kharif oilseeds production. In 2020-21 Tamil Nadu stood Third in area coverage with 0.48 lakh ha for groundnut. The percentage of total area used for groundnut cultivation in Tamil Nadu was 14.24. (Source: AGRICOOP.NIC.IN). India produced 185 thousand metric tons of sunflower oilseeds in fiscal year 2021. The production volume of all oilseeds that year in the country stood at 38.49 million metric tons.

This study is mainly focused on the computing the suitable Non-linear regression models for groundnut and sunflower. This study helps to know about the trend analysis in area, Production and Productivity of Groundnut and sunflower.

A mathematical model is an equation or a set of equations which represents the behavior of a system (France and Thornley, 1984). It can be either ‘linear’ or ‘nonlinear’. A linear modelis one in which all the parameters appear linearly. A ‘nonlinear model’ is one in which at least

one of the parameters appears nonlinearly. More formally, in a 'nonlinear model', at least one derivative with respect to a parameter should involve that parameter. Examples of a nonlinear model are:

$Y(t) = \exp(at+bt^2)$

The term 'intrinsically linear' to indicate a nonlinear model which can be transformed to a linear model by means of some transformation. Parameters in a nonlinear model can also assessed by the method of least squares. Levenberg-Marquardt's method is the most widely used method for computing nonlinear least square estimators. Because it is always converges and does not slow down at the latter part of the iterative process. Prajneshu and P.K. Das (2000) [6] applied some important nonlinear growth models to inspect analytically state wise wheat productivity pattern in India.

Materials and Methods

Annual data of area and production of Sunflower & Groundnut in Tamil Nadu for the period of 1990 to 2017 (27 years) were collected from Season and crop Report Tamil Nadu. There are four nonlinear models used for this study.
The Nonlinear models are given below

1. Exponential model is $Y = Ae^{bx}$
2. Logistic Model of the form $Y = \frac{a}{1+be^{-cx}}$
3. Sinusoidal model $Y = A + B\cos(CX - D)$
4. Hoerl Model $Y = AB^xX^c$

Goodness of Fit of a Model

Goodness of fit of a model is assessed by computing the co-efficient of determination R^2, Root Mean square error (RMSE), Coefficient of determination is defined as the proportion of the variance in the dependent variable that is predictable from the independent variable(s). Kvalseth (1985) has prioritize that

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Y_i - \widehat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} \quad 0<R^2<1$$

Root Mean Square Error (RMSE)

RMSE is defined as the square root of the average of squared errors.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - \widehat{Y}_i)^2}{n}}$$

Table 1: Estimation of parameters for fitted nonlinear models of area (ha) in Groundnut (1990-2017)

Parameters	Exponential model	Logistic model	Sinusoidal model	Hoerl model
a	1278244.206	7.823E-7	778672.762	1131418.29
b	1278244.206	1.055	452968.18	0.930
c	-	-	0.096	0.161
d	-	-	0.586	-
R^2	0.956	0.956	0.948	0.960
RMSE	71141.4	71141.4	63513.86	55990.44

Table 2: Estimation of parameters for fitted nonlinear models of production (ha) in Groundnut (1990- 2017)

Parameters	Exponential model	Logistic model	Sinusoidal model	Hoerl model
a	1685009.723	5.935E-7	1209331.548	1522955.267
b	-0.028	1.028	368830.088	0.955
c	-	-	0.156	0.152
d	-	-	-0.386	-
R^2	0.644	0.644	0.726	0.713
RMSE	189651	189651	171995.8	176240.1

Result and Discussion

There are four nonlinear models were used for studying of Sunflower & Groundnut in Tamil Nadu such as Exponential, Logistic, Hoerl and Sinusoidal models were used. The criteria for deciding the best model for Area in Groundnut was based on R^2 and RMSE. Table:1 showed that Hoerl model was the best model among the four models. Because it has maximum R^2 (96%), minimum RMSE. The best fitted model for production in groundnut was found to be Sinusoidal model mentioned in Table 2, since it has low RMSE and high R^2 value.

The Table 3 indicate that the Area of Sunflower for four nonlinear models. The criteria for deciding the best fit model for Area in Sunflower was based on R^2 and RMSE. It shows that showed that Hoerl model was the best model among the four models considered, since it has maximum R^2 (78%), minimum RMSE value.

Table 3: Estimation of parameters for fitted nonlinear models of area (ha) in Sunflower (1990-2017)

Parameters	Exponential model	Logistic model	Sinusoidal model	Hoerl model
a	27769.875	3.601E-5	6768864.70	28563.29
b	-0.042	1.043	6767645.58	0.949
c	-	-	0.002	0.094
d	-	-	3.05	-
R^2	0.641	0.545	0.674	0.780
RMSE	9660.582	9660.582	9457.35	9418.802

Table 4: Estimation of parameters for fitted nonlinear models of production (ha) in Sunflower (1990-2017)

Parameters	Exponential model	Logistic model	Sinusoidal model	Hoerl model
a	25641.549	0.00039	-3466789	15464.599
b	-0.039	1.040	3468000	0.947
c	-	-	0.002	0.41
d	-	-	-0.025	-
R^2	0.549	0.649	0.814	0.65
RMSE	15277.02	15277.02	13813.28	14185.85

Among the four models fitted Table4 indicates that the criteria for deciding the best model for Production of Sunflower. It showed that Sinusoidal model was the best model among the four models. Because it has maximum R^2 (81%), minimum RMSE.

Conclusion

An attempt has been made to study the Area & production of main Oilseed crops Ground nut and Sunflower in Tamil Nadu. In this study four non linear models were fitted for Area & Production of Oilseed crops Ground nut and Sunflower for the state Tamil Nadu. A secondary data was collected over a period from 1990 to 2017 (27 years). Among the four nonlinear models such as Exponential, Logistic Sinusoidal, and Hoerl models, the best model is selected based on R^2 and RMSE values. According to area of Ground nut and Sunflower, Hoerl model is found to be the best fit. The Sinusoidal model is found to be the best fitted model for the production of Groundnut and Sunflower oilseed crops respectively.

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