International Journal of Statistics and Applied Mathematics 2025; 10(7): 111-117

International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
NAAS (2025): 4.49
Maths 2025; 10(7): 111-117

https://www.mathsjournal.com
Received: 15-05-2025
Accepted: 18-06-2025

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Effect of weather variables on rice crop in Satna district, Madhya Pradesh, India

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Abstract
Rice is the major crop of Madhya Pradesh, which covers about 4.55 per cent area of total gross-cropped area in Madhya Pradesh. The present study mainly deals with the effect on weather variables like minimum temperature, minimum temperature, relative humidity in morning, relative humidity in afternoon, wind direction, wind velocity. The study has been undertaken for rice crop in the district of Satna, Madhya Pradesh, India. The present study is formulated to determine the individual effect of weather variables on rice yield. For the Satna District, Regression models for rice productivity were fitted in this work. Linear model, Quadratic model, Cubic, Compound, Exponential models were used. We utilized different comparison metrics to assess model fitting performance like R-Square. According to the findings, the cubic and quadratic models are the best at forecasting all of the important elements in Satna District.

Keywords: Model, regression, rice crop, R square

Introduction

India, with its diverse agro-climatic zones, is heavily dependent on agriculture for both food security and economic stability. Among the various crops grown across the country, rice holds a significant place as a staple food crop, particularly in the central and eastern regions. In Madhya Pradesh, the Satna district is one of the major agricultural hubs, with rice being a predominant crop. However, the productivity of rice in this region is vulnerable to climatic variability, which significantly affects the yield and overall agricultural performance.

Rice cultivation in Satna, as in many other parts of India, is largely rain-fed and depends on the timely onset and distribution of monsoon rains. Over the past few decades, the region has experienced significant shifts in its climatic patterns, including changes in temperature, rainfall, humidity, and extreme weather events. These shifts are primarily attributed to the broader phenomenon of climate change, which is expected to exacerbate the uncertainties in crop production. Given the importance of rice in the livelihoods of the farming community in Satna, understanding the impact of weather variables on rice production is essential for developing strategies that ensure food security and sustainable agricultural practices.

Climate change can be characterized as long-term changes in temperature and other meteorological characteristics, as well as an increase in the frequency of extreme events. Because crop agriculture is directly and significantly dependent on climate, scientists and policymakers have acknowledged that it is vulnerable to climate change and questioned farmers' ability to adapt (Reid *et al.*, 2007; Roudier *et al.*, 2011) [7, 8]. To maintain sustainability in the face of present population growth, we as a species must continuously raise production, which is where the impact of climate change on the unpredictability of rice and wheat yields comes into play. Rice accounts for more than 60% of total crop cultivation value. Yu *et al.* (2010) [9] and Asaduzzaman *et al.* (2010) [2].

Materials and Methods

Satna District is nestled in the Madhya Pradesh of India. The Satna District lies between latitude and longitude are 23^0 58' to 25^0 12' N and 80^0 21' to 81^0 23' E respectively. It is situated at an elevation of about 305 m above mean sea level.

Source of data

For the present research work secondary data of weather variable and crop yield were collected from NASA Data Access Viewer and Farmer welfare and Agriculture Development Department, Madhya Pradesh. Different metrological data *viz.*, maximum temperature, minimum temperature, relative humidity in morning, relative humidity in afternoon, rainfall, wind direction, wind velocity for the period of 2007 to 2023. Here we have considered 2 crops including rice and wheat. The collected data have been analyzed with the help of suitable statistical techniques.

Methodology

The five models were fitted on the data of year wise, one year at a time, up to the 16 year, which was the final step. These models' functional for RMSE are as follows:

- Linear: $Y_t = \alpha + \beta 1t + \varepsilon_t$ ……………………….…………. (1)
- Quadratic: $Y_t = \alpha + \beta 1t + \beta 2t2 + \varepsilon_t$ ……….….…. (2)
- Cubic: $Y_t = \alpha + \beta 1t + \beta 2t2 + \beta 3t3 + \varepsilon_t$………….. (3)
- Compound: $Y_t = \alpha\ (\beta 1)^t \times \varepsilon_t$………………...…. (4)
- Exponential: $Y_t = \alpha\ (t)^\beta \times \varepsilon_t$ ……..…………...….(5)

Where, Y_t = response of the i-th factor in the t-th year

- α, β = unknown parameter, to be estimated, of the model, α (constant).
- εt = multiplicative error

Measures for the comparison and validation of different models

Coefficient of determination (R^2)

The coefficient of determination (R^2) is a statistical measure that shows how well a model fits data and predicts outcomes. It is a number between 0 and 1, and is often expressed as a percentage.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)}{\sum_{i=1}^{n}(y_i - \bar{y}_i)^2}$$

Where y_i ,$\hat{y}_i$ and $\bar{y}_i$ is the value of the i^{th} observation, estimated value of the i^{th} observation and mean value of Y.

