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Statistical Analysis of Extremes of Temperature, Precipitation and Humidity in Swat Region

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Abstract: If a specific area (station) data cannot be obtained due to natural disaster, Meteorological instrument limitations and instability in that area (terrorist attack swat 2009).We need a solid equation to calculate the missing values. Climate change is important factors now a day extreme events of precipitation and temperature are increasing for that purpose we need an equations of extreme.11 year (2006-2016) data of daily basis temperature, precipitation and humidity of three stations Saidu Sharif, Malam Jabba and Kalam is collected quality and controlled of data maintained by removing errors in data. The result is divided in two parts basic statistics of each individual station and dependence structure among different stations. Basic Statics consist of mean, standard deviation, Skewness, kurtosis, histograms and percentiles curves for better understanding of statistical behavior of data of each station. Dependence structure among different station consist Q-Q Plots to verify normality of data. Points closed to reference line means data is normally distributed and give more accurate linear regression model. Correlation and extreme correlation are developed to analyze the strength of relation among different station. Coefficient of determination and extreme coefficient of determination guide us to check the accuracy and validity of linear regression model. Linear regression equations of normal and extreme temperature, precipitation and humidity are developed from linear regression models. These linear regression equations of normal, upper extreme (90%) and lower extreme (10%) used to compute the missing data of one station from data of another station. It does not give us the actual temperature, precipitation and humidity actually happens at that day but closest to the actual value.

Keywords: Skewness, Kurtosis, histogram, linear regression, Q-Q Plots.

1. INTRODUCTION

A. *Different Weather Parameters*.

This thesis will cover study of basic statics of precipitation, temperature and humidity of each station in valley of swat. This thesis will cover normal and extremes of precipitation, temperature and humidity from one region to another in swat region. The annual precipitation in Pakistan in which area of jocabad, nushki and pangur receive precipitation 125-250 mm. Quetta, Multan, Kalat, D.I khan and Karachi receives precipitation 250-375mm. Zhob,Sahiwal and Peshawar receive precipitation 375-500mm. Rawalpindi, Sargodha,Lahore and Parachinar receive precipitation 500-750mm. Islamabad, Chitral and Gilgit receive precipitation above 750mm. Maximum Temperature in Pakistan in which Sindh and south Punjab maximum temperature is 32 -36°C.Kirthar region of Baluchistan, makran coastal region, Baluchistan plateau of south west of Pakistan, central Punjab , central and south Khyber Pakhtunkhwa and Fata maximum temperature is 28-32°C. Azad Kashmir, upper Khyber Pakhtunkhwa, Quetta and Chaman of Baluchistan maximum temperature is 24-28°C. Nanga parbat, kaghan, kalam of Khyber Pakhtunkhwa maximum temperature is 18-24°C.

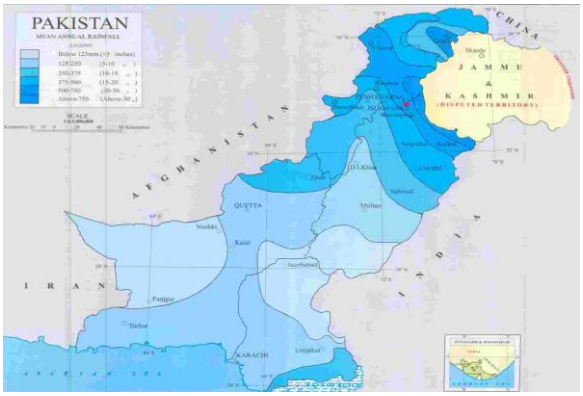

Fig 1. Precipitation Map of Pakistan

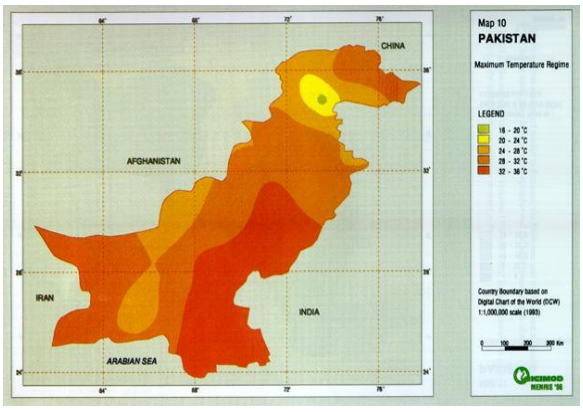

Fig 2. Maximum Temperature Map of Pakistan

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Minimum Temperature in Pakistan in which Sindh, Makran coastal region and Rahim Yar Khan of Punjab shows minimum temperature 20-24℃.From Kirthar range, Central Punjab, upper Punjab, central Khyber Pakhtunkhwa, south Khyber Pakhtunkhwa and Fata minimum temperature is 16-20℃.Upper Khyber Pakhtunkhwa, Baluchistan plateau south east region of Pakistan and Azad Kashmir minimum temperature is 8-12℃. Quetta, Chaman and Gilgit shows minimum temperature less than 8°.C

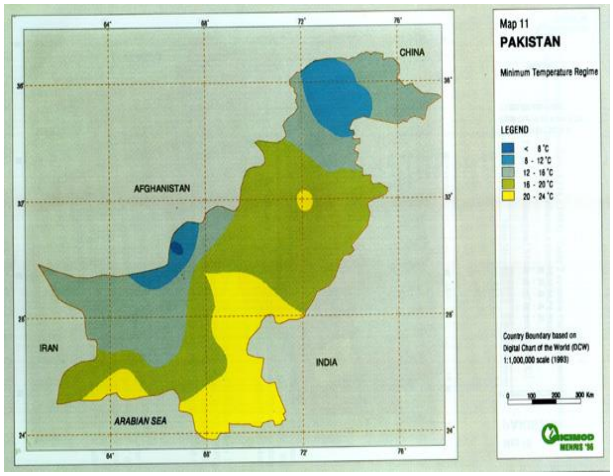


Fig 3. Minimum Temperature of Pakistan

B. About Swat Area.

Swat is topographically mountainous area. It can be further subdivided in two region swat Kohistan and swat valley. Swat Kohistan is the mountainous region of swat and upper area of Swat River. Swat valley is further subdivided in two lower Swat and upper Swat .Kalam station is located in Khyber Pakhtunkhwa of Pakistan between latitude is 35’50’’, longitude 72’59’’ and elevation of 2103.01 meter. The study area is surrounded by upper dir in the west, lower swat in south, Kohistan in east, Ghizer district in north and chitral in south west. Catchment whole area of kalam is approximately 2032 square kilometer. (H.mateeul 2008).Saidu Sharif station is located in Khyber pakhtunkhwa of Pakistan between latitude is 34’44’’, longitude is 72’21’’ and elevation of 961 meter. The study area is surrounded by kalam in north, Shanglain east, lower dir in west and Malakand division in south.Malam Jabba hill station is located in Khyber Pakhtunkhwa of Pakistan between latitude of 35’49’’, longitude is 72’54’’ and elevation is 2590.67 meter. The study area is surrounded by kalam in north, Shanglain east, lower dir in west and Malakand division in south.The whole catchment of swat valley belong to tributaries of Indus River. Swat River joins the Kabul River then from Kabul River it reaches to Indus River. The distance between Saidu Sharif to malamjabba station is 48 km.The distance between stations of kalam to SaiduSharif is 102 Kilometer. The distance between kalam to malam Jabba station is 126 Kilometer.

