A STATISTICAL STUDY ON WEATHER PARAMETERS RELATIONSHIP WITH RICE CROP YIELD IN THANJAVUR DISTRICT OF TAMIL NADU

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ABSTRACT

The present study is planned to investigate the relationship between weather parameters and their effect on rice crop yield in Thanjavur district of Tamil Nadu by using the data from period 1990-91 to 2014-15. The combinations of linear and non linear models are one of the most popular and widely used hybrid models for improving the forecasting accuracy. Analysis of relationship of rice crop yield with weather parameters shows non-significant and negatively correlated with rainfall, maximum temperature and relative humidity. Minimum temperature was highly significant and negatively correlated with rice yield and wind speed was positively correlated and non-significant with rice yield. In case of multiple regression analysis, minimum temperature shows significant and negatively influence on rice crop yield. In Prediction of rice crop yield, cubic model was found to be the best model with highest R^2 value for all weather parameters. The most contributing weather parameter on yield was examine by using back ward regression technique and result found that minimum temperature (R^2 0.354) contributes more to the rice yield of Thanjavur district.

KEYWORDS: Rice Yield, Weather Parameters, Correlation, Nonlinear Models, Multiple Linear Regression & Backward Regression

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1. INTRODUCTION

Rice is among the three leading food crops of the world, with maize and wheat being the other two and it is one of the most important cereal crop of India occupying an area of 43.39 million hectare with an annual production of 104.32 million tonnes with an average productivity of 2404 kg/ha (2015-16). India is the second largest producer and consumer of rice and accounts for 22.3% of global production. (Source: Annual Report 2015-16, Ministry Of Agriculture and Farmers Welfare). Rice plays a vital role in the national food security and would continue to remain so because of its wider adaptability to grow under diverse ecosystems. Rice contributes 40.8% of total food grain and remains the principal source of livelihood for more than 58% of the population.

Tamil Nadu secured third position in rice productivity in India and from total gross cropped area (58.97 La ha) of the state, paddy alone cultivated in 17.75 L ha (31%) and it ranks first in area and production among other cereal crop cultivated in state (source: Policy Note 2015-16, Govt of TN), because it is the main staple food of the state with regard to human nutrition and caloric intake. Thanjavur district stands unique from time immemorial for its agricultural activities and is rightly acclaimed as the granary of south India lying in the deltaic region of Cauvery river which supports for agriculture. It is known as “Rice bowl of Tamil Nadu”, among 32

districts of Tamil Nadu, Thanjavur district rank second in area (1.77 L ha) and production (8.5 L tones) of rice (2014-15) after Thiruvavur district. The major crops cultivated in this district are paddy, pulses, gingelly, groundnut and sugarcane. Paddy is the principle crop grown in three season viz. Kuruvai, Samba and Thaladi. Rice is a nutritious cereal crop, used mainly for human consumption. It is the main source of energy and is an important source of protein providing substantial amounts of the recommended nutrient intake of zinc and niacin.

Crop growth and development are primarily governed by environmental conditions. The success or failure of crops is intimately related to the weather during the crop periods. Weather has significant influence on every phase of agricultural activity from preparatory tillage to harvesting and storage. In recent years the agricultural problem has become much more severe and intense. Thanjavur district has differed by deficit of irrigation. Thanjavur district agriculture has continued to be a gamble in the hands of monsoon, failure of rainfall and excessive rains and consequent floods also affected this area. Hence, a sound knowledge of the weather parameters and its interactions with crop yield is essential for successful agriculture hence objective is formulated to access relationship of weather parameters with rice yield in Thanjavur district.

2. METHODOLOGY

This study is based on secondary data of weather parameters such as rainfall, relative humidity, maximum temperature, minimum temperature and wind speed were collected from Agro Climate Research Centre, Tamil Nadu, Indian Meteorological Department-Regional Meteorological Centre, Chennai, and research stations of Thanjavur district. Data on area, production and yield data for rice crop have been taken from Directorate of Economics and Statistics, Tamil Nadu, Season and Crop report and Tamil Nadu state website. The study covers data from 1990-91 to 2014-15.