Result and Discussion

4.1 Effect of maximum temperature on rice yield of Satna District.

Equation	Parameter Estimates				R^2
	Constant	b_1	b_2	b_3	
Linear	-174.56	4.38	-	-	0.129
Quadratic	2768.51	-124.83	1.41	-	0.160
Cubic	1755.51	-59.17	0.010	-	0.159
Compound	9.60-ES	1.30	-	-	0.165
Exponential	9.60-ES	0.268	-	-	0.164

4.2 Effect of minimum temperature on rice yield of Satna District.

Equation	Parameter Estimates				R^2
	Constant	b_1	b_2	b_3	
Linear	54.90	-6.44	-	-	0.516
Quadratic	48.33	-3.46	-0.384	-	0.527
Cubic	28.45	17.22	-5.802	-	0.564
Compound	96.75	0.707	-	-	0.513
Exponential	96.75	-0.347	-	-	0.511

4.3 Effect of relative humidity in morning on rice yield of Satna District.

Equation	Parameter Estimates				R^2
	Constant	b_1	b_2	b_3	
Linear	112.90	-1.345	-	-	0.019
Quadratic	112.90				0.019
Cubic	3127.32	-72.69	0.006	-	0.037
Compound	4238.70	0.921	-	-	0.025
Exponential	4238.70	-0.083	-	-	0.025

4.4 Effect of relative humidity in after noon on rice yield of Satna District.

Equation	Parameter Estimates				R^2
	Constant	b_1	b_2	b_3	
Linear	193.56	-3.83	-	-	0.120
Quadratic	-6024.69	281.37	-3.26	-	0.270
Cubic	-1933.51	-	3.17	-0.49	0.270
Compound	133698.22	0.818	-	-	0.119
Exponential	133698.22	-0.20	-	-	0.119

4.5 Effect of rainfall on rice yield of Satna District.

Equation	Parameter Estimates				R^2
	Constant	b_1	b_2	b_3	
Linear	-14.27	0.042	-	-	0.460
Quadratic	-49.81	0.11	-3.320E-5	-	0.480
Cubic	-38.90	0.07	-	-1.053E-8	0.480
Compound	2.85	1.00	-	-	0.380
Exponential	2.85	0.002	-	-	0.380

4.6 Effect of wind direction on rice yield of Satna District.

Equation	Parameter Estimates				R^2
	Constant	b_1	b_2	b_3	
Linear	131.93	-0.35	-	-	0.290
Quadratic	-394.41	3.30	-0.006	-	0.350
Cubic	-203.21	1.39	-	-6.891E-6	0.340
Compound	5781.69	0.98	-	-	0.290
Exponential	5781.69	-0.019	-	-	0.290

4.7 Effect of wind velocity on rice yield of Satna District.

Equation	Parameter Estimates				R^2
	Constant	b_1	b_2	b_3	
Linear	200.12	-39.79	-	-	0.200
Quadratic	-1202.79	609.75	-75.08	-	0.230
Cubic	-352.34	-	70.33	-11.53	0.230
Compound	101414.33	0.14	-	-	0.160
Exponential	101414.33	-1.94	-	-	0.160

Table No. 4.1 shows that the best fitting models with parameter R^2 was found to be compound, exponential, quadratic, cubic and linear model for effect of maximum temperature on rice yield of Satna district.. The value ofcompound, exponential, quadratic, cubic and linear model with parameter R^2 is 0.165, 0.164, 0.160, 0.159 and 0.129.

Table No. 4.2 shows that the best fitting models with parameter R^2 was found to be cubic, quadratic, linear, compound and exponential for effect of minimum temperature on rice yield of Satna district. The value ofcompound, exponential, quadratic, cubic and linear model with parameter R^2 is 0.564, 0.527, 0.516, 0.513 and 0.511.

Table No. 4.3 shows that the best fitting models with parameter R^2 was found to be cubic, compound, exponential, quadratic, and linear model for effect of relative humidity in morning on rice yield of Satna district. The value of cubic, compound, exponential, quadratic, and linear model with parameter R^2 is 0.037, 0.025, 0.025, 0.019 and 0.019.

Table No. 4.4 shows that the best fitting models with parameter R^2 was found to be cubic, compound, exponential, quadratic, and linear model for effect of relative humidity in morning on rice yield of Satna district. The value of cubic, quadratic, linear, compound and exponential model with parameter R^2 is 0.270, 0.270, 0.120, 0.119 and 0.119.

