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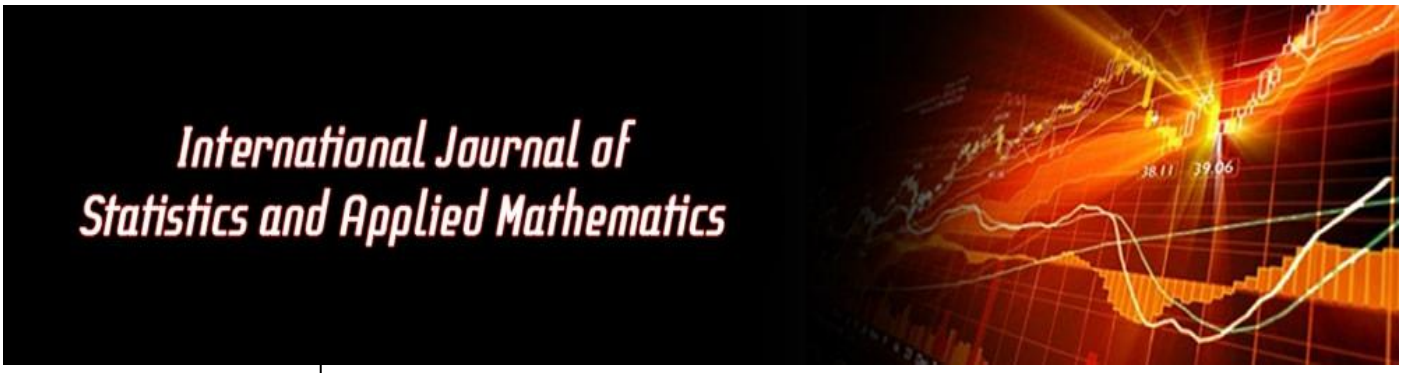

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Panchali Meena S
PG Scholar (Agrl. Statistics), Agricultural College & Research Institute, Madurai, Tamil Nadu, India

K Prabakaran
Assistant Professor (Agrl. Statistics), Agricultural College & Research Institute, Madurai, Tamil Nadu, India

Correspondence
Panchali Meena S
PG Scholar (Agrl. Statistics), Agricultural College & Research Institute, Madurai, Tamil Nadu, India

Linear and non linear models on paddy crop in different agro climatic zones of Tamil Nadu

Panchali Meena S and K Prabakaran

Abstract
Agriculture is the backbone of Indian nation. Agriculture in India and Tamil Nadu are unique in its character, with respect to climate and performance. The study focuses on to identify the model to predict the past, present and future performance of paddy crop in varied climatic regions. For this, five agro climatic zones and one district in each zone were purposively selected. Secondary data from the period 1990-1991 to 2009-2010 were used for this study. Various models like linear, log, quadratic, cubic, growth, exponential, logistic, compound, S curve, power and inverse models were fitted for the data. The best models were identified based on the highest R^2 value and minimum error value. The results shows that the cubic model was found to be best for paddy crop in the selected districts.

Keywords: Agro climatic zones, models, paddy and R^2 value

Introduction
Agriculture in India is unique in its characteristics, where over 250 different crops are cultivated in the country, because India has wide varied agro - climatic regions like desert Rajasthan, ice Jammu and Kashmir and Warmer states. This helps in the growing of various types of crops in the country while in some other developed countries of the world grow just 25 to 30 crops. Our country is widely suitable for agriculture and the major economy depends on agriculture.

Similarly Agriculture in Tamil Nadu also having a unique characteristics. The state blessed with wide range of agro climatic regions similar to India this helps in the growing of various types of crops in the State while comparing to other states. In Tamil Nadu, cold climatic fruit apple is cultivated in Ooty and the arid fruit guava is also cultivated in the state. While in other states some crops only grown because of the monotonic agro – climatic region.

A number of research workers have used linear models. There are some drawbacks of these models i.e. the data may not be following the linear or exponential models or may require fitting of higher degree polynomials or non-linear models. Further, these models lack the economic considerations i.e. normality and randomness of residuals. This paper apply various linear and non - linear models, to study the suitability of the model in the selected parameter like area, production and productivity of the selected crop in the selected district and identifying best statistical model for analyzing the area, production and productivity of the paddy crop. For this, the objective was formulated as to identify the statistical models for the area, production and productivity of paddy crop in different agro climatic zones of Tamil Nadu.