2.1. Correlation Analysis

The correlation analysis was carried out to determine the degree of association between two variables. In the present study, the degree of relationships between crop yield and each of the weather parameters viz., rainfall, relative humidity, temperature and wind speed were determined by using Karl Pearson's correlation coefficient which was calculated as,

$$r_{(x,y)} = \text{Cov}(X, Y) / \sigma_x \sigma_y. \text{ In case of bivariate distribution}$$

$$\text{Cov}(X, Y) = \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{n - 1}$$

$$\sigma_x^2 = \frac{\sum (X_i - \bar{X})^2}{n - 1}$$

$$\sigma_y^2 = \frac{\sum (Y_i - \bar{Y})^2}{n - 1}$$

Where,

$r_{(x,y)}$ is the correlation coefficient between X and Y.

X_i is the first variable and Y_i second variable.

$\bar{X}$ is the mean of the variable X_i and $\bar{Y}$ is the mean of the variable Y_i .

2.2. Significance of the Correlation Coefficient

To test the significance of the correlation coefficient 't' test was used. Here null hypotheses was set as,

H0: $\rho = 0$ against alternative hypothesis **H1:** $\rho \neq 0$

This was tested by using test statistic

$$t_{(n-2)} = \frac{r \sqrt{n-2}}{\sqrt{1-r^2}}$$

Where,

n is the number of pairs of observation

r is the correlation coefficient.

2.3. Linear and Non Linear Models

The simplest way of representing any relation is by fitting a linear equation using the variables under study. But, in all the cases it may not follow. In the present study, taking crop yield as dependent variable and weather parameters as independent variables, linear and various non linear models (Table 1) were tried to fit to the data (Gomez and Gomez, 1984). Among the below several model the best model were selected based on R^2 Value.

Table 1: Linear and Non Linear Models

S. No	Model	Equation	Description
1	Linear	$Y_t = a + bt$	Y and t are yield and weather parameter respectively. A and b are constants to be estimated
2	Logarithmic	$Y_t = a + b \ln(t)$	Y and t are yield and weather parameter respectively. b_0 and b_1 are constants to be estimated and ln is Natural Log
3	Quadratic	$Y_t = b_0 + b_1 t + b_2 t^2$	Y and t are yield and weather parameter respectively. b_0 and b_1 are constants to be estimated. The quadratic model can be used to model a series that "takes off" or a series that dampens
4	Cubic	$Y_t = b_0 + b_1 t + b_2 t^2 + b_3 t^3$	Y and t are yield and weather parameter respectively. b_0 and b_1 are constants to be estimated
5	Power	$\ln(Y) = \ln(a) + b \ln(t)$ or $Y = a t^b$	Y and t are yield and weather parameter respectively. b_0 and b_1 are constants to be estimated and ln is Natural Log
6	Compound	$Y = b_0 t^{b_1}$ or $\ln(Y) = \ln(b_0) + \ln(b_1)t$	Y and t are yield and weather parameter respectively. b_0 and b_1 are constants to be estimated and ln is Natural Log.
7	S Curve	$Y = e^{\frac{b_0 + (b_1/t)}{1}}$ or $\ln(Y) = b_0 + (b_1/t)$	Y and t are yield and weather parameter respectively. b_0 and b_1 are constants to be estimated, ln is Natural Log and "e" is the exponential function.
8	Logistic	$Y = 1 / (1/u + b_0 b_1 t)$ or $\ln(1/y - 1/u) = \ln(b_0) + \ln(b_1)t$	Y and t are yield and weather parameter respectively. b_0 and b_1 are constants to be estimated, ln is Natural Log and u is the upper boundary value.