Table No. 4.5 shows that the best fitting models with parameter R^2 was found to be cubic, compound, exponential, quadratic, and linear model for effect of relative humidity in morning on rice yield of Satna district. The value of cubic, quadratic, linear, compound and exponential model with parameter R^2 is 0.480, 0.480, 0.460, 0.380 and 0.380.

Table No. 4.6 shows that the best fitting models with parameter R^2 was found to be cubic, compound, exponential, quadratic, and linear model for effect of relative humidity in morning on rice yield of Satna district. The value of quadratic, cubic, linear, compound and exponential model with parameter R^2 is 0.350, 0.340, 0.290, 0.290 and 0.290.

Table No. 4.7 shows that the best fitting models with parameter R^2 was found to be cubic, compound, exponential, quadratic, and linear model for effect of relative humidity in morning on rice yield of Satna district. The value of cubic, quadratic, linear, compound and exponential model with parameter R^2 is 0.230, 0.230, 0.200, 0.160 and 0.160.

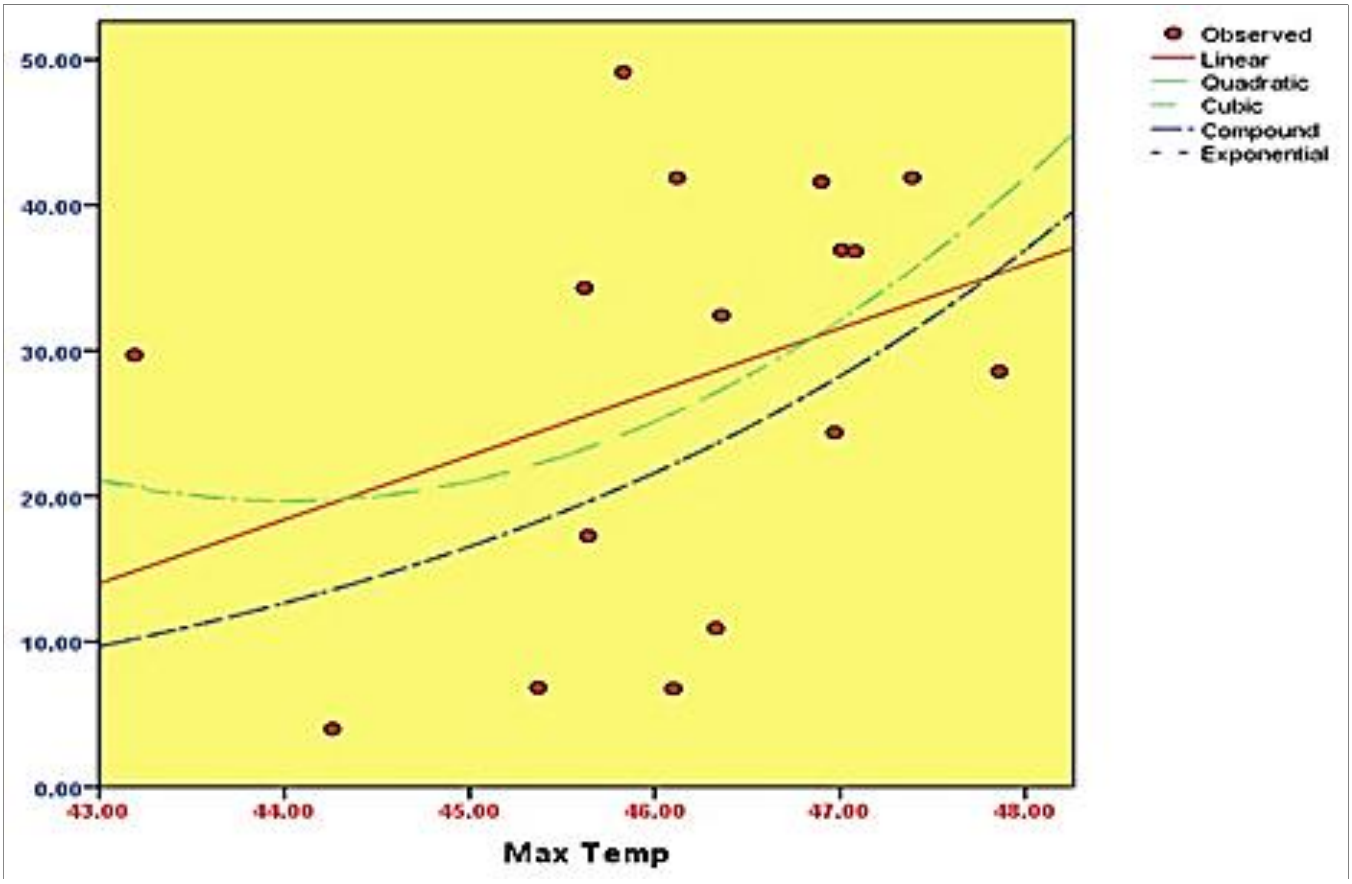

Fig 4.1: Diagram showing the fitting of maximum temperature on rice yield of Satna District.

