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APPLICATION OF SIMPLE EXPONENTIAL SMOOTHING METHOD FOR TEMPERATURE FORECASTING IN TWO MAJOR CITIES OF THE PUNJAB, PAKISTAN

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ABSTRACT

Weather forecasting has been getting more attention from researchers and becoming influential factor for effective policy and planning at local and global level. Climatic variations have been directly affected by global warming and happened to rise atmospheric temperature; as the temperature of earth has been increased by 0.74°C during last 100 years. In Pakistan, daily environmental temperature has been increasing; on average there is 0.6°C rise of daily environmental temperature has been observed. The present research has focused on the modeling and forecasting about daily temperature of Faisalabad and Lahore districts of Punjab, Pakistan. It is found that simple exponential technique is more appropriate technique for modeling the temperature data as compared to other methods such as Holt's exponential and Holt's winter exponential techniques. The forecasting of temperature data was made on the optimum value of smoothing constant. The selection of optimal smoothing constant was based on the minimum values of mean absolute error (MAE), mean absolute percentage error (MAPE) and root mean square error (RMSE). The application of simple exponential technique is therefore recommended for considering to predict about the climatic variables like rainfall, humidity and wind speed because of its forecasting accuracy for short term period. This research will be helpful for researchers and policy makers who are associated with environment-based work.

***Keywords*:** Temperature Forecasting, Simple Exponential Smoothing Method, Punjab, Pakistan

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1. INTRODUCTION

Climate is the average weather for a specific place at certain time with respect to different climatic factors such as temperature, precipitation, humidity and wind taken over 3 decades (Vucijak et al. 2012). The climate has been changing for last many years globally and getting attention from all quarters of researchers and policy makers (Ahmed et al. 2011; Marera 2016; Duku et al. 2018). The climate changes have been affecting severely the agriculture sector of developing countries, like Pakistan whose economy mainly based on agriculture. Food production and economic activities of a region are the leading sectors which are directly affected by the climate changes (Khan et al. 2016; Ali et al. 2017; Duku et al. 2018; Aslam et al. 2018; Ahmed et al. 2019).

The Pakistan's economy mainly depends on agriculture sector and provides livelihood to majority of rural population. The GDP portion of agriculture sector is about 19% and utilizing 39% of the labor force. Unfortunately, agriculture sector has been facing serious environmental challenges like temperature rise, drought and floods. These factors happened to increase the losses of crops' yield (Ali et al. 2017; Raza et al. 2019). The superficial research initiates usually cause adverse climate affects in Pakistan; like in recent past: the drought during 1998-2001 and flood during 2010. Both of the climate incidences affected the socio-economic development of the Pakistan. The temperature of Pakistan and many other countries are rising because of global warming; which resultantly posing major risks for agricultural productivity (Farooqi et al. 2005). Due to increase in temperature glaciers are melting quickly, peak areas such as mountains show fluctuated temperature values (Liu and Chen 2000). Therefore, it is very important to model the temperature patterns using statistical methods.

Simple exponential smoothing is commonly used econometric approach to model and forecast the time series data (Chatfield 1995; Makridakis et al. 2008; Chatfield and Xing 2019). The application of simple exponential smoothing (SES) method has not been frequently considered for time series modeling by the researchers (Burney et al. 2017). Very few researchers of Pakistan (Shamshad et al. 2019) have considered simple exponential smoothing method for modeling environment data. Exponential smoothing is a forecasting method used for determining the trend and seasonality among data (Masood et al. 2018). Exponential smoothing is commonly used approach for time series data analysis as it is simple to understand and easy to apply. The objective of this paper is to analyze the temperature data of two major districts of Punjab, Pakistan and examining their variability using simple exponential smoothing technique.

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2. MATERIALS AND METHODS

To meet the objectives of the study, six-year monthly temperature data from 2013-2019 of Faisalabad and Lahore districts of Punjab were obtained from Pakistan metrological department. In order to do forecasting; the dataset was divided into two parts. The first part which is used as training data set was taken from 2013 to 2018 while the remaining data was considered as test data set. The training data is used to evaluate the application of simple exponential smoothing method which is explained below.

2.1. Simple Exponential Smoothing (SES)

The SES method assumes that the level of time series should vary about a constant level; whose objective is to smooth the given time series data like moving average; which has been used for future forecasting. Moreover, the SES method assigned more weightage to the recent data points as compared to the immediately preceding data values which makes this technique more practical method as compare to other forecasting methods (Olaofe 2015; Murat et al. 2016; Siregar et al. 2017).