Table 1: Contd.,			
9	Growth	$Y = e^{(b_0 + (b_1 * t))}$ or $\ln(Y) = b_0 + (b_1 * t).$	Y and t _i 's are yield and weather parameter respectively. b ₀ and b _i 's are constants to be estimated, ln is Natural Log and "e" is the exponential function.
10	Exponential	$Y_t = ab^t$	Y and t _i 's are yield and weather parameter respectively. b ₀ and b _i 's are constants to be estimated.

2.4. Multiple Linear Regression Analysis

To study the influence of weather parameters on rice crop yield, multiple regression analysis was used. The multiple linear regression equation is,

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p X_p + \varepsilon$$

Where, Y is the dependent variable and X_i's are the independent variables with β_i as the partial regression coefficients of Y on X_i's where i=1, 2,.....P.

In the present study, Y was taken as crop yield and X_i's were weather parameters viz., rainfall, relative humidity, maximum temperature, minimum temperature and wind speed.

2.5. Backward Regression Approach

When the numbers of variables in regression equation are more we can eliminate the variables which are not contributing significantly to the R² or if numbers of variables are less then we can add variables which are having significant effect on dependent variable and increase in R² by step wise regression analysis. The basic steps (Draper and Smith, 1966) in the procedure are given below:

- A regression equation containing all possible X-variables is computed
- The X- variables are then deleted one at a time. The decision to delete a variable is made on the basis of the significance of b, the partial regression coefficient.
- If the t-values for all the available b's are significant we retain all the X- variables in the model.
- If some of the t-values are not significant then X- variable is deleted from the model.
- Another rule is to omit a X if its t² for its b is less than 1.
- A new multiple regression equation is fitted with the remaining X variable. This procedure is followed until all the t-values for the b's in the model are found to be significant.

The initial equation in the model of backward regression is

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p X_p + e$$

which is a multiple regression equation and after entering all the variables in the model in the first stage, variables which contribute least to the dependent variable are eliminated one by one. For each stage the Multiple R² is determined.

3. RESULTS AND DISCUSSIONS

3.1. Correlation Analysis

Correlation coefficient between yield and weather parameters (viz., Rainfall, Maximum temperature, Minimum

temperature, Relative humidity, Wind speed) for rice yield in Thanjavur district were calculated by using data from period 1990-91 to 2014-15 and the results are presented in Table 2. The results revealed that the yield level of rice in Thanjavur district was negatively correlated and non significant with rainfall, maximum temperature and relative humidity and yield was highly significant and negatively correlated with minimum temperature and wind speed was positively correlated and non significant with yield of rice. Result concludes that there is a reduction in yield with increase in rainfall, relative humidity, maximum and minimum temperature respectively.

Table 2: Correlation Coefficient between Rice Crop Yield and Weather Parameters in Thanjavur District

Rice Crop	Rainfall	Maximum Temperature	Minimum Temperature	Relative Humidity	Wind Speed
Yield	0.273 ^{NS} (0.187)	-0.255 ^{NS} (0.219)	- 0.595** (0.002)	-0.060 ^{NS} (0.775)	0.304 ^{NS} (0.140)

Figures in parenthesis indicates P value ** Significance at 1% NS – Non Significant

As the rice crop requires optimum temperature ranges from 20-30 ° C to be most favourable for growth and development of rice crop, but while examined the temperature pattern of study period in Thanjavur district it shown that it had experienced most frequently the temperature above 30 °C which may result in reduction of yield. Even though the rainfall received above the rice crop requirement for growth it experiences reduction in yield as rainfall increases because of uneven distribution of rainfall during growing period.

3.2. Prediction Model for Rice Yield in Thanjavur District

The linear and various non linear models were used to predict rice yield level with the help of different weather parameters are given in Table 3. The best model was selected based on the highest R² value. For predicting yield level with the help of rainfall, relative humidity, maximum temperature, minimum temperature and wind speed, cubic model was found to be the best with highest R² value (0.075), (0.051), (0.075), (0.365) and (0.155) respectively.