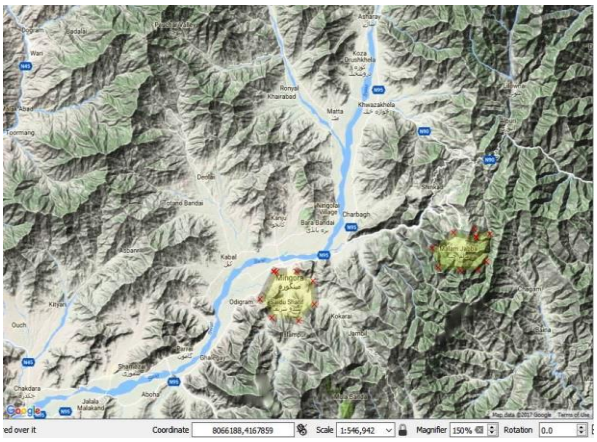


Fig 4. Physical characteristic of Saidu Sharif and Malam Jabba

C. Temperature and Precipitation of Swat region.

The swat is climatically the subtropical and moist temperate zone with heavy rain fall and snow. This area has pleasant summer and severe winter. The summer of swat is moderate and short. Lower swat valley like SaiduSharif show warm but cool in upper north part like kalam. Kalam mean annual minimum temperature is-4℃ and mean annual maximum temperature is 24℃.Kalam maximum relative humidity 100% and minimum relative humidity is 31%.Kalam receives annual precipitation of 900mm (millimeter).SaiduSharif annual minimum temperature is 2℃ and mean annual maximum temperature is 31℃.Saidu Sharif maximum relative humidity 100% and minimum relative humidity is 30%.Saidu Sharif receives annual precipitation of 849 (millimeter).Malam Jabba mean annual minimum temperature -2℃ and mean annual maximum temperature 21℃. Malam Jabba maximum relative humidity 100% and minimum relative humidity is 31%.Saidu Sharif receives annual precipitation of 1971mm (millimeter).According to Peshawar meteorological department Khyber Pakhtunkhwa Pakistan 2016.

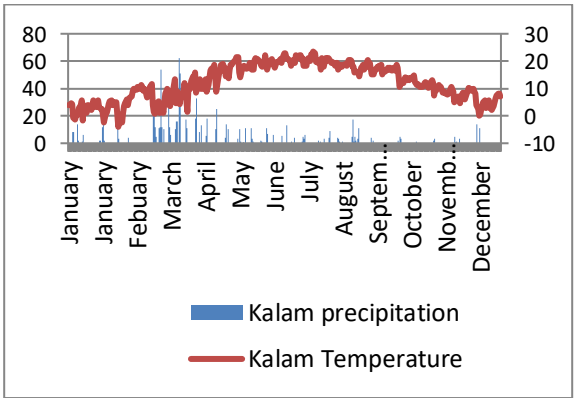


Fig 5. Precipitation and Temperature of Kalam of 2016

Shows annual precipitation and temperature of kalam station as shown in graph. Temperature is constant from January to start of February then in March, April and May there is increase in temperature. June and July shows peak maximum temperature. August, September, October, November and December shows decrease in temperature. March and April shows maximum frequency of precipitation.

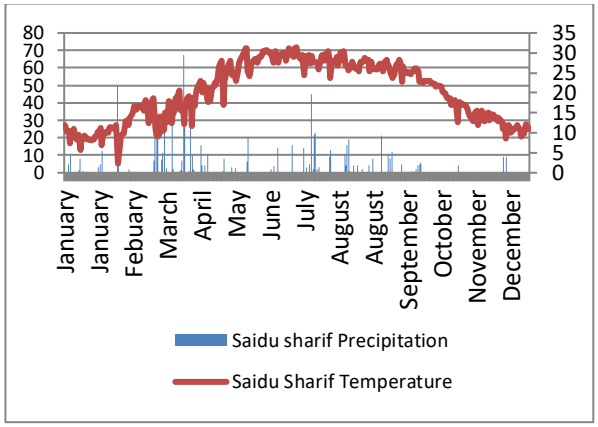
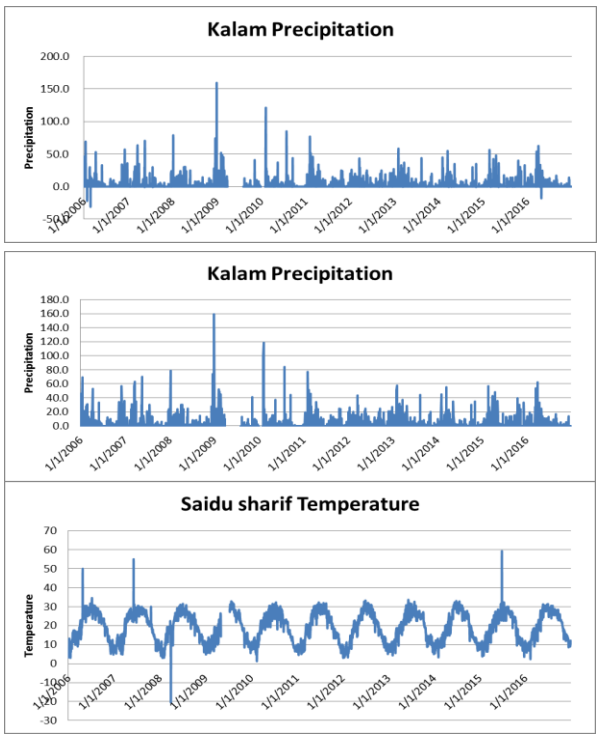


Fig 6. Precipitation and Temperature of Saidu Sharif of 2016.

Annual precipitation and temperature of Saidu Sharif station. Temperature is constant from January to start of February then in March, April and May there is increase in temperature. June and July shows peak maximum temperature. August, September, October, November and December shows decrease in temperature. February, March, April and July shows maximum frequency of precipitation.



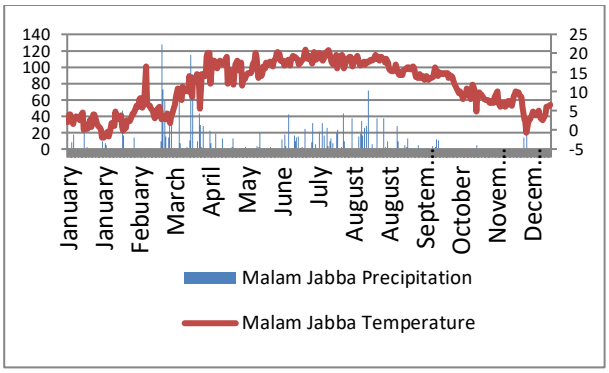


Fig 7 Precipitation and Temperature of Malam Jabba of 2016.