2.1.1 Mathematical Formulation

Mathematically the SES model is written as

$$Z(k) = \mathrm{y}(k) + \epsilon(k) \quad (1)$$

Where, ɣ (k) is a constant at the time k and it changes slowly with time. On the other hand the term ε(k) is a random error, which is used for reporting the effect of stochastic variation. Suppose there is a time series $z_1, z_2, z_3, \dots z_n$ with n observations then the general formula for SES model will be

$$F_K = \alpha Z_K + (1-\alpha)F_{k-1} \quad (2)$$

Where, Z_K is the real data value at time k. The term F_k represents the forecasted value of Z at time k. The coefficient α showed the smoothing constant which lies between 0 and 1 (Ostertagova and Ostertag 2012; Marera 2016). In equation 2, the choice of initial value of F_k is very important. The recursive application of equation 2 helps to determine the behavior of weights which is given as

$$F_K = \alpha Z_K + (1-\alpha)[\alpha Z_{k-1} + (1-\alpha)F_{K-2}] \quad (3)$$

$$F_K = \alpha Z_K + \alpha(1-\alpha)Z_{k-1} + (1-\alpha)^2 F_{K-2} \quad (4)$$

$$F_K = \alpha Z_K + \alpha(1-\alpha)Z_{k-1} + \alpha(1-\alpha)^2 Z_{k-2} + - + \alpha(1-\alpha)^{k-1}Z_1 + (1-\alpha)^k F_0 \quad (5)$$

From the above equations (3-5) it is noted that the weights decay geometrically and is a discrete exponential function. After rearranging the equation (2), the SES model can be written as

$$F_{k+1} - F_k = \alpha(z_k - F_k) \quad (6)$$

Forecast error is proportional to the change in forecast value. That is

$$F_{k+1} = F_k + \alpha e_k \quad (7)$$

Where residual is equal to

$$e_k = z_k - F_k \quad (8)$$

where e_k is the forecast error at time k. From this, the forecast equation, given below, can be written as

$$F_{k+1} = \alpha \sum_{k=0}^{k-1}(1-\alpha)^l z_{k-l} + (1-\alpha)^k z_1, \; k \epsilon N \quad (9)$$

From equation (9), it can be seen that the exponential smoothing forecast is obtained by adding the previous forecast value and adjusting error value which is used in the last forecast.

2.2. Measuring forecast error

In order to check the accuracy of the forecast models; the following measures are commonly used in literature (Ostertagova and Ostertag 2012).

$$\text{MAE} = \frac{1}{n}\sum_{k=1}^{n}|e_k| \quad (10)$$

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{k=1}^{n}|e_k^2|} \quad (11)$$

$$\text{MAPE} = \frac{1}{n}\sum_{k=1}^{n}\frac{|e_k|}{z_k}.100\% \quad (12)$$

Where MAE is the mean absolute error, RMSE is the root mean square error and MAPE is defined as mean absolute percentage error.

3. RESULTS AND DISCUSSION

3.1. Data Exploration

Descriptive statistics and exploratory plots are useful tools to understand the salient features of data (Chatfield 1995; Marera 2016). The temperate dataset used in this study consists of daily average temperature in Faisalabad and Lahore district for the years from 2013 to 2018. The descriptive statistics of the 6-year time series data consist of 2191 total values for each district; and are reported in Table 1.

Table 1: Descriptive Statistics of Lahore and Faisalabad district temperature data from 2013-2018

Statistic	Faisalabad Station	Lahore Station
Minimum Value	4.80	5.50
Maximum Value	39.50	38.90
Mean	24.79	24.49
Standard Deviation	3.98	4.30
1st Quartile	17.80	18.10
Median	26.50	26.40
3rd Quartile	31.80	30.60

Table 2: Mean square error (MSE) of different exponential methods

Methods	(MSE)	
	Faisalabad Station	Lahore Station
Simple exponential smoothing	1.8916	2.3639
Holt's exponential smoothing	1.8986	2.7800
Holt's Winter exponential smoothing	1.9445	2.7174

Table 3: The accuracy measures using training data for different values of smoothing constant (α)

α	Faisalabad			Lahore		
	MAE	MAPE	RMSE	MAE	MAPE	RMSE
0.2	1.55	12.67	1.94	1.69	11.98	2.16
0.3	1.36	11.43	1.73	1.48	10.67	1.92
0.4	1.24	10.50	1.60	1.37	10.09	1.77
0.5	1.15	9.71	1.50	1.29	9.62	1.66
0.6	1.08	9.13	1.42	1.22	9.19	1.58
0.7	1.05	8.79	1.36	1.16	8.83	1.51
0.8	1.02	8.47	1.33	1.12	8.58	1.46
0.9	0.99	8.16	1.30	1.08	8.38	1.42

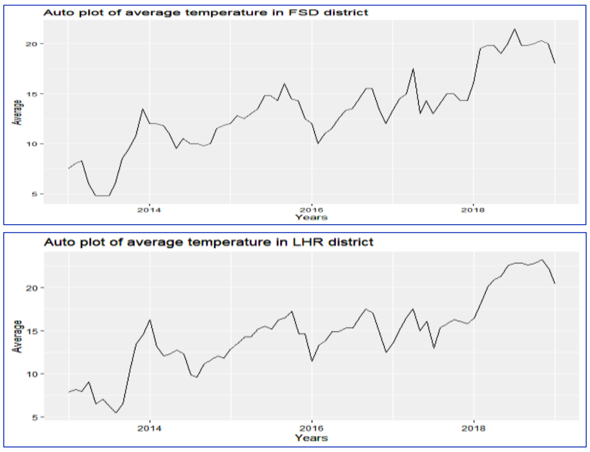

Fig. 1: Time series plot of Faisalabad (FSD) and Lahore (LHR) District from 2013-2018.

