Comparative Study of Temperature and Rainfall Fluctuation in Hunza-Nagar District

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Abstract: Climate assessment essentially involves a good understanding of rainfall and temperature patterns. As such, there are many factors to be considered while studying climate. Although, temperature and rainfall are playing an extremely important and manifold role in climatic research particularly in various environmental hazards. The aim of this study was to develop and validate a forecasting model that could predict temperature and rainfall and provide timely early warning in Hunza-Nagar. In this paper temperature and rainfall dataset (2007-2011) have used and developed a quantitative treatment using different statistical methods such as regression and time series/stochastic modeling. The regression analysis proposes that the rainfall increased with increasing temperature. It also found that trends in monthly mean maximum temperature indices increase from years 2007 to 2011 while the amount of rainfall has decreased. The available data presented that AR (1) model is most adequate for a forecast of temperature. These forecasts will be useful for public, private and government organization.

Keywords: Rainfall, Stochastic Modeling, Temperature.

1. INTODUCTION

It is known that rainfall and temperature events are important causes of recent severe flooding in the Pakistan and such events may have negative impacts on infrastructures such as flora, fauna, dams, settlement and drainage systems. This frequency analysis to produce generalized extreme value growth curves for long return-period rainfall events for regions. Usually a high temperature and rainfall bring to various environmental hazards. Floods and other natural disasters may result in loss of infrastructure, energy insecurity, political, socio-economic and social life instability and decline of natural ecosystems. According to press survey during the horrible summer monsoon rainfall in 2010, about 1,500 deaths and hundreds of thousands of people trapped by flooding triggered in Pakistan, millions of hectares of crops, underwater villages and destroyed roads, bridges washed away, there was a threat of damaging dams in the south and different diseases spread over the flood affected areas across the country. Recorded temperature shows that mean maximum temperature have increased in the Hunza-Nagr District. The annual rainfall in the region is 136.2mm with maximum 28.3mm in April and minimum 2.1mm in November [1]. The extreme temperature events have the greatest economic and social impacts by affecting mortality rates, energy consumption, crop production and fire risk [2].

According to Toth *et.al.*, 2000, a comparison of time-series analysis techniques for short-term rainfall forecasting to be used as input in a deterministic rainfall–runoff model for real-time flash-flood forecasting [1]. Sadiq and Qureshi reported climatic variability and linear trend models for the five major cities of Pakistan [3].

2. STUDY AREA

The Hunza - Nagar District is the seventh district of Gilgit-Baltistan province. The district comprises Hunza and Nagar valleys. Before the announcement of the new district, Hunza-Nagar was part of District Gilgit. Formerly this region was divided into two states; Hunza and Nagar. The total area is approximately 15101Km^2 as shown in Figure **1**. It is situated at the altitude of 3000m. Gilgit is the capital city of Gilgit-Baltistan. Nagar River is the main tributary of the Indus River in the Province. Its ecological status is very important to keep an ecological balance of the water system. It is formed by the confluence of the Kilik and Khunjarbnalas which are fed by the extensive glaciers of Nagar and Hunza. It is joined by the Gilgit River and the Naltar River before it flows into the Indus River. Skindrabad is the administrative center of this district. More than 20 tributaries link with Hunza-Nagar River i.e, Hassan Abad River, Minpin River, Thul River, Chalt River, Budalus River, and Aliabad River. The climate of the study area is moderate with an average maximum temperature 35.9˚C and minimum 16 ˚C. The monsoon winds are blocked by the high mountains of Nanga Parbat and clouds cannot reach Gilgit which makes it dry and rugged. The annual rainfall in the region is

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136.2mm with maximum 28.3mm in April and minimum 2.1mm in November [4]. The geomorphology is characterized by deep canyons. The land cover areas are defined within the different zones such as most of agricultural activities are performed in the down valleys while natural forest and pastures located on the top of mountains. The Karakoram Highway (KKH) is also through the Hunza-Nagar District. The Huzna-Nagar District covered by Karakorum Mountain. The Central Karakorum National Park (CKNP) and Khunjearb Park also located within this district.