Annual precipitation and temperature of Malam Jabba station. Temperature is constant from January to start of February then in March, April and May there is increase in temperature. June and July shows peak maximum temperature. August, September, October, November and December shows decrease in temperature. March, April and August shows maximum frequency of precipitation.

2. METHODOLOGY

D. Quality Control of the data.

There are a lot of errors in data. If the error is greater than or equal to 50% of value then we have to correct those values. Precipitation data of kalam show negative values as precipitation cannot be negative so these negative precipitations are converted to positive values. The temperature of Saidu Sharif show errors as some temperature values are unexpectedly high 55, 50, 59 and some values are unexpectedly low -20 so we correct values of Saidu Sharif to normal expected values. Some values of Malam Jabba humidity are mistakenly written zero these values has been corrected.

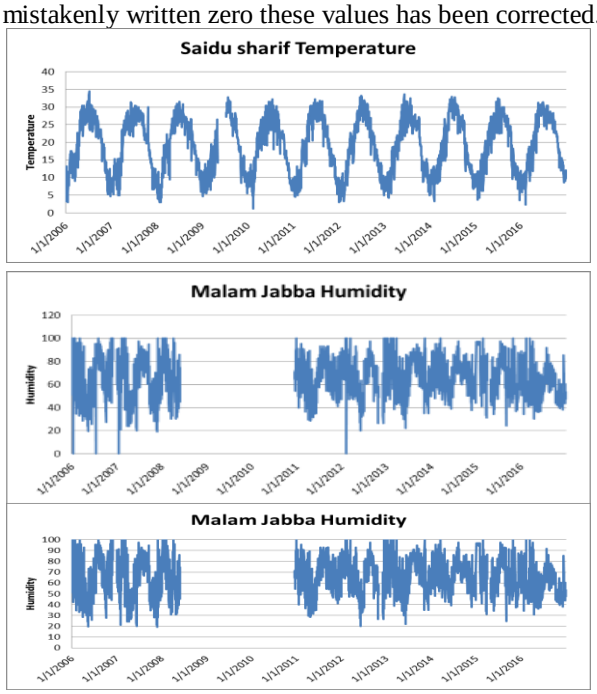


Fig 8. Graphs of Precipitation, Humidity and Temperature of Kalam, Malam Jabba and Saidu Sharif with Missing values.

E. Statistical Analysis Parameters.

Table 1. Mean, Standard deviation, Skewness and Kurtosis.

		Mean		Standard deviation		Skewness		Kurtosis	
Location	Variable	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Kalam	Temp (°C)	17	4.75	3.97	5.28	-0.91	0.23	0.77	-0.50
	Humidity (%)	61	72	14.10	15.41	-0.04	0.02	-0.18	-0.90
	Rain (mm)	7.32	12.48	9.82	15.77	3.61	3.58	18.09	20.99
S.Sharif	Temp (°C)	25.5	13.14	3.97	5.03	-0.90	0.46	0.77	-0.43
	Humidity (%)	60	63	14	12.43	-0.10	0.81	0.26	-0.25
	Rain (mm)	11.24	11.23	16.16	13.76	4.26	2.31	32.11	6.81
M.Jabba	Temp (°C)	16.05	4.72	3.66	5.00	-1.07	0.20	1.43	-0.57
	Humidity (%)	65	65	17.18	17.05	-0.24	0.16	-0.84	-0.59
	Rain (mm)	13.62m	16.33	15.60	17.76	2.28	2.32	6.76	7.45

F. Histogram of Humidity

Histogram of kalam humidity is unimodal and symmetric with one peak highest frequency of 61-70% humidity .Histogram of Saidu Sharif is unimodal and symmetric with one peak highest frequency 61-70% humidity .Histogram of Malam Jabba humidity is unimodal and symmetric with one highest frequency of 51-60% humidity.The highest frequency of Malam Jabba humidity is 20% less than highest frequency of kalam and Saidu Sharif humidity.

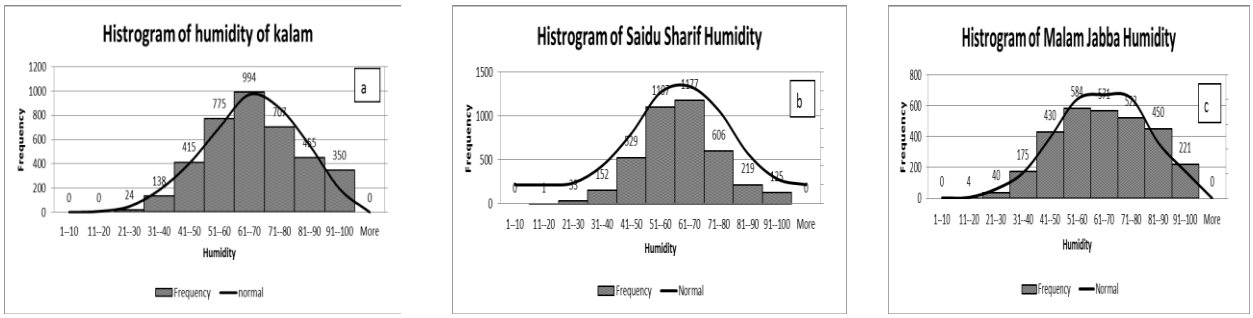


Fig 9. Humidity histogram of Kalam, Saidu Sharif and Malam Jabba

G. Histogram of Temperature.

Histogram of kalam is unimodal and symmetric with one peak of 15-20℃. Histogram of Saidu Sharif is unimodal and symmetric with large peak of 25-30℃. Histogram of Malam Jabba temperature is unimodal and symmetric with largest peak of 15-20℃.The highest frequency of Saidu Sharif temperature is 20% greater than Kalam and Malam Jabba temperature .