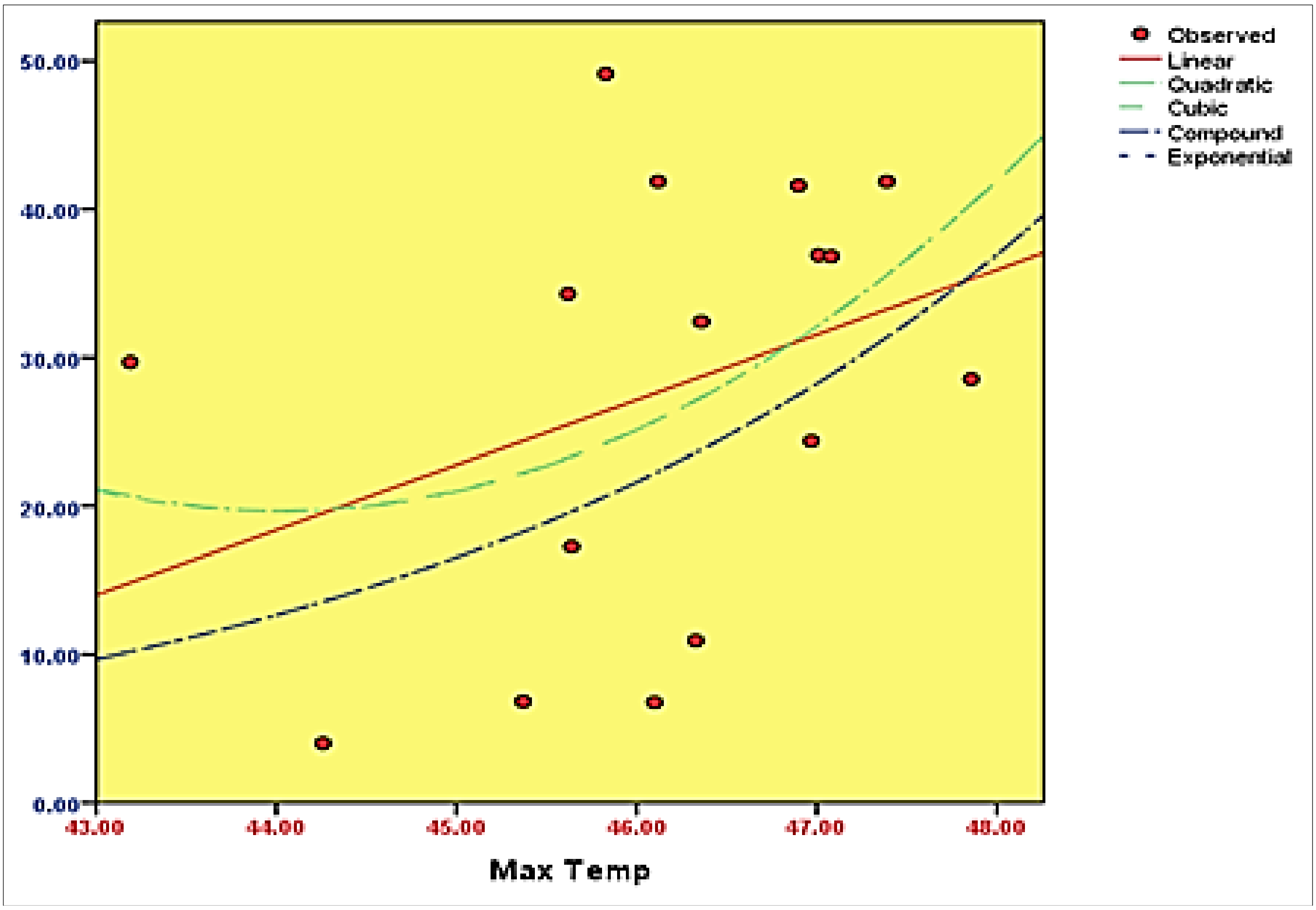

Fig 4.2: Diagram showing the fitting of minimum temperature on rice yield of Satna District.