Methodology
Paddy crop was purposively selected for the study. It was majorly cultivated in Tamil Nadu. Out of seven agro climatic zones, five agro climatic zones are selected purposively for this study the agro climatic zones are selected based on the crops commonly cultivated and also occupying major area under cultivation in the selected zones. In each zone, one district was purposively selected for the study viz., Thanjavur district from Cauvery Delta Zone, Viluppuram district from North Eastern Zone, Salem district from North Western Zone, Erode district from the Western Zone and Virudhunagar district from Southern Zone.

Identification of Statistical Models

The following linear and non linear models are fitted to identify the best model for area, production and yield of paddy crop. The model was selected on the basis of highest R^2 value with minimum error.

The models selected for the study were listed below:

Table 1: Models selected for the study

S. No	Model	Equation
1.	Linear	$Y= a + bt$
2.	Logarithmic	$Y= a + b \ln(t)$
3.	Exponential	$Y = abt$
4.	Power	$\ln(Y) = \ln(a) + b \ln(t)$
5.	Quadratic	$Y= a + b_1 t_1 + b_2 t_2$
6.	Compound	$\ln(Y) = \ln(a) + \ln(b)t$
7.	Cubic	$Y = a+ b_1 t_i + b_2 t_{i2} + b_3 t_{i3}$
8.	S Curve	$\ln(Y) = a + (b/t)$
9.	Inverse	$Y= a + b / t$
10	Logistic	$Y = 1 / (1/u + a b t)$
11.	Growth	$\ln(Y) = a + (b*t)$

Where,

Y = Area/Production/Productivity of the selected crops in the year't'

t = time element which takes the value 1, 2, 3 …n

a = intercept, b = regression coefficient

ln = natural log, e = exponential function and u = upper boundary value.

Results and Discussion

Identification of Statistical Models for the Area, Production and Productivity of Paddy Crop

In the present study, eleven growth models *viz.*, linear, logarithmic, inverse, quadratic, cubic, compound, power, S-curve, growth, logistic and exponential have been fitted to the data on area, production and productivity of paddy crop in the selected districts.

Area, Production and Productivity of Paddy Crop in the Selected Districts

The results of different models estimated for area, production and productivity of paddy crop in the selected districts of Tamil Nadu are presented in the following tables 2,3,4,5 and 6.

1. Viluppuram District

Table 2 shows that area under paddy crop in Viluppuram district the value of coefficient of determination ranges from 0.017 to 0.232. The models like Growth, Compound, Exponential and Logistic have lowest R^2 values. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of area under paddy in Viluppuram district. The regression coefficient (b_1) is positive for most of the models except Inverse and S models. From this, we conclude that the area under paddy in Viluppuram district is increasing rate with respect to time.

Table 2: Statistical Models for Area, Production and Productivity of Paddy Crop in Viluppuram District (1990-1991 to 2009-2010)

S. No	Models	Area		Production		Productivity	
		Regression Coefficients (b_1)	R^2	**Regression Coefficients** (b_1)	R^2	**Regression Coefficients** (b_1)	R^2
1	Linear	795.099	0.024	17995.780	0.288	126.074	0.406
2	Log	10047.571	0.074	168521.313	0.476	1138.797	0.625
3	Inverse	-48147.147	0.128	-599009.594	0.455	-3912.72	0.560
4	Quadratic	5465.317	0.075	89450.185	0.559	588.791	0.733
5	Cubic	26707.981	0.232	202268.099	0.661	1071.242	0.787
6	Compound	1.005	0.017	1.106	0.393	1.100	0.426
7	Power	0.069	0.053	0.907	0.605	0.838	0.625
8	S	-3.49	0.102	-3.124	0.543	-2.775	0.518
9	Growth	0.005	0.017	0.100	0.393	0.095	0.426
10	Exponential	0.005	0.017	0.100	0.393	0.095	0.426
11	Logistic	0.995	0.017	0.904	0.393	0.909	0.426

Paddy production in Viluppuram district the value of coefficient of determination ranges from 0.288 to 0.661. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy production in Viluppuram district. The regression coefficient (b_1) is positive for most of the models. From this, we conclude that the paddy production in Viluppuram district is increasing rate with respect to time.

Paddy productivity in Viluppuram district the value of coefficient of determination ranges from 0.406 to 0.787. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy productivity in Viluppuram district. The regression coefficient (b_1) is positive for most of the models. From this, we conclude that the paddy productivity in Viluppuram district is also increasing rate with respect to time.