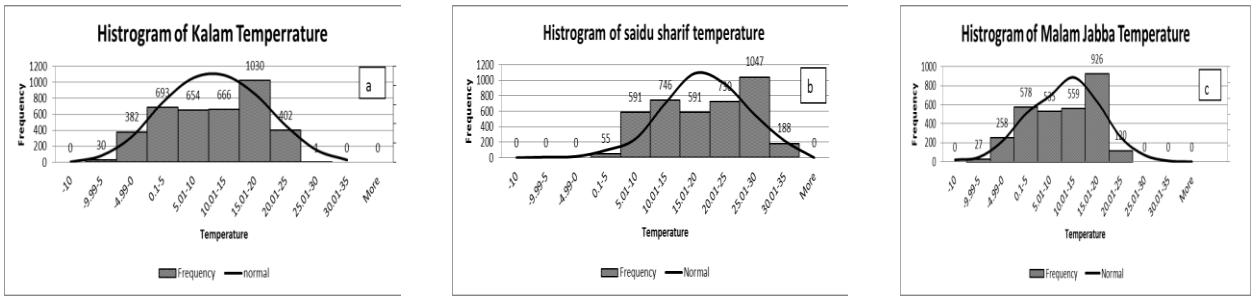


Fig 10. Temperature Histogram of Kalam, Malam Jabba and Saidu Sharif

H. *Histogram of Precipitation.*

Histogram of kalam precipitation is a unimodal and skewed right with one peaks of 1-10mm precipitation. The frequency of precipitation greater than 100mm is 3 times. Precipitation of kalam has 24% wet days with precipitation and 76% dry days without precipitation. Histogram of Saidu Sharif precipitation is a unimodal and skewed right with one peak of 1-10mm precipitation. The frequency of precipitation greater than 100mm is two times. Precipitation of Saidu Sharif has 21% wet days with precipitation and 79% dry days without precipitation. Histogram of Malam Jabba precipitation is unimodal and skewed right with one peaks of 1-10m m precipitation. The frequency of precipitation greater then 100mm is 2times. Precipitation of Malam Jabba has 29.5% wet days with precipitation and 70.5% dry days without precipitation. The frequency of precipitation greater than 100mm in swat region is 5 times this data can be used for hydrological design

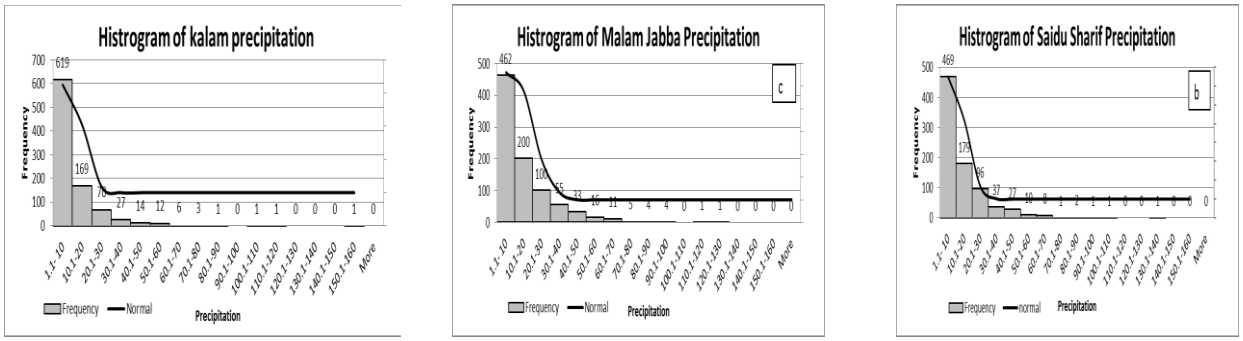


Fig 11. Precipitation histogram of Saidu Sharif, Kalam and Malam Jabba.

I. Percentile Curve of Humidity.

Percentile curve of kalam humidity have 10% of values are less than 46.5% humidity, 50% of values are less than 66% and 90% of values are less than 88.5% humidity. Saidu Sharif temperature percentile curve have 10% of values less than 45.5%, 50% of values are less than 61% and 90% of values are less than 78% humidity. Malam Jabba percentile curve have 10% of values are less than 42.5%, 50% of values are less than 64.5% and 90% of values are less than 88% humidity. The result we conclude is percentile humidity curve values of kalam and Malam Jabba is similar with 2-3% of difference. The Kalam and Saidu Sharif percentile humidity curve at point 10%, 50% is approximately same with 2-4% variation and 90% of percentile curve values are not similar.

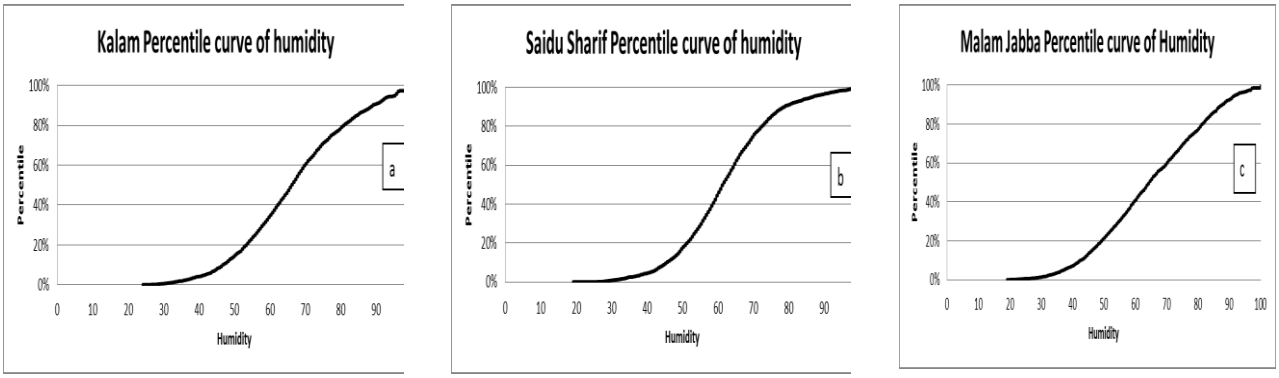


Fig 12. Percentile Curve for humidity

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J. Percentile Curve of Temperature.

Percentile curve describe how data is distributed from (0-100%).Kalam temperature Percentile curve have 10% of values are less than 0℃, 50% of values are less than 11.4℃ and 90% of values are less than 20℃.Saidu Sharif temperature curve have 10% values less than 8.5℃, 50% of values less than 19.7℃ and 90% values less than 28.75℃. Malam Jabba temperature Percentile curve have 10% of values less than 0℃, 50% of values are less than 11.4℃ and 90% of values are less than 20℃. The result we conclude 10%, 50%, 90% of kalam percentile temperature curve is approximately similar to Malam Jabba percentile temperature curve.8.5℃ approximately temperature difference of kalam and Malam Jabba to Saidu Sharif.

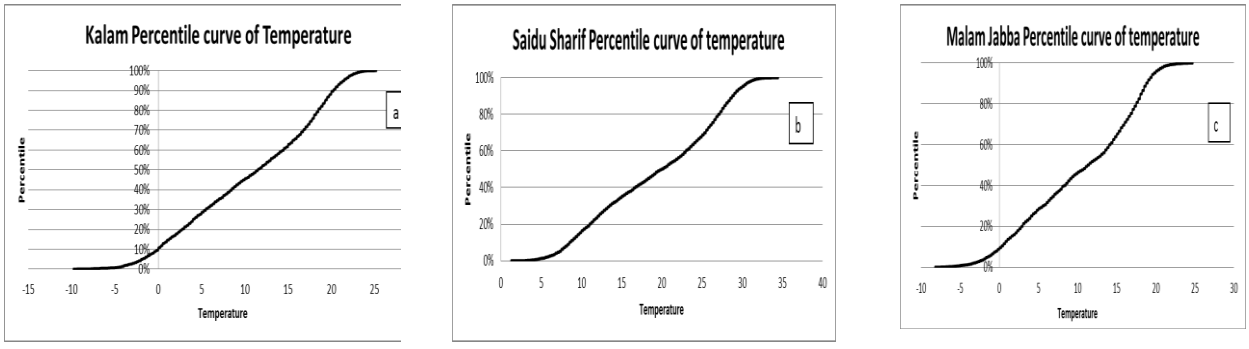

Fig 13. Percentile Curve of Temperature.

