OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

Spatio – Temporal Evaluation of Temperature Variability, Trend and Pattern in Jhelum River Basin, Western Himalaya

Basit Nadeem
Ph. D Scholar, Department of Geography and Geomatics, University of Peshawar, Pakistan
Email: basitnadeem@bzu.edu.pk
Atta-ur-Rahman
Chairman, Department of Geography and Geomatics, University of Peshawar, Pakistan
Muhammad Dawood
Assistant Professor, Department of Geography, Bahauddin Zakariya University, Multan Pakistan
Muhammad Kashif
Department of Geography, Bahauddin Zakariya University, Multan Pakistan
Muhammad Hashim
Ph. D, Department of Geography and Geomatics, University of Peshawar, Pakistan

Abstract

This study examines the variability, increasing or decreasing trends, and patterns of temperature in the Jhelum River Basin, located in the Western Himalayas. Using secondary data sources, temperature data was collected from eight meteorological stations within the basin, provided by the Pakistan Meteorological Department. The data covers a 33-years period from 1993 to 2023. Monthly maximum, minimum, and normal temperatures were analyzed for each station. The results indicate varying temperature intensities across different stations due to their wide distribution and differing elevations. The analysis employs the Sen's Slope Estimation Magnitude (SSEM) based on the Mann-Kendall trend model to detect trends in the temperature data. The findings reveal a general rise in temperatures across all stations. Specifically, the SSEM values for maximum temperatures range from 0.050 in Jhelum to 0.388 in Gharidupatta. Minimum and normal temperatures also show increasing trends, with some stations experiencing stronger rises than others. This study highlights the significant warming trends in the Jhelum River Basin, which could have profound impacts on the region's climate and environment. The insights gained from this research are crucial for developing adaptive strategies to mitigate the effects of climate change in the Western Himalayas.

Keywords: Climate Change, Met Stations, Maximum Temperature, Minimum Temperature

Introduction

Temperature variations are being significantly altered by climate change, which is a serious worldwide concern (El-Sayed and Kamel, 2020). Researchers often use temperature data to analyze climate changes through geo-statistical models (Murad, 2023). Concerns are there that climate change is increasing temperature fluctuation and elevating the likelihood of calamities like floods over the last three decades is growing (Mantoo, 2020; Nagendra and Mundoli, 2023). Hydrological patterns are directly impacted by rising average temperatures, as demonstrated by long-term temperature data used by academics to evaluate trends in climate change (Hu & Wu, 2021). There has been a general increase in temperature between 1992 and 2023, particularly in the parts of the Jhelum River Basin Western Himalaya (JRBWH) where flash floods are caused by the topography and melting glaciers.

Effective disaster risk management is crucial in adapting to climate change, requiring the development and implementation of strategies to mitigate vulnerabilities (Sharma and Kala, 2022). Various models, including the Global Circulation Model, Regional Climate Model, and Mann-Kendall Trend Model, are used to evaluate temperature variability and trends (Shah & Sen, 2024) . In JRBWH regions, glacial and snow melting significantly contribute to river discharge. Statistical models help explore the impact of changing climate on hydro-meteorological events. Studies indicate strong changes of climate change, with downscaling models identifying uncertainties in these impacts (Loukas & Garrote, 2021). Data from eight meteorological stations within the Jhelum River basin in the western Himalayas (JRBWH) were used. The Mann-Kendall Trend Model and Sen's Slope analysis revealed an increasing trend in monthly maximum temperature at some stations and rising monthly minimum temperature at others, indicating climate change influences on temperature (Alemu & Dioha 2020; Bhat & Tali, 2021). These variations highlight the dynamic nature of the climate in the JRBWH region (Sharma & Batish, 2020).

Significant changes in temperature fluctuations, river discharge, and precipitation patterns are brought about by climate change, which is an urgent global concern (Siddha and Sahu, 2022). Research shows that certain climate characteristics are greatly impacted by human activity (Farooq et al., 2023). Scientists frequently employ temperature data in unification with geo-statistical models to examine changes in the climate (Hashim et al., 2024). Concern over the rising unpredictability of temperature variations (Qasim et al., 2023) brought on by climate change, which has increased the risk of flooding throughout the last three decades, is growing (Upadhyay, 2020). Researchers analyze long-term temperature data to evaluate trends related to climate change, demonstrating that rising average temperatures directly impact patterns of precipitation and hydrological systems (Dong & Jia, 2020).

There has been a general rise in river discharge between 1992 and 2023, particularly in mountainous areas where the topography and melting glaciers cause flash floods (Amrutha & Patnaik, 2023). To effectively adapt to climate change, measures to mitigate vulnerabilities must be developed and put into action (Hashim et al., 2023). This is known as disaster risk management (Joakim & Mortsch, 2021). Temperature variability and trends are assessed using a variety of models, such as the Mann-Kendall Trend Model, Regional Climate Model, and Global Circulation Model (Ekwueme and Agunwamba, 2021).