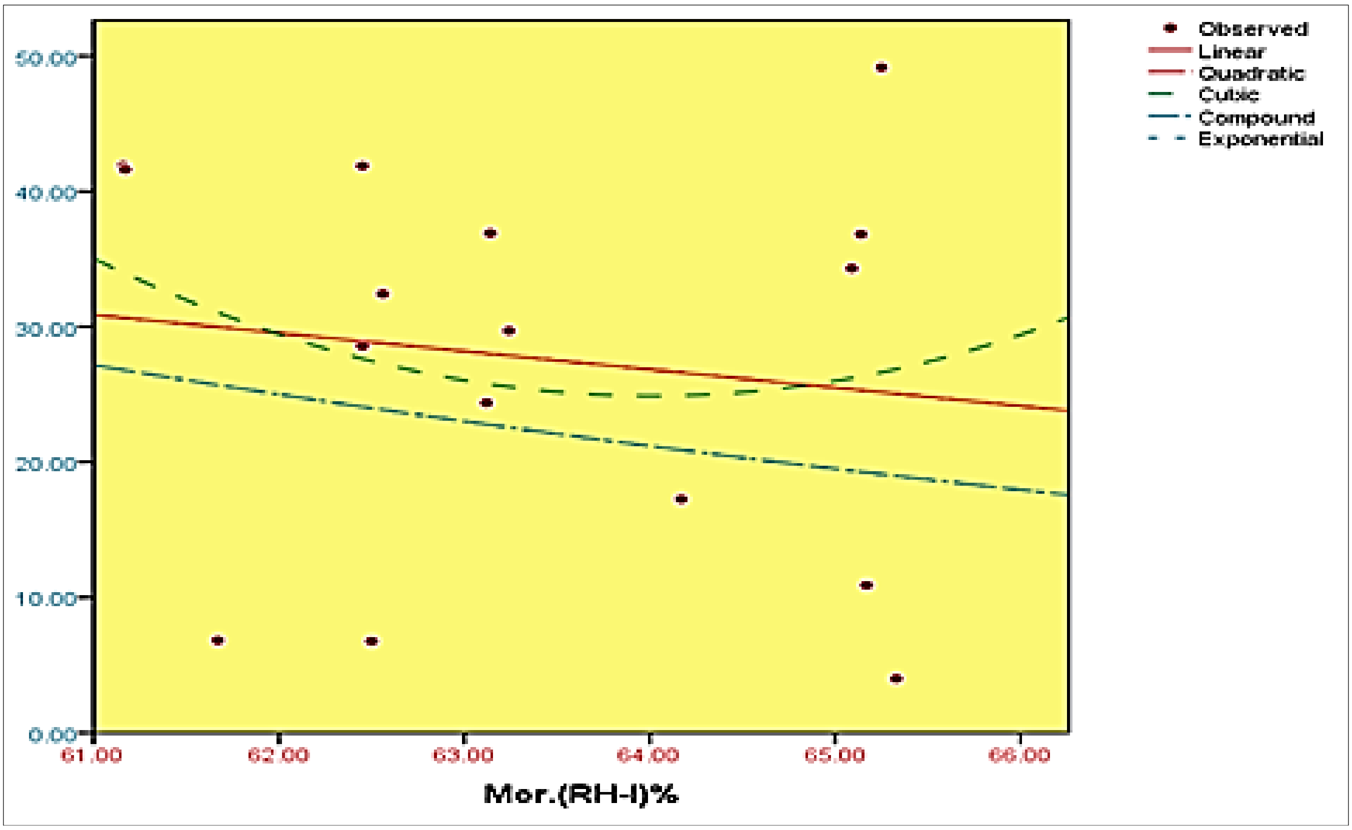

Fig 4.3: Diagram showing the fitting of RH in morning on rice yield of Satna District.