K. Percentile Curve of Precipitation.

Kalam precipitation percentile curve have 10% of values are less than 1mm, 50% of values 5.3mm and 90% of values 8.5mm.Saidu Sharif precipitation percentile curve have 10% of values less than 1mm, 50% of values 5.3mm and 90% of values 28mm.Malam Jabba precipitation percentile curve have 10% of values less than 2mm, 50% of values 8.5mm and 90% of values 35mm. The result we conclude is Kalam and saidusharif 10% and 50% of percentile curves values are same but there is 4mm little difference between 90% percentile of both the percentile curves. Kalam and Saidu Sharif Percentile precipitation curve values are different from Malam Jabba at all three points 10%, 50% and 90%.

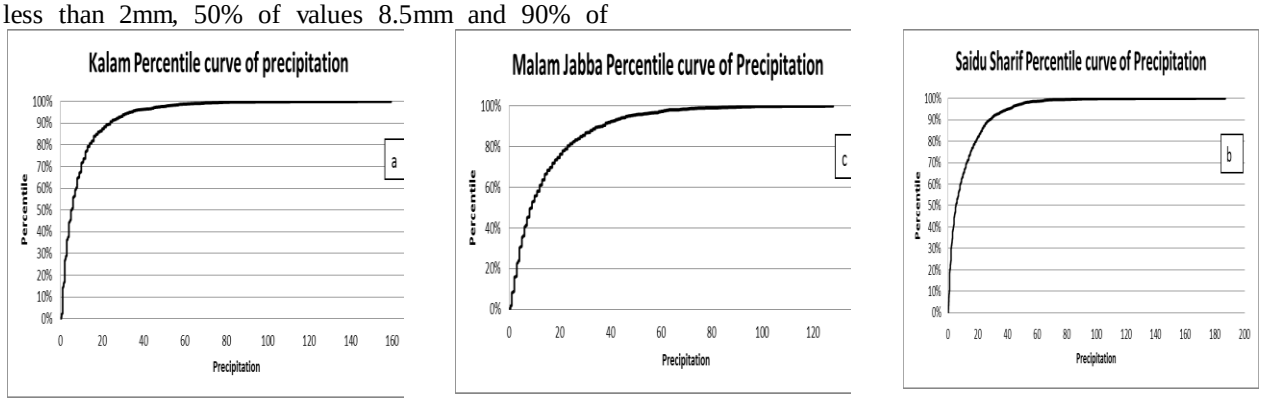

Fig 14. Percentile Curve of Precipitation

L. Q-Q Plot of Humidity.

Q-Q plot of Saidu Sharif and Malam Jabba temperature show thin tail negative at bottom and fat tail positive at top of the reference line center area is normal distributed. At the bottom the values of kalam are greater than Saidu Sharif humidity values. Kalam values changes from 23% to 32% then moves toward normal.at the top values of Saidu Sharif are greater than kalam humidity values. Kalam values changes from point 85%, 95% and 100%. Q-Q plot of kalam and Malam Jabba show thin negative tail at bottom and fat positive tail top of the reference line center area is normal distributed of reference line.at bottom values of Malam Jabba are grater then kalam. Malam Jabba humidity values changes from point 18% to 32% then comes to normal. At top vales of kalam are greater than Malam Jabba. Kalam humidity values change from point 92% to 100%. Q-Q plot of Malam Jabba and Saidu Sharif humidity shows fat negative tail at bottom and fat positive tail at top center area is normal distributed of reference line. At bottom values of Malam humidity are greater than Saidu Sharif humidity values. Malam Jabba humidity values changes from point 20% to 32% then moves normal. At top values of Saidu Sharif values are greater thanMalam Jabba .Saidu Sharif values changes from point 90% to 100%.

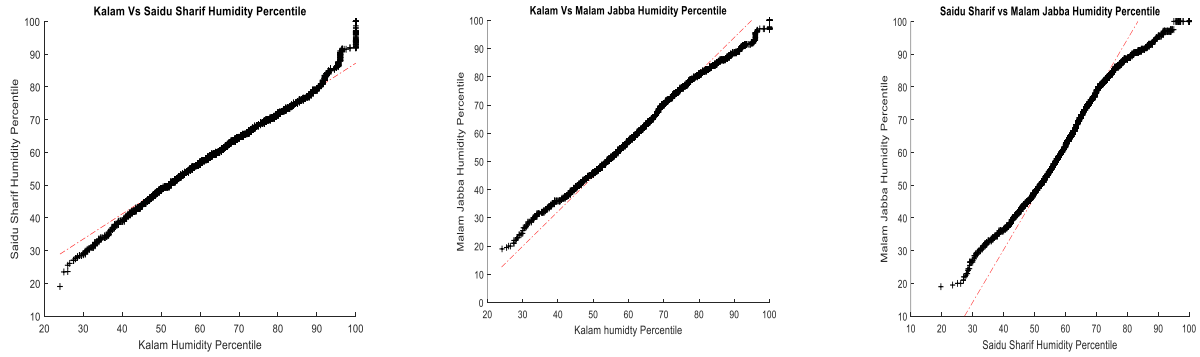

Fig 15. Q-Q plots for Humidity.

M. Q-Q Plot for Temperature.

Q-Q plot of Saidu Sharif temperature and kalam temperature show the fat negative tail at bottom of reference line and above is normal distribution at bottom the Saidu Sharif temperature vales are greater than the kalam temperature values changes from point 1℃ to 3℃ then lines goes toward normal. Q-Q plot of kalam temperature and Malam Jabba temperature show the straight to reference line which means its normal distributed. Q-Q plot of Saidu Sharif and Malam Jabba show thin tail negative at bottom of the reference line above it is normal distributed. At the bottom the values of Saidu Sharif are greater than the Malam Jabba temperature values. Saidu Sharif temperature vales changes from point 1℃ to 6℃ then moves toward normal.