2. Erode District

Table 3 reveals that area under paddy crop in Erode district the value of coefficient of determination ranges from 0.079 to 0.604. The S model has lowest R^2 values. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of area under paddy in Erode district. The regression coefficient (b_1) is negative for most of the models except Inverse, Cubic, Compound, S and Logistic Models. From this, we conclude that the area under paddy in Erode district is decreasing rate with respect to time.

Table 3: Statistical Models for Area, Production and Productivity of Paddy Crop in Erode District (1990-1991 to 2009-2010)

S. No	Models	Area		Production		Productivity	
		Regression Coefficients (b_1)	R^2	Regression Coefficients (b_1)	R^2	Regression Coefficients (b_1)	R^2
1	Linear	-2315.074	0.520	-8807.270	0.452	17.117	0.091
2	Log	-15505.286	0.440	-56912.408	0.356	141.997	0.119
3	Inverse	38535.305	0.206	139623.503	0.162	-380.953	0.064
4	Quadratic	-3732.588	0.532	-10465.860	0.453	71.646	0.147
5	Cubic	5342.335	0.604	34043.759	0.557	186.161	0.184
6	Compound	0.994	0.175	0.948	0.151	1.004	0.090
7	Power	-0.399	0.159	-0.366	0.133	0.033	0.121
8	S	1.021	0.079	0.932	0.065	-0.089	0.066
9	Growth	-0.057	0.175	-0.053	0.151	0.004	0.090
10	Exponential	-0.057	0.175	-0.053	0.151	0.004	0.090
11	Logistic	1.059	0.175	1.055	0.151	0.996	0.090

Paddy production in Erode district the value of coefficient of determination ranges from 0.065 to 0.557. The S model has lowest R^2 values. At the same time the Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy production in Erode district. The regression coefficient (b_1) is negative for most of the models. From this, we conclude that the paddy production in Erode district is decreasing rate with respect to time.

Paddy productivity in Erode district the value of coefficient of determination ranges from 0.064 to 0.184. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy productivity in Erode district. The regression coefficient (b_1) is positive for most of the models. From this, we conclude that the paddy productivity in Erode district is increasing rate with respect to time.

3. Salem District

Table 4 shows that area under paddy crop in Salem district the value of coefficient of determination ranges from 0.003 to 0.542. The S model has lowest R^2 values. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of area under paddy in Salem district. The regression coefficient (b_1) is negative for most of the models except Quadratic, Cubic, Compound and Logistic Models. From this, we conclude that the area under paddy in Salem district is decreasing rate with respect to time.

Paddy production in Salem district the value of coefficient of determination ranges from 0.005 to 0.485. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy production in Salem district. The regression coefficient (b_1) is negative for most of the models except Quadratic, Cubic, Compound and Logistic Models. From this, we conclude that the paddy production in Salem district is decreasing rate with respect to time.

Table 4: Statistical Models for Area, Production and Productivity of Paddy Crop in Salem District (1990-1991 to 2009-2010)

S. No	Models	Area		Production		Productivity	
		Regression Coefficients (b_1)	R^2	Regression Coefficients (b_1)	R^2	Regression Coefficients (b_1)	R^2
1.	Linear	-923.253	0.197	-2683.845	0.086	20.939	0.088
2.	Log	-3368.035	0.050	-4863.684	0.005	203.058	0.157
3.	Inverse	-4060.493	0.005	-40946.785	0.029	-729.762	0.153
4.	Quadratic	2140.894	0.327	13735.373	0.280	112.727	0.190
5.	Cubic	12276.346	0.542	57219.868	0.485	393.999	0.334
6.	Compound	0.972	0.150	0.977	0.077	1.006	0.090
7.	Power	-0.112	0.042	-0.058	0.009	0.054	0.161
8.	S	-0.114	0.003	-0.308	0.019	-0.194	0.159
9.	Growth	-0.029	0.150	-0.023	0.077	0.006	0.090
10.	Exponential	-0.029	0.150	-0.023	0.077	0.006	0.090
11.	Logistic	1.029	0.150	1.024	0.077	0.995	0.090

Paddy productivity in Salem district the value of coefficient of determination ranges from 0.088 to 0.334. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy productivity in Salem district. The regression coefficient (b_1) is positive for most of the models. From this, we conclude that the paddy productivity in Salem district is increasing rate with respect to time.

4. Thanjavur District

Table 5 shows that area under paddy in Thanjavur district the value of coefficient of determination ranges from 0.000 to 0.344. The Inverse model has lowest R^2 values. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of area under paddy in Thanjavur district. The regression coefficient (b_1) is positive for most of the models except Linear, Log, Power, Growth and Exponential Models. From this, we conclude that the area under paddy in Thanjavur district is increasing rate with respect to time.