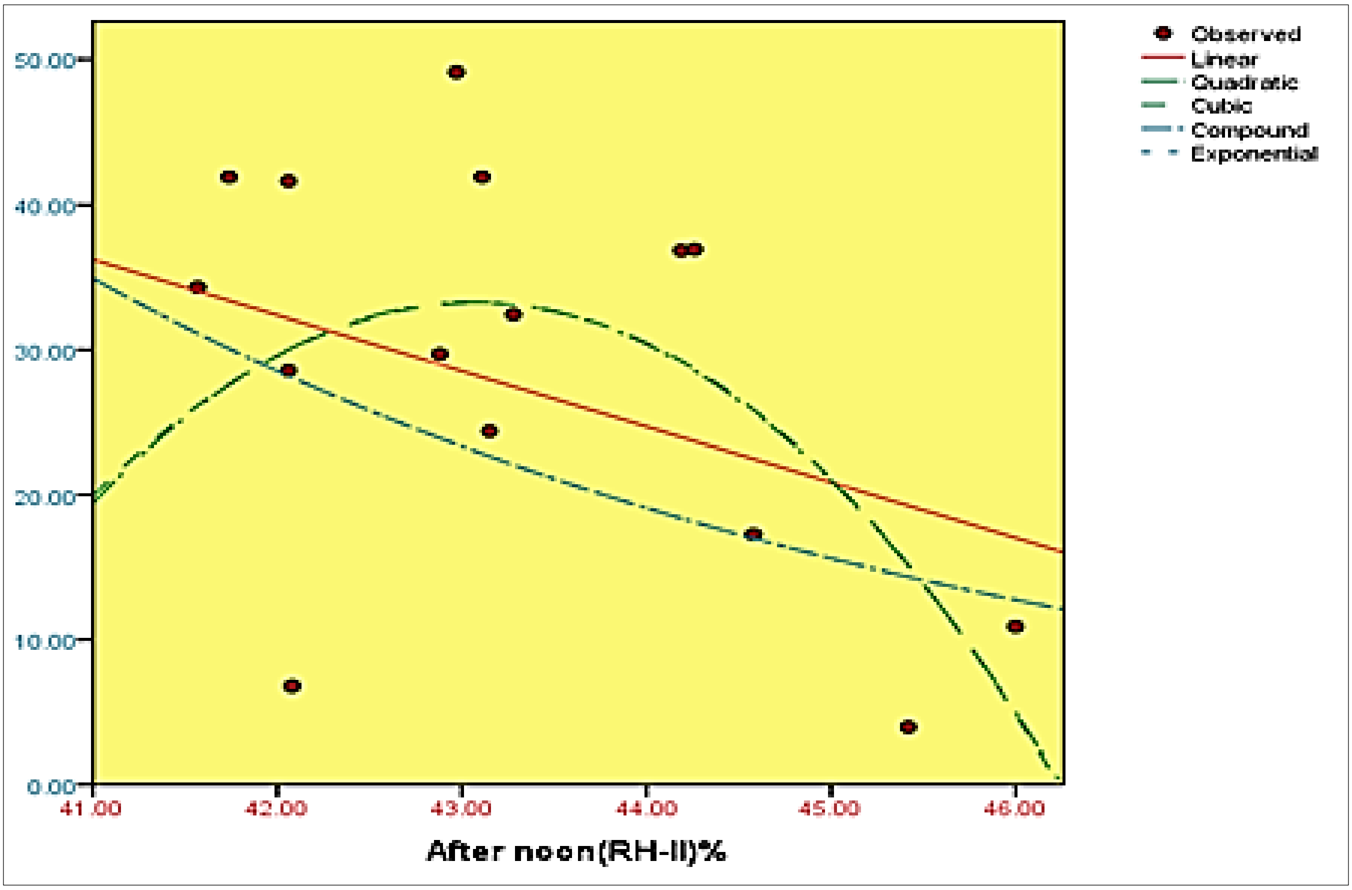

Fig 4.4: Diagram showing the fitting of RH in afternoon on rice yield of Satna District.