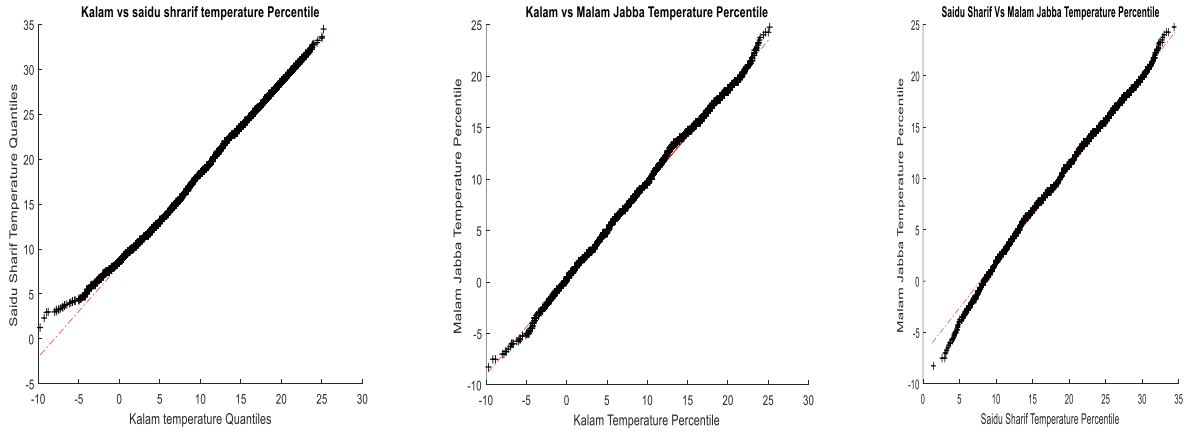

Fig 16. Q-Q plots of Temperature.

N. Q-Q Plot of Precipitation.

Q-Q plot of precipitation of Saidu Sharif and Malam Jabba values shows normal distribution on reference line at start then moves toward right which means that is left skewed. The right curve shows that Saidu Sharif precipitation values are greater than Malam Jabba precipitation values. Saidusharif precipitation values changes from point 78mm to 180mm precipitation. Q-Q plot of precipitation of Saidu Sharif and kalam show normal distribution at start then move towards right which mean means this is left skewed. The right curve shows that kalam precipitation values are greater than Saidu Sharif precipitation values. Saidu Sharif precipitation values changes from 40mm to 160mm. Q-Q plot of precipitation of Malam Jabba and kalam shows normal distribution at start then move towards right which means skewed left. The right curve shows that kalam precipitation values are greater than Malam Jabba precipitation values. Kalam precipitation values changes from point 30mm to 160mm.

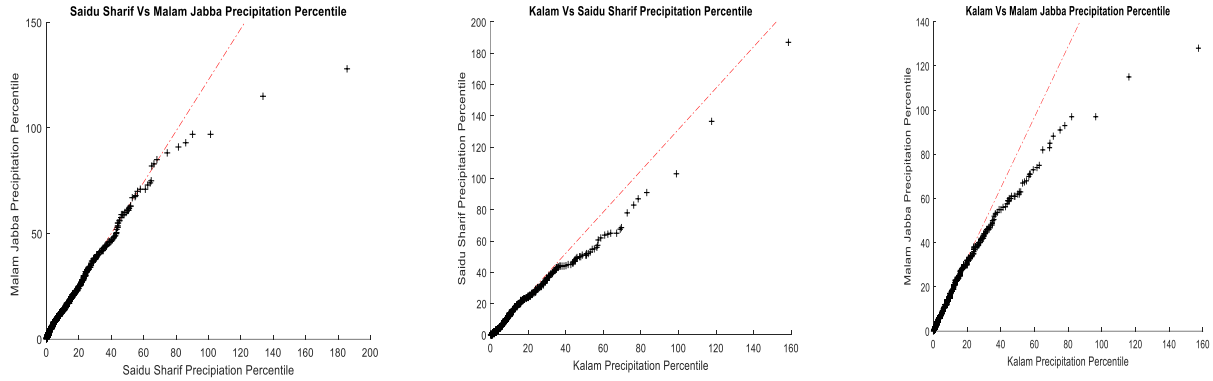

Fig 17. Q-Q plots of Precipitation.

Q-Q–plot is constructed to verify normality of data. Points closed to reference lines means data is normally distributed and the data will give more accurate in result of regression models The result we concluded that the Q-Q plots of Temperature and humidity the data is on reference line normal distributed with little variation at extremes tails but the Q-Q plot of precipitation shows normal distribution at start but variation at extreme end tail of precipitation plots in all three station KalamSaidu Sharif Malam Jabba.

O. Correlation Matrices using Pearson Method.

Table 2. Humidity, Temperature and Precipitation relations.

	Humidity			Temperature			Precipitation		
	Kalam	Saidu Sharif	Malam Jabba	Kalam	Saidu Sharif	Malam Jabba	Kalam	Saidu Sharif	Malam Jabba
Kalam	1	0.61	0.63	1	0.95	0.96	1	0.55	0.52
Saidu Sharif	0.61	1	0.71	0.95	1	0.97	0.55	1	0.67
Malam Jabba	0.63	0.71	1	0.96	0.97	1	0.52	0.67	1

O. Coefficient of determination R².

P. Graphical view of Correlation.

Table 3. Coefficient of determination in percentage.

	Humidity %			Temperature %			Precipitation %		
	Kalam	Saidu Sharif	Malam Jabba	Kalam	Saidu Sharif	Malam Jabba	Kalam	Saidu Sharif	Malam Jabba
Kalam	100	38	40	100	91	92	100	33	28
Saidu Sharif	38	100	51	91	100	93	33	100	46
Malam Jabba	40	51	100	92	93	100	28	46	100