Table 3: Comparison of Models for Predicting Rice Yield With the Help of Weather Parameters in Thanjavur District

Model	Rainfall		Relative humidity		Maximum temperature		Minimum temperature		Wind speed	
	Coefficient	R ²	Coefficient	R ²	Coefficient	R ²	Coefficient	R ²	Coefficient	R ²
Linear	-1.129	0.074	-29.134	0.004	-407.409	0.065	-1196.264	0.354	2291.234	0.092
Logarithmic	-976.070	0.071	-1738.094	0.003	-14378.065	0.064	-28121.377	0.355	7100.789	0.095
Quadratic	-0.089 -0.001	0.072	7435.324 -59.340	0.045	0.000 -5.771	0.065	-1196.264 0.000	0.354	121120.597 -19394.544	0.154
Cubic	-0.093 -0.001 0.000	0.075	3704.304 0.000 -0.314	0.051	11065.564 0.000 -3.051	0.075	-14119.933 0.000 7.813	0.365	62491.470 0.000 -2136.704	0.155
Compound	1.000	0.060	0.992	0.003	0.883	0.068	0.703	0.341	2.050	0.101
Power	-0.265	0.058	-0.482	0.003	-4.405	0.067	-8.289	0.342	2.221	0.103
S-Curve	212.724	0.053	28.648	0.002	155.389	0.067	194.691	0.342	-6.858	0.105
Growth	0.000	0.060	-0.008	0.003	-0.125	0.068	-0.353	0.341	0.718	0.101
Exponential	0.000	0.060	-0.008	0.003	-0.125	0.068	-0.353	0.341	0.718	0.101
Logistic	1.000	0.060	1.008	0.003	1.133	0.068	1.423	0.341	0.488	0.101

3.3. Multiple Linear Regressions

Multiple linear regression fitted by using rice yield as dependent variable and rainfall, relative humidity, maximum temperature, minimum temperature and wind speed as independent variables and the results are given in Table

4. The fitted model was found to be significant (5%) with R^2 value of 0.417 and out of five independent variables selected for the study, only minimum temperature was found to be significant to the yield.

Table 4: Relationship between Rice Yield and Weather Parameters in Thanjavur District

Variables	b	SE	P Value
Constant	15683.823	17497.908	0.381
Rainfall	-.651	0.825	0.440
Maximum temperature	567.058	532.750	0.330
Minimum temperature	-1585.152*	603.549	0.017
Relative humidity	80.703	118.241	0.503
Wind Speed	145.570	1723.748	0.934

* Significance at 5 %

3.4. Backward Regression Approach

Factors affecting crop production and crop growth includes internal factors (Genetic or heredity) and external factors (climatic, edaphic, biotic, physiographic and socio economic factors). Among this nearly 50% of yield is attributed to the influence of climatic factors (rainfall, temperature, relative humidity, solar radiation, wind velocity and atmospheric gases). Thus in order to determine the contribution of each independent variable (weather parameters) to the yield, backward regression technique was carried out, where the variables which contribute least to the dependent variable are eliminated one by one.

Prediction of rice yield in Thanjavur district was carried out with the help of weather parameters. To know which one of the parameter is most significantly contributing to the rice yield, the backward regression approach was carried out and Step by step weather parameters were removed/ excluded from model is given in the Table 5. At the beginning all independent variables were included in the prediction and the model was found to be significant with highest R^2 value of 0.417 and in the next step the variable which was contributing less was removed *i.e.* wind speed was removed and the R^2 value observed in this model was 0.417 and again removing one more variable from the remaining *i.e.* relative humidity was removed with $R^2 = 0.403$ and again removing one more variable from the remaining *i.e.* rainfall was removed with $R^2 = 0.388$ and in the final model maximum temperature was removed. As a whole wind speed, rainfall, relative humidity and maximum temperature were removed. In this model only minimum temperature was retained which is contributing to the yield and R^2 was found to be 0.354.