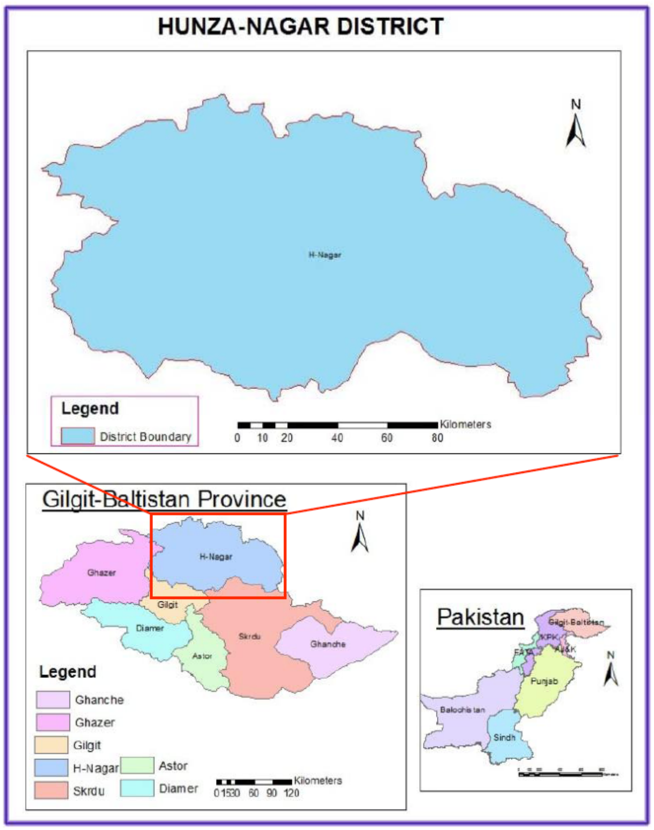

Figure 1: Study Area of Hunza-Nagar.

3. METHODOLOGY

Data Collection

In this paper mean monthly maximum temperature and rainfall data of Hunza-Nagar was used from 2007 to 2011 recorded by the Pakistan Meteorological Department, Government of Pakistan.

Statistical Method

The method adopts in this paper is based on statistical methods by using software (Minitab 14). For each variable (temperature and rainfall), Regression, Correlation and Time series have been calculated.

Regression Analysis

Regression analysis describes the estimation of the unknown value of one variable from the known value of the other variable. There are two types of variables in regression analysis first tell us that the variable whose value is influenced or is to be predicted is called the dependent variable and the variable which influences the values or is used for prediction is called independent variable. Therefore, regression is the measure of the average relationship between two or more variables in terms of the original units of the data.

A multiple regression model between an explanatory variable (X, s) and a response variable (Y) is

$$Y = a + b_1X_{1j} + b_2X_{2j} \ldots\ldots\ldots\ldots\ldots\ldots\ldots + bnXnj + ej$$

Simply a linear regression model may expressed as

$$Y = a + bX + ej$$

If b positive means, an increase in X i.e. temperature leads to an expected increase in response variable Y i.e. rainfall and negative in X means, an expected decrease in response variable. Where ‘a’ and ‘b’ are find using least square procedure.

Time Series or Stochastic Modeling

Time series or stochastic modeling is a set of observations taken at specified times usually at equal interval. Thus a set of data depending on time is called a Time series; here temperature and rainfall represent the time series. The time series analysis is helpful to compare the actual performance and analyze the cause of variations. By comparing different time series we can draw important conclusions. Trend’ is a common terminology used and it helps in analyzing the phenomenon in terms of the effects of various technological, atmospheric and other factors on its behavior over time. Time series analysis helps to study in the forecasting of future values of a time series from current and past values.

In Trend analysis the variables are observed over a long period of time and any changes related to time and a Trend of these changes is established.

Some persist relatively constants and reverse from growth to decline or from decline to growth over a period of time. A change in these conditions would affect the forecast.

Autoregressive Model /AR (1)

Now construct of time series model to predict temperature and rainfall for Hunza-Nagar. Since a model can define the real situation of a system. An observed time series can be thought of a particular realization of stochastic time series is defined by a record of the values of any fluctuating quantity measured at different points of time. In this study temperature and rainfall over a period of 5 years (2007-2011) is used. If we can obtain an adequate model for time series, it may provide valuable insight into the physical mechanism generating the data, and it can be used to forecast i.e. the future values of the series.