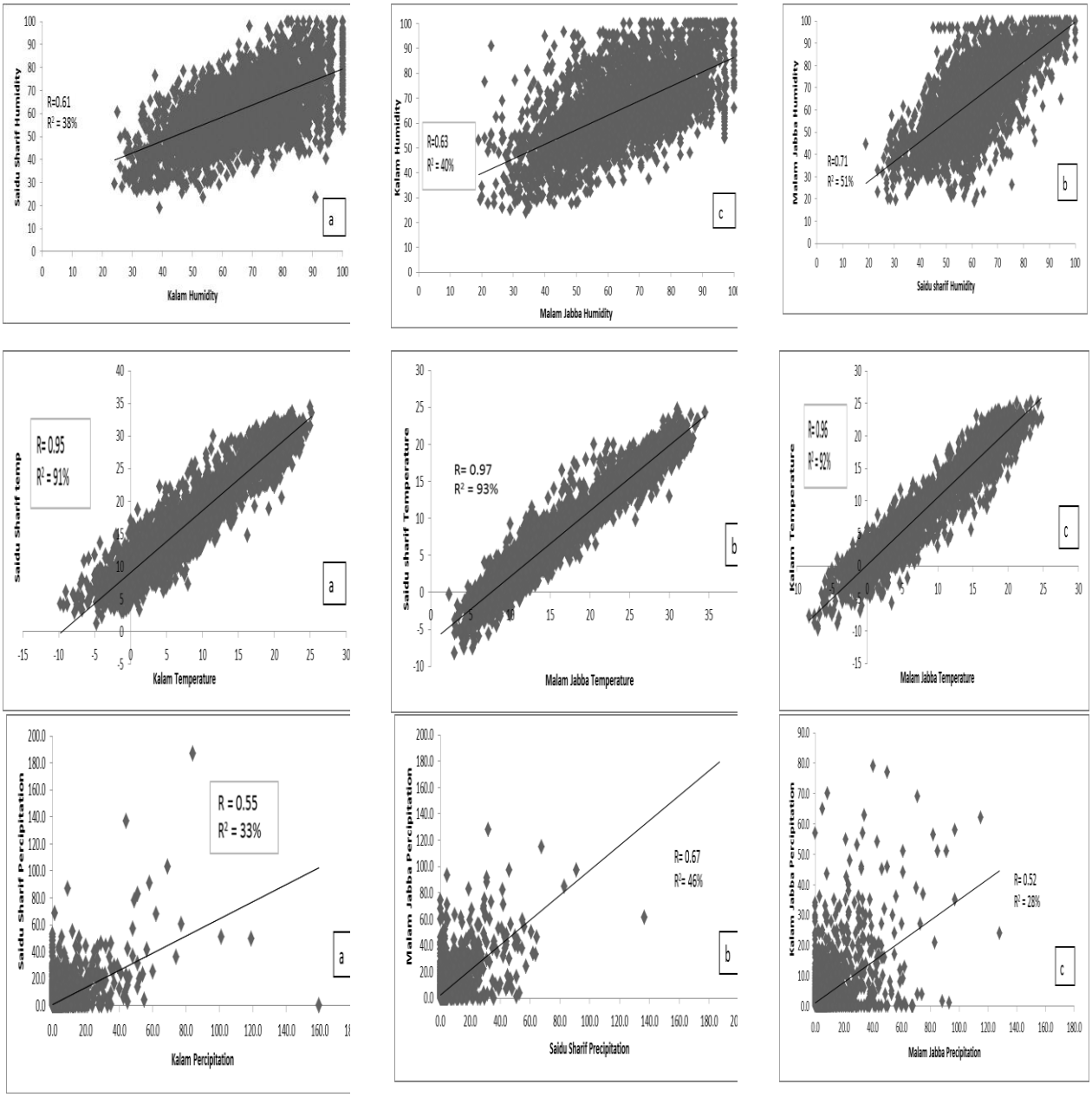

Fig. 18. Different Correlation graphs with R value.

3. RESULTS AND CONSCULSION

Q. Linear Regression Equations.

Table 4. Linear Regression equations of humidity.

Linear regression equations of Humidity			
	Kalam	Saidu Sharif	Malam Jabba
Kalam		y = 0.7279x + 21.639	y = 0.583x + 28.031
Saidu Sharif	y = 0.5233x + 27.09		y = 0.5646x + 24.819
Malam Jabba	y = 0.6891x + 19.558	y = 0.8953x + 9.9129	
Kalam		y = 0.9578x - 7.7134	y = 1.0352x + 0.1792
Saidu Sharif	y = 0.951x + 9.0521		y = 1.0569x + 8.3285
Malam Jabba	y = 0.8892x + 0.6644	y = 0.884x - 6.6809	
Kalam		y = 0.5076x + 1.2898	y = 0.3393x + 1.0888
Saidu Sharif	y = 0.6363x + 1.0686		y = 0.4804x + 0.4623
Malam Jabba	y = 0.82x + 2.5112	y = 0.9484x + 2.1289	

R. Graphical View with Equations.

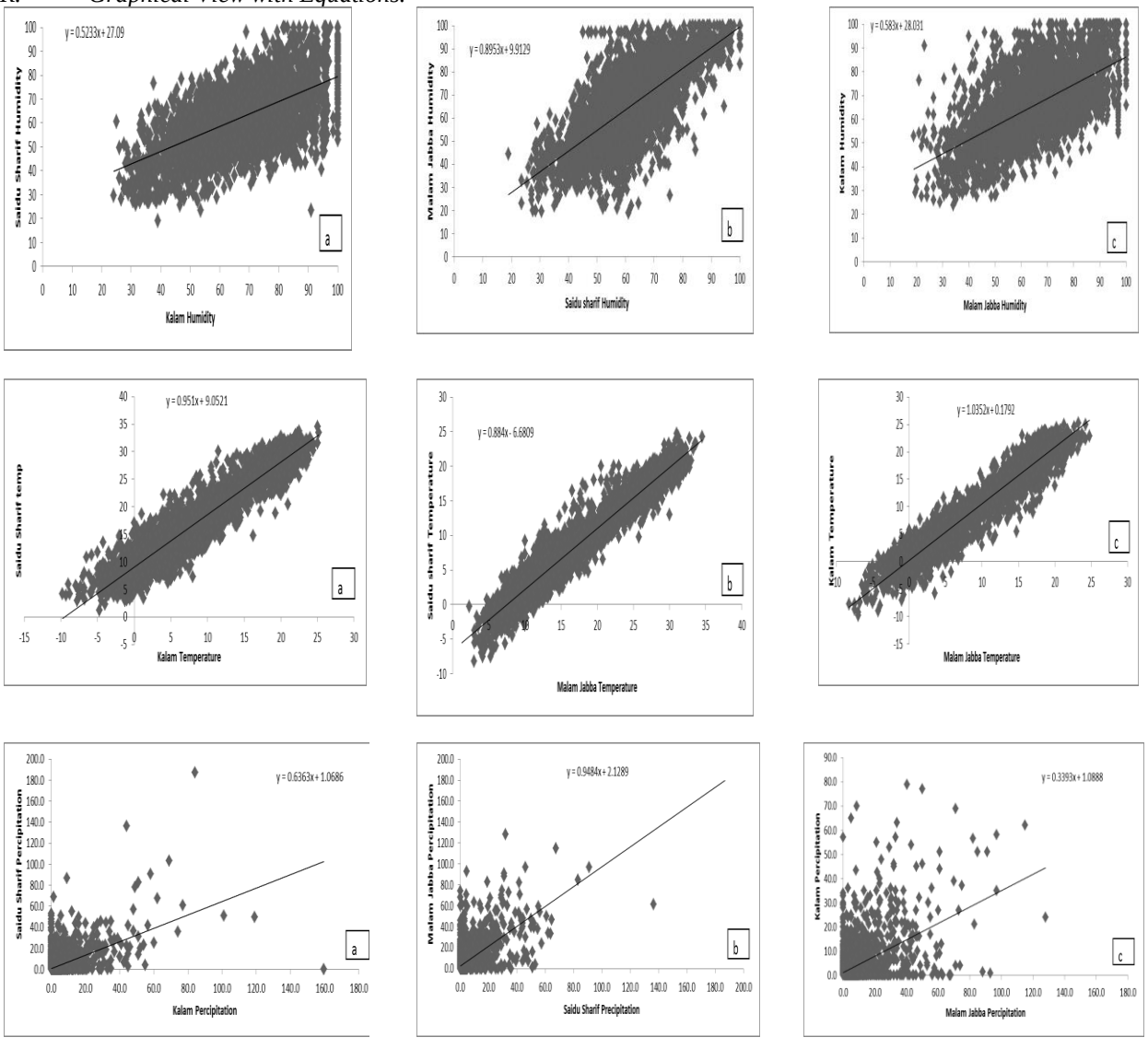

Fig 19. Correlation graphs with equations.