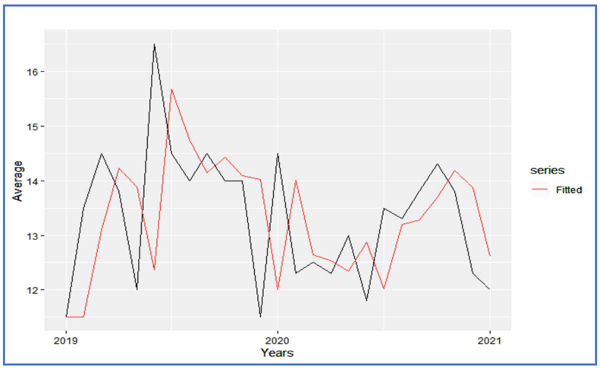

Fig. 2: Observed and forecasted values of Faisalabad (FSD) District at optimal α.

Fig. 3: Observed and forecasted values of Lahore (LHR) District at optimal α.

The temperature ranged between 4.80ºC and 39.50ºC with mean temperature over the period was 24.79ºC in Faisalabad district. Whereas in Lahore the average temperature was 24.40ºC which varies from 5.50ºC to 38.90ºC. In order to recognize the trend and behavior of both series; graphical analysis has been performed and presented in Fig. 1.

Form Fig. 1 it is observed that overall temperature increased at both locations, but there is no significant trend present in data. In order to choose the appropriate exponential smoothing among simple exponential smoothing, Holt's exponential smoothing and Holt's Winter exponential smoothing techniques were applied on both series and mean square error (MSE) is calculated; which are reported in Table 2.

In both cases, it can be noted that simple exponential smoothing gives the minimum error value as compared to other two techniques (Fatima et al. 2019). Therefore, it is better to choose simple exponential smoothing method for this data.

3.2. Selection of Appropriate Smoothing Constant

The forecasting power of SES technique based on appropriate smoothing constant (Chatfield and Xing 2019). The appropriate value of smoothing constant (α) minimizes the error and produces better forecasting (Murat et al. 2016; Siregar et al. 2017). In order to choose the appropriate α value grid search method is used by taking parameter space from 0.1 to 0.9 with increments of 0.1 (Makridakis et al. 2008; Reynolds et al. 2018). The MAE, MAPE and

RMSE are calculated on each selected α value for both series and results are reported in Table 3. From table 3 it is noted that the value of MAE, RMSE and MAPE is decreased with the increase of α up to 0.9. A rapid decrease has been observed in all error measures when α value varies from 0.2 to 0.7 and showed minimum value at α=0.8 and α=0.9. The smoothing constant values at α=0.8 and α=0.9 has been selected as the optimal value because they produce minimum values of MAE, RMSE and MAPE.

The forecasting of Faisalabad and Lahore district temperature data has been performed using simple exponential smoothing method by choosing optimal value of smoothing constant and results are presented in Fig. 2 and Fig. 3, respectively. The results indicate that data the simple exponential produce very reliable forecasting as forecasted values are very close to the current values. The results of present study are similar to what other studies have reported about the utilization of simple exponential smoothing for forecasting environmental variables (Salas and Subburayalu 2019; Fatima et al. 2019; Septiarini and Musikasuwan 2018; Milanovic et al. 2018; Ruekkasaem and Sasananan 2018).

CONCLUSION: Pakistan is an Agricultural country and its economic sector has been attached in multiple ways with agriculture. Weather fluctuations directly affect to the agricultural areas and their productions. Temperature plays an important role towards crops production. This study has provided an application of Simple Exponential Smoothing (SES) on temperature data. Exponential smoothing model assigns larger weights to the recent observations. These weights decline exponentially as the observations move apart from the recent values. The 6-years (from 2013 to 2018) temperature data of Faisalabad and Lahore stations have been used for the modeling and forecasting using simple exponential method. Firstly, dataset has been split into two parts, one is called training dataset and other is test dataset. Descriptive statistics and graphical exploration of data have been presented to find the salient characteristics of the data. Three measures of forecasting error used: Mean Absolute Error, Mean Absolute Percentage Error and Root Mean Square Error. Minimum values of these three forecasting errors were found at α=0.8 and α=0.9. Forecasting was made by using these two-smoothing constant (α) values. It is concluded that simple exponential model provides better forecasting as it gives less variant values of the error measures. This study will likely be a helping resource for the researchers and policy makers who are rigorously studying environmental data.

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