To understand the concept we can illustrate the case of autoregressive model which is frequently used in time series model. It is the special type of multiple regression models on which some or all the explanatory variables are lagged values of X_t.

An autoregressive model takes the form

$$X_t = \alpha_o + \varphi_1 X_{t-1} + \varphi_2 X_{t-2} + \ldots\ldots\ldots\ldots\ldots + \varphi_s X_{t-s} + e_t$$

The value X_{t-s} is called the lagged value of Y at the time (t-s). The order of regression models is s, where X_t is expressed as a linear combination of its two immediately preceding values. The value variables X_{t-1} and X_{t-2} are constructed easily by moving the values down the available data. Autocorrelation between X_t and X_{t-1} and between X_t and X_{t-2} can be computed. A simple autoregressive model of order one or AR (1) can be defined as

$$X_t = \varphi_1 X_{t-1} + \alpha_o \quad (2)$$

Where, φ_1 and α_o can find using the least square procedure.

4. RESULTS AND DISCUSSION

Applying this model on the appropriate results we have explored the following results, which are appriporiately discussed below:

Regression Analysis

There is a great debate about the causes of the changing climate of the earth. In examining, the relationship between temperature and rainfall. Figure **2** is a plot of rainfall P (mm) against the temperature T (^{0}C) in monthly from 2007 to 2011. The plot appears to be straight line having positive slop. Sample data consisting of n= 60 observations. This relationship may be represented as

$$\hat{P} = 15.4 + 0.0655\text{T} \quad (1)$$

Where a= 15.4 (parameter value of intercept), b = 0.0655 (parametric value of the slop of line) with correlation coefficient r = 0.387, R^2 = 15.0% and R^2 (adj) = 13.5%. The regression coefficient b = 0.0655 is well significant because P-value =0.002at 1% level of significance whose confidence interval is 99%. The observed value of F is 10.25 and P-value < 0.05.It is good significant.

The standard error of the model is $S_\varepsilon = \sqrt{MS} = \sqrt{673.17}$ = 25.9455. Therefore, the above model may be a useful linear model.

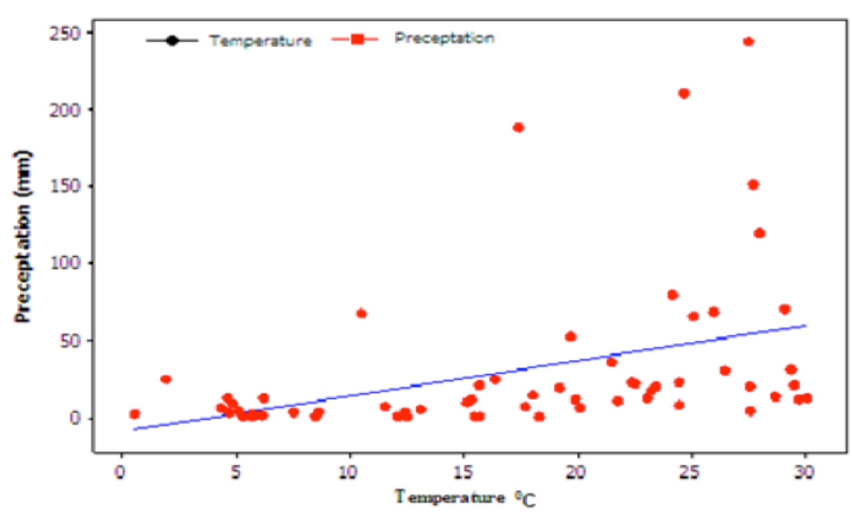

Figure 2: Scatter Plots between Temperature and Rainfall at Hunza-Nagar over the period 2007-2011.