Paddy production in Thanjavur district the value of coefficient of determination ranges from 0.000 to 0.149. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy production in Thanjavur district. The regression coefficient (b_1) is positive for most of the models. From this, we conclude that the paddy production in Thanjavur district is increasing rate with respect to time.

Table 5: Statistical Models for Area, Production and Productivity of Paddy Crop in Thanjavur District (1990-1991 to 2009-2010)

S. No	Models	Area		Production		Productivity	
		Regression Coefficients (b_1)	R^2	Regression Coefficients (b_1)	R^2	Regression Coefficients (b_1)	R^2
1	Linear	-1090.776	0.122	-2295.236	0.008	0.468	0.00
2	Log	-4917.692	0.047	-33471.552	0.032	-153.969	0.021
3	Inverse	1798.083	0.000	210557.891	0.094	1331.976	0.119
4	Quadratic	875.506	0.146	-4004.681	0.008	-67.229	0.013
5	Cubic	15446.876	0.344	-106283.86	0.149	-899.153	0.307
6	Compound	0.933	0.120	1.000	0.000	1.007	0.015
7	Power	-0.032	0.051	-0.037	0.008	-0.006	0.000
8	S	0.020	0.001	0.370	0.060	0.350	0.055
9	Growth	-0.007	0.120	0.000	0.000	0.007	0.015
10	Exponential	-0.007	0.120	0.000	0.000	0.007	0.015
11	Logistic	1.007	0.120	1.000	0.000	0.993	0.015

Paddy productivity in Thanjavur district the value of coefficient of determination ranges from 0.000 to 0.307. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy productivity in Thanjavur district. The regression coefficient (b_1) is positive for most of the models. From this, we conclude that the paddy productivity in Thanjavur district is increasing rate with respect to time.

5. Virudhunagar District

Table 6 reveals that area under paddy in Virudhunagar district the value of coefficient of determination ranges from 0.011 to 0.035. The models like Growth, Exponential, Logistic and Compound have lowest R^2 values. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of area under paddy in Virudhunagar district. The regression coefficient (b_1) is negative for most of the models except Inverse, Compound, S and Logistic Models. From this, we conclude that the area under paddy in Virudhunagar district is decreasing rate with respect to time.

Paddy production in Virudhunagar district the value of coefficient of determination ranges from 0.00 to 0.60. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy production in Virudhunagar district. The regression coefficient (b_1) is positive for most of the models. From this we, conclude that the paddy production in Virudhunagar district is increasing rate with respect to time.

Table 6: Statistical Models for Area, Production and Productivity of Paddy Crop in Virudhunagar District (1990-1991 to 2009-2010)

S. No	Models	Area		Production		Productivity	
		Regression Coefficients (b_1)	R^2	Regression Coefficients (b_1)	R^2	Regression Coefficients (b_1)	R^2
1	Linear	-178.230	0.035	-300.217	0.200	17.761	0.140
2	Log	-1295.956	0.035	-2601.482	0.300	97.627	0.080
3	Inverse	4651.084	0.034	13873.093	0.600	-82.186	0.000
4	Quadratic	-257.723	0.035	-194.042	0.200	23.455	0.140
5	Cubic	-111.381	0.035	-4347.828	0.600	-204.626	0.360
6	Compound	0.996	0.011	1.005	0.300	1.008	0.210
7	Power	-0.029	0.013	0.011	0.000	0.040	0.090
8	S	0.125	0.019	0.120	0.300	-0.005	0.000
9	Growth	-0.004	0.011	0.005	0.300	0.008	0.210
10	Exponential	-0.004	0.011	0.005	0.300	0.008	0.210
11	Logistic	1.004	0.011	0.995	0.300	0.992	0.210

Paddy productivity in Virudhunagar the value of coefficient of determination ranges from 0.00 to 0.36. Cubic model have highest R^2 value. Based on the R^2 value, the Cubic model is found to be best model for prediction of paddy productivity in Virudhunagar district. The regression coefficient (b_1) is positive for most of the models. From this, we conclude that the paddy productivity in Virudhunagar district is increasing rate with respect to time.

For paddy area, production and productivity the cubic model is found to be best. The similar result was obtained by Ramesh *et al.* (2015) [8] in the study of trend estimation by parametric and nonparametric modeling for area, production and yield of Rice crop and they also obtain Cubic Function to be best fit for area, production and productivity.

Conclusion

Cubic model is found to be best for prediction of past and future performance of paddy crop area, production and productivity in the selected districts.

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