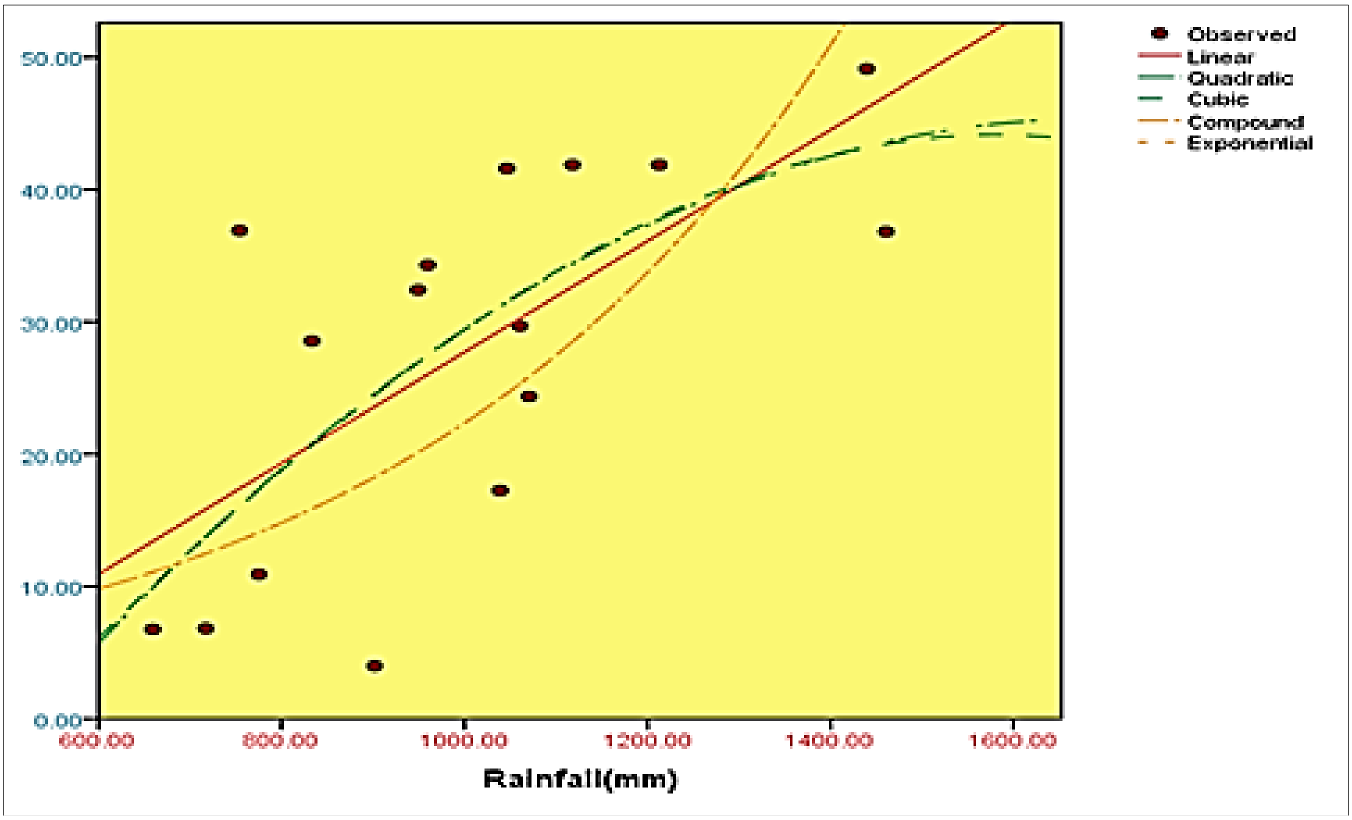

Fig 4.5: Diagram showing the fitting of rainfall on rice yield of Satna District.