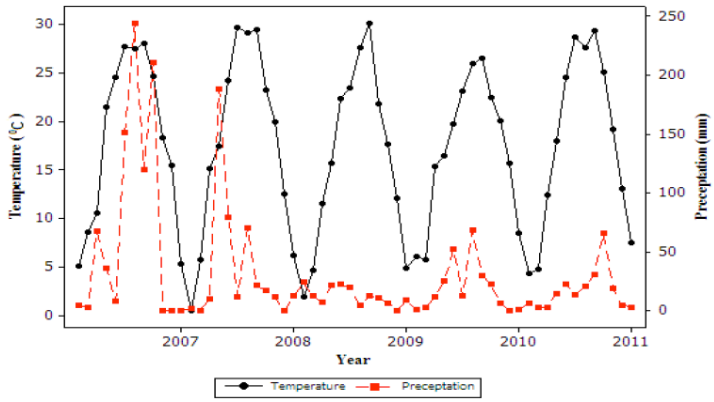

Figure 3: Monthly maximum temperature and rainfall at Hunza-Nagar District over the time period 2007-2011.

Time Series or Stochastic Modeling

A Time series (TS) is a sequence of observations ordered in time. Most these observations are collected at equally spaced discrete time intervals. A basic assumption in any time series analysis modeling is that some aspects of the past pattern will continue to remain in the future. Also under this setup often the time series process is assumed to be based on past values of the main variable but not on explanatory variables which may affect the system. So the system act as a black box and we may only be able to know "what" will happen rather than "why" it happens. Here it is tactically assumed that information about the past is available in the form of numerical data [5, 6]. Ideally at least 50 observations are necessary for performing time series analysis/modeling but in this study area climatic station was established in 2007.

Time series analysis can be used more easily for forecasting purposes because historical sequences of observations upon study variables are readily available from published sources. These successive observations are statistically dependent and Time series modeling is concerned with techniques for the analysis of such dependencies [5, 6].

Figure **3** shows the time variation of monthly maximum temperature and the amount of rainfall over Hunza-Nagar from 2007-2011. Rainfall and temperature reveals up and down pattern in every month from 2007-2011. The five years monthly amounts of rainfall and maximum temperature plotted in Figure **3** shows that the highest rainfall of the season is 244 mm recorded in July 2007 and the maximum temperature recorded 30.10 ^{0}C in August 2009. The mean monthly rainfall trend continuously slackens from 2007 to 2011 and mean monthly maximum temperature shows steadily increasing trend as shown in Figures **4** and **5**.

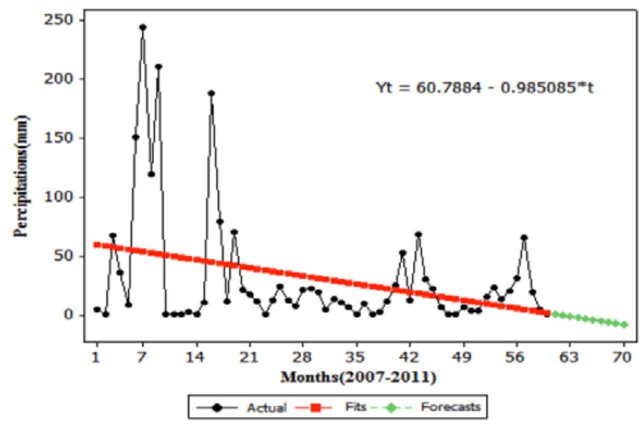

Figure 4: Time plot of monthly maximum rainfall with fitted linear trend model at Hunza-Nagar District over the time period 2007-2011.

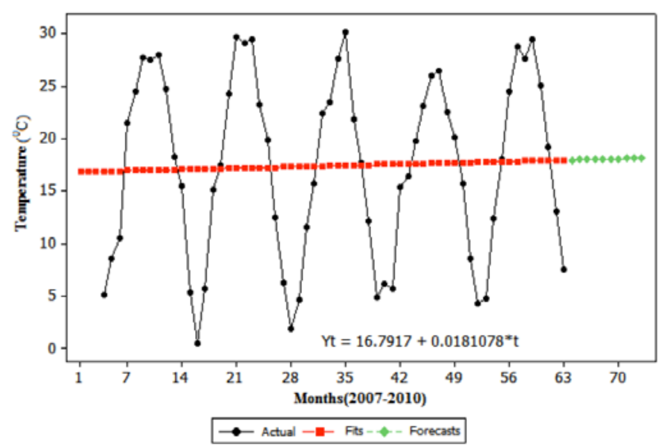

Figure 5: Time plot of monthly maximum Temperature with fitted linear trend model at Hunza-Nagar District over the time period 2007-2011.