Table 5: Backward Regression Model for Rice Yield and Weather Parameters in Thanjavur District

Model	Variables entered	Variables removed	R^2	Significance
1	Min T, Max T, RF, RH, WS	-	0.417	0.051
2	Min T, Max T, RF, RH	WS	0.417	0.023
3	Min T, Max T, RF	WS, RH	0.403	0.011
4	Min T, Max T	WS, RH, RF	0.388	0.005
5	Min T	WS, RH, RF, Max T	0.354	0.002

4. CONCLUSIONS

Weather parameters play an important and unique role in the growth and development of crops and affect the crops differently during different stages of development. There is a need to educate the farmers to consider weather parameters during cropping period and selection of crops in order to mitigate food scarcity. Comprehensive research studies that focus on weather parameters and the crops Yield.

The result obtained from analysis of relationship of rice crop yield with weather parameters shows non significant and negatively correlated for rainfall, maximum temperature and relative humidity. Minimum temperature was highly significant and negatively correlated with rice yield and wind speed was positively correlated and non significant with rice crop yield. In case of multiple regression analysis, minimum temperature shows significant and negatively influence on rice crop yield. In Prediction of rice crop yield, among different linear and non linear models, cubic model was found to be the best for Thanjavur district rice crop yield (highest R^2 value) with respect to all weather parameters (viz., Rainfall, Relative humidity, Maximum temperature, Minimum temperature and wind speed). The most contributing weather parameter on yield was examine by using back ward regression technique and result found that when all parameters are combined it contributes 41.7% ($R^2 = 0.417$) to yield among this minimum temperature solely contributes 35% ($R^2 = 0.354$) to the rice yield of Thanjavur district.

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6. REFERENCES

1. Anshul, J. (2016). *Studies on crop weather relationships of rice under Raipur condition*. M. Sc. (Ag) Thesis, Department of Agro meteorology, College of Agriculture, Indira Gandhi KrishiVishwavidyalaya, Raipur, India.
2. Chaudhari, K. N., Oza. M.P and Ray. S. S. (2009). *Impact of climate change on yields of major food crops in India*. *Proceedings of ISPRS Archives*, 38(8): 1-6.
3. Das, H. P., Kamble. M. V and Shaikh. S.M.(1989). *Impact of Climate Change On Agricultural Productivity In India*, India Meteorological Department, Agricultural Meteorology Division, Pune-411 005.
4. Draper, N.R and Smith. H.(1996). *Applied regression analysis*. John, Wiley and sons, New York.
5. Gomez, K. A. And Gomez. A. A.(1984). *Statistical procedures for agricultural research* 2nd ed. John Wiley & Sons, New York.
6. Kandianan, K., Chandaragiri. K.K., Sankaran. N, Balasubramanian. T.N. and Kailasam. C.(2002). *Crop-weather model for turmeric yield forecasting for Coimbatore district, Tamil Nadu, India*. *Agricultural and Forest Meteorology*, 112(3/4): 133-137.
7. Rachel, E., Aggarwal. A.K., Mahajan. P.K, NegI. Y.S and Bhardwaj. S.K. (2014). *Trend study of Meteorological Parameters and Crop Yield in Solan District of Western Himalayan State*. *Universal Journal of Environmental Research & Technology*, 4(4).
8. Singh, R.S, Patel.C, Yadav. M. K. and Singh. K.K.(2014). *Yield forecasting of rice and wheat crops for Eastern Uttar Pradesh*. *Journal of Agrometeorology*, 16(2): 199.
9. Subrahmaniyan, K., Subramanian.P, Balasubramanian.T.N, Kalaiselvan.P and Ramanathan.S. (2004). *Relative temperature disparity and rice yield across seasons in Tamil Nadu*. *J. of Agro Meteorology*, 6(2): 254-256.