S. Missing values calculated from equations.

Saidu Sharif and Kalam precipitation on 13th may 2018 analyzed by upper, lower and general equation. We observed that 90% Kalam equation value closest to the 13th may kalam precipitation with 9mm difference.10% and general values difference is 57mm and 11mm respectively. Upper (heavy precipitation) equation 90% closest among all equations to 13th May kalam precipitation. Malam Jabba and Saidu Sharif 4th June 2018 precipitation analyzed by equations .90% Saidu Sharif equation value closest to 4th June SaiduSharif precipitation with 13mm difference.10% and general values difference is 16mm and 29mm respectively. Upper (heavy Precipitation) equation 90% closest among all equations to 4th July Saidu Sharif precipitation. Kalam and Saidu Sharif 24th February 2018 precipitation analyze by equations.10% Saidu Sharif equation value is equal to 24th February Saidu Sharif precipitation.90% and general values difference is 6mm and .3mm respectively. Lower (low precipitation) equation 10% value is equal to 24th February Saidu Sharif precipitation.

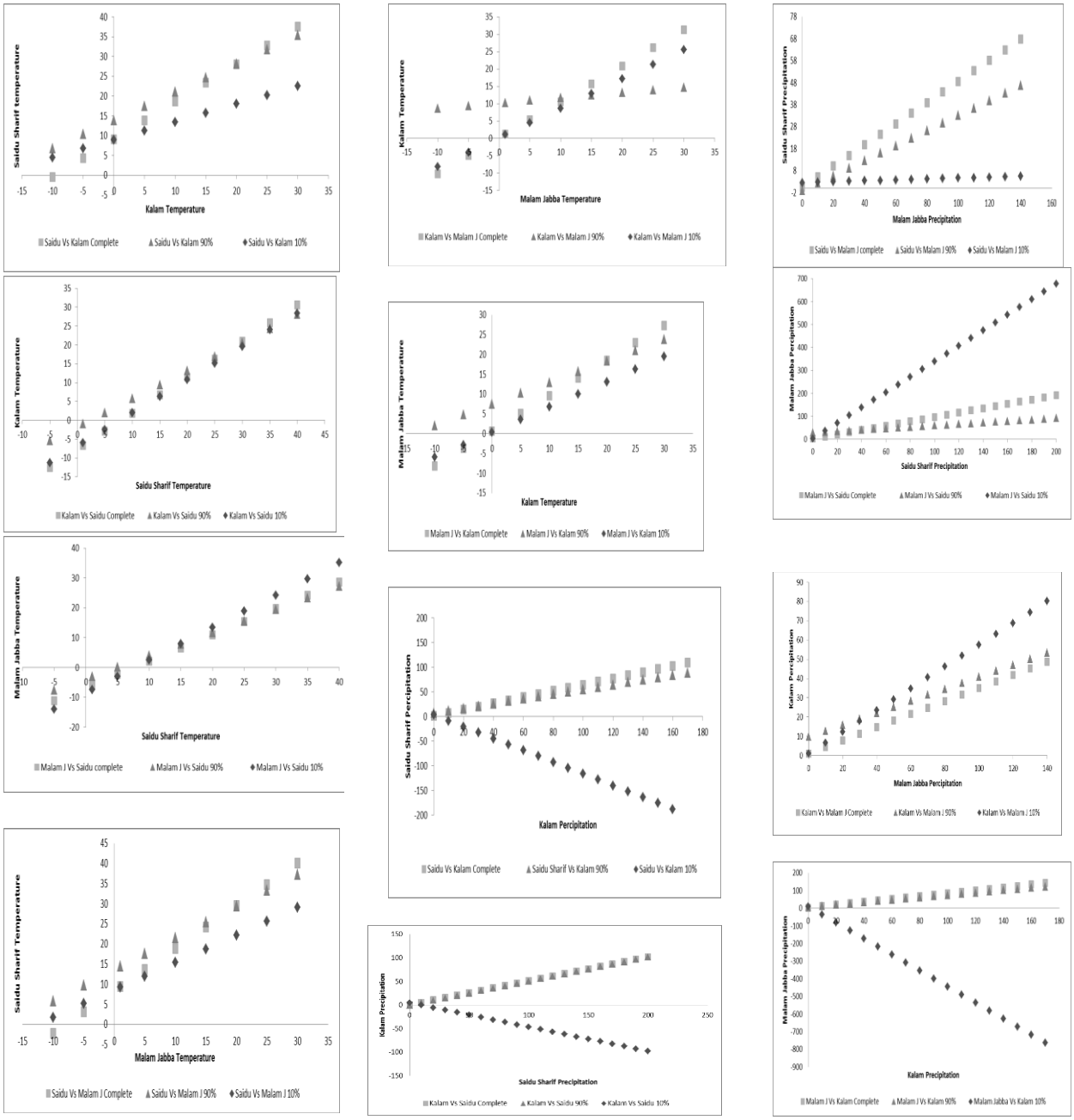

Fig 20. Graphs of Precipitation, Humidity and temperature

Table 5. Obtained Missing values from equations

	Weather parameters	Malam Jabba	Saidu Sharif	Kalam
3/6/2018	Temperature	23°C	31°C	
7/1/2018	Temperature		7°C	1°C
18/1/2018	Temperature	0°C		-3°C
13/5/2018	Precipitation		71mm	26mm
4/7/2018	Precipitation	103mm	21mm	
4/7/2018	Precipitation	1mm	2mm	

This thesis attempted successfully to critically analyze the precipitation, temperature and humidity data for three important hydrological and meteorological stations of swat i.e. Kalam, Malam Jabba and Saidu Sharif. The statistical relationships were developed between these variables for different percentile domains. The percentile domain were related in such a way that extremes of each variable could be related to extremes of other two variables. The relationships were developed so that effect of climate change could be considered. Additionally the relationship's skill was checked by comparing the results obtained from these relationships with historical data e.g. the historical observation temperature at kalam was compared with result obtained from our relationship and result were found satisfactory. The skill was checked for all variables and for each domain of high, low and medium percentiles. It is believed that the developed relationship can be used to forecast variables under study in the selected region of swat. Given that the data is usually difficult to obtain, the exercise could be very helpful in approximation of extremes of precipitation, temperature and humidity.This thesis can be extended further by considering more stations in the region. This would help us in developing even better result and relationships .Secondly if we incorporate the data from different regional and global climate models the relations can be further be improved.

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