Autoregressive Model /AR (1)

AR (1) for Mean Maximum Monthly Temperature

Using equation (2) we have find AR (1) for mean maximum monthly temperature of Hunza-Nagar as

$$\hat{T} = 0.8493 \quad \hat{T}_{t-1} + 2.3587 \tag{3}$$

Where α_o = 2.3587, φ_1 = 0.8493 which indicates that $\varphi_1 < 1$. The t-Statistic for $\varphi_1$is 11.57 and the value of P = 0.000. The' t' statistics in AR model do not exactly follow the t distribution because one of the basic assumptions of the classical linear regression model has been violated.

For analysis of variance (ANOVA), the coefficient of determination (R^2) can be calculated as

$$R^2 = \frac{SST - SSE}{SST} \tag{4}$$

$$R^2 = \frac{4667.92 - 1406.66}{4667.92}$$

$$R^2 = 0.698654$$

This shows that 69.8654% of the variation explained by the regression model and remaining itself unexplained. It shows that a good forecast of the value of 'T' is possible when the previous value of 'T' known. Using equation (3) forecast temperature for Hunza-Nagar.

$$\hat{T}_{61} = 0.8493 \ \hat{T}_{60} + 2.3587$$

$$\hat{T}_{61} = 8.7281$$

$$\hat{T}_{62} = 0.8493 \ \hat{T}_{61} + 2.3587$$

$$\hat{T}_{62} = 9.7710$$

Further forecast values are shown in Table **1**

Table 1: Forecasts Values of Mean Monthly Temperature for District Hunza-Nagar

Period	X_t	X_{t-1}
61	8.7281	7.5
62	9.7710	8.7281
63	10.6568	9.7710
64	11.4090	10.6568
65	12.0478	11.4090
66	12.5904	12.0478
67	13.0511	12.5904
68	13.4424	13.0511
69	13.7747	13.4424
70	14.0569	13.7747

AR (1) Model for the Mean Monthly Amount of Rainfall

Now again follow equation (2) construct AR (1) model for the mean monthly amount of rainfall of Hunza-Nagar as

$$\hat{P}_t = 0.4564 \quad \hat{P}_{t-1} + 16.28$$

Where α_o= 16.28, φ_1 = 0.4564 which indicates that $\varphi_1 < 1$. The t-Statistic for φ_1 = 3.89 and the value of P = 0.000 for φ_1. The 't' statistics in AR model do not exactly follow the t distribution because one of the basic assumptions of the classical linear regression model has been violated. For analysis of variance (ANOVA), the coefficient of determination (R^2) can be calculated by using equation (4)

$$R^2 = \frac{157329 - 124766}{157329}$$

$$R^2 = 0.206973$$

This shows that 20.6973% of the variation explained by the regression model and remaining itself unexplained. It shows that AR (1) model is not good for forecasting of rainfall of Hunza-Nagar. Because, for good forecast the value of R^2should be exceed to 50%.

5. CONCLUSION

Temperature and a rainfall are important climatic inputs for environmental hazards, especially in the context of climate change. It is known that rainfall and temperature are physically related through the dependence of atmospheric humidity on temperature. The link between the amount of rainfall and temperature is, however, often screened in observed records because of the influence of other factors on rainfall. For climate change scenario development it may be extremely useful to make the rainfall-temperature dependence visible. This requires a proper selection of predictor variables.

The results conclude that there is a direct connection between temperature and rainfall i.e. rainfall is increased due to increase in temperature respectively. Investigation of the trends in monthly mean maximum temperature indices shows that the frequency of warm events has generally increased over at least the 5 years i.e. from 2007 to 2011, while the amount of rainfall has decreased.

The forecasting reliability was evaluated by comparing the actual and predicted temperature and rainfall values. The results show that the AR (1) model can be an important tool for temperature forecasting.

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