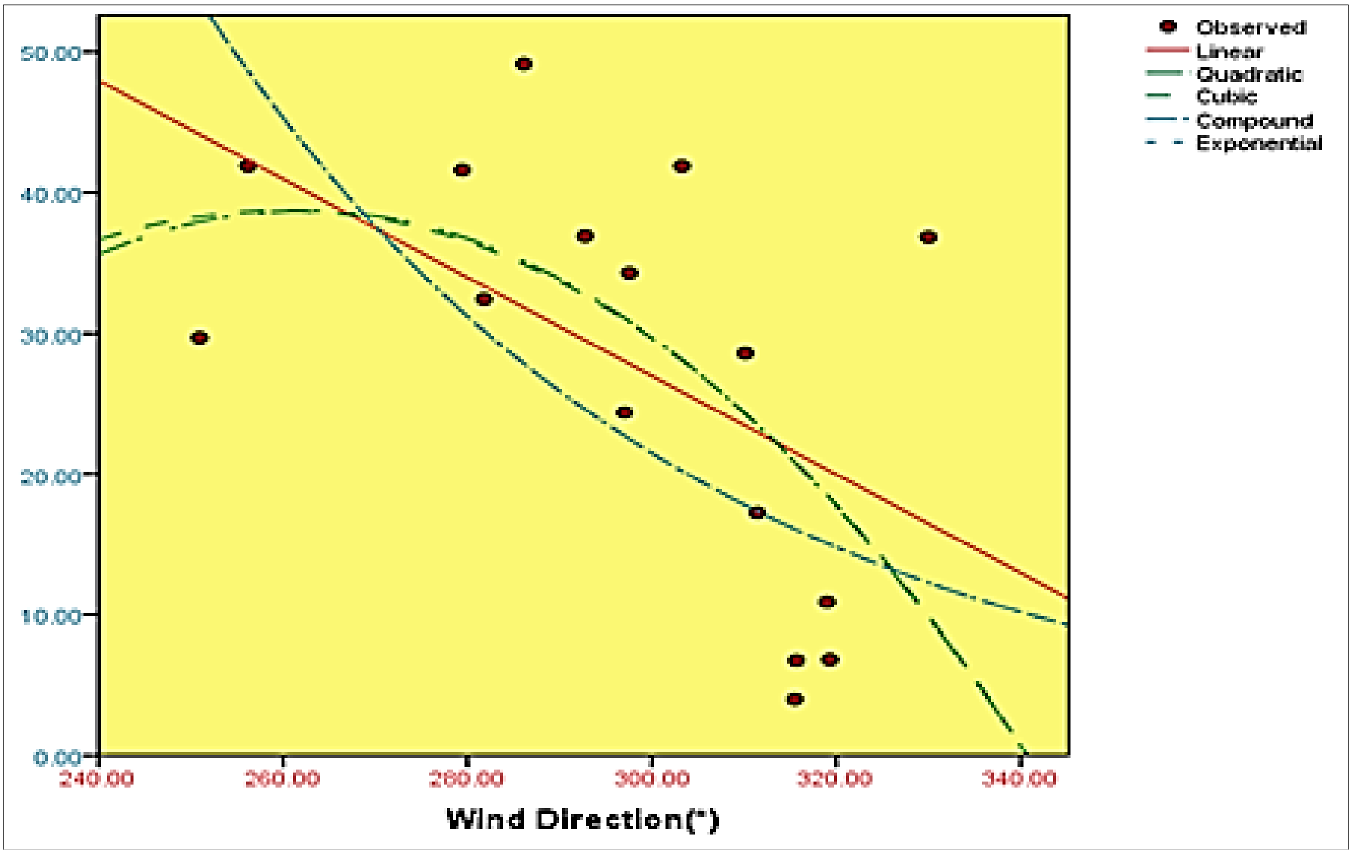

Fig 4.6: Diagram showing the fitting of wind direction on rice yield of Satna District.

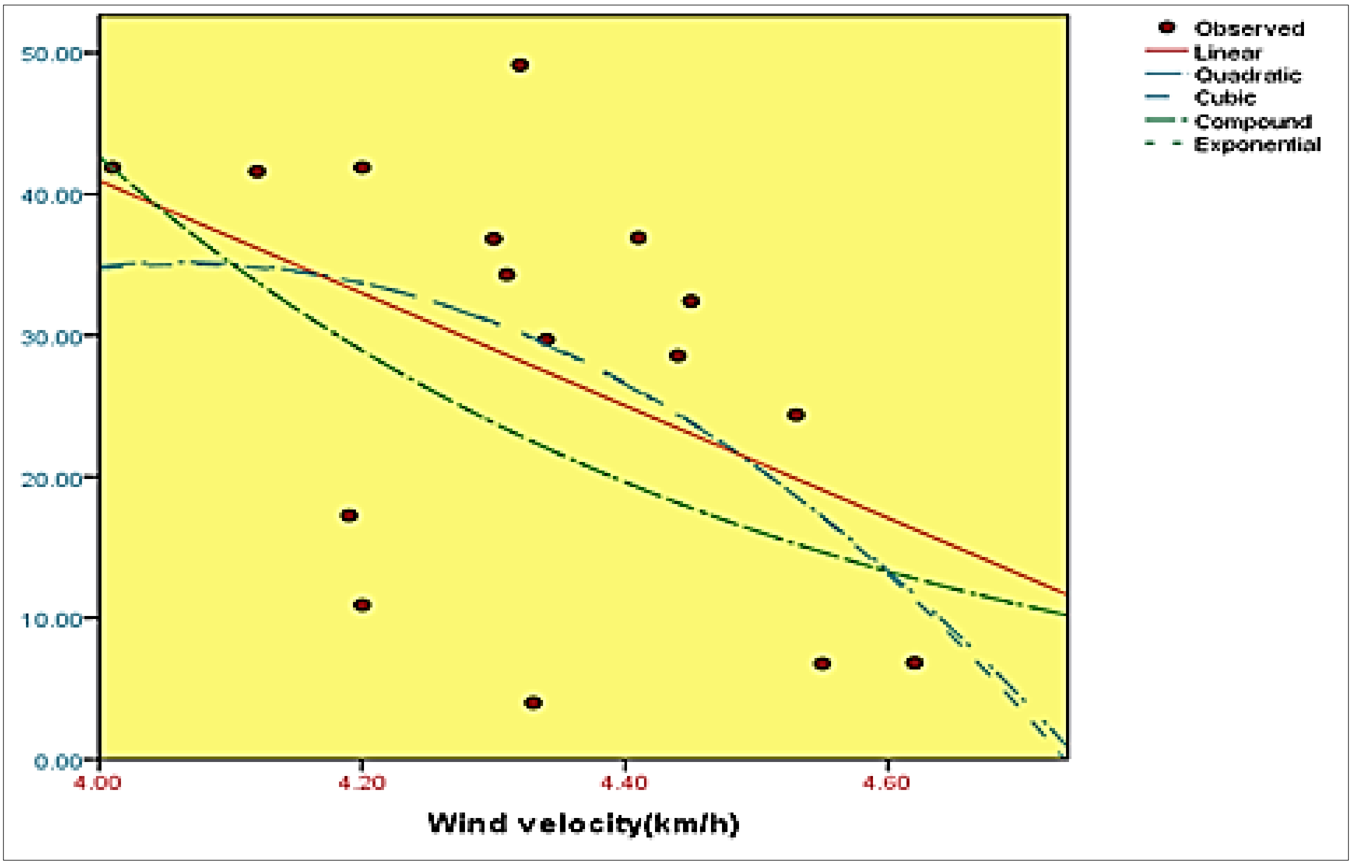

Fig 4.7: Diagram showing the fitting of wind velocity on rice yield of Satna District.

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