The melting of glaciers and snow has a major impact on river discharge in mountainous areas (Qasim et al., 2024). The investigation of how hydro-meteorological occurrences are impacted by climate change is aided by statistical models (Chen et al., 2020). Research shows that there is a significant relationship between river discharge and climate change (Farooq et al., 2023) and downscaling models reveal the uncertainty in these effects (Gao & Booij, 2020). Eight meteorological stations in the (JRBWH) provided the data. Sen's Slope analysis and the Mann-Kendall tendency Model showed a tendency toward rising monthly minimum temperatures at some stations and increasing monthly maximum temperatures at others, suggesting the influence of climate change on river discharge (Sharafati & Pezeshki, 2020). These fluctuations demonstrate how the climate in the JRBWH region is dynamic.

Study Area

Jhelum river basin Western Himalayan region consist approx. 34,775 square kilometers. The study focus Jhelum River basin covers western part of Himalaya. The geographical location of this region is between latitudes 32° 58' 42" N to 35° 08' 02" N and longitudes 73° 23' 32" E to 75° 35' 57" E. The Jhelum River originate from the verinag spring and flows northwest direction

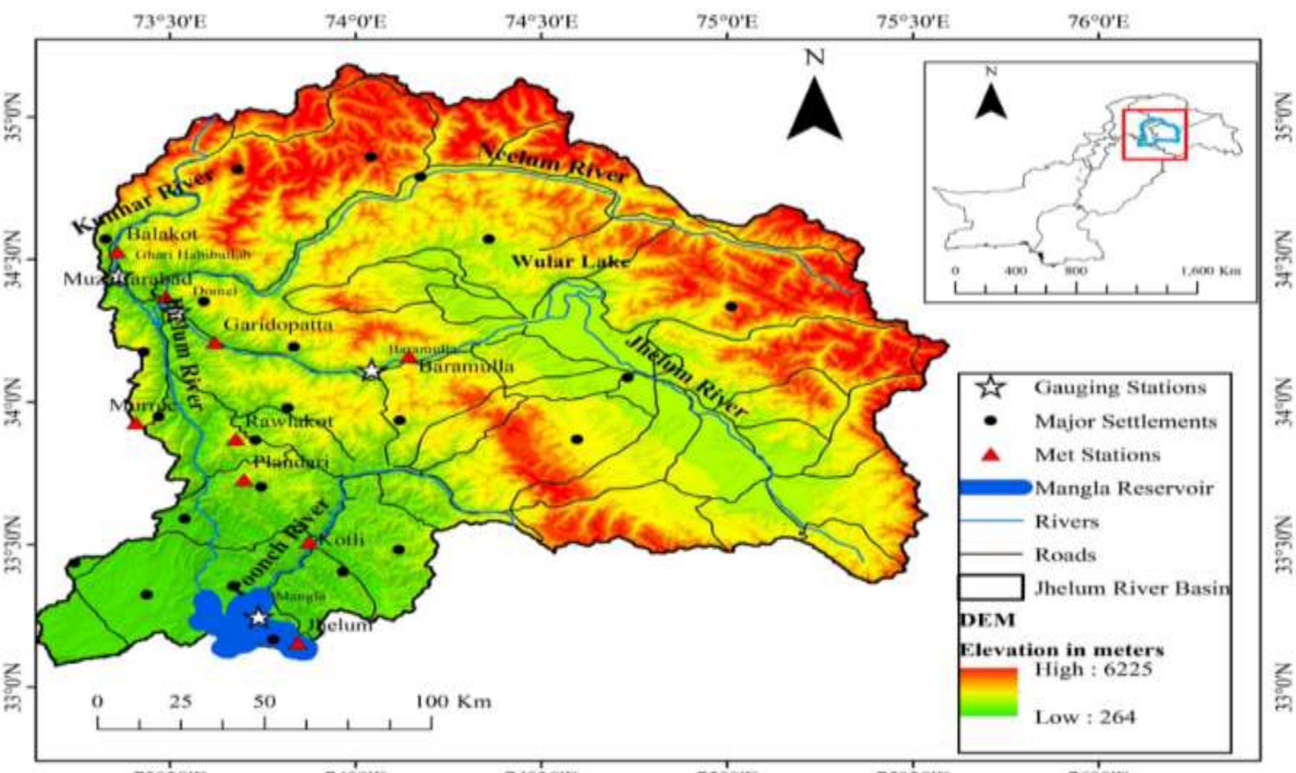
OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

through the Wular lake. The Jhelum River flows through Indian occupied Kashmir and enters in Azad Kashmir which is administered by Pakistan reached in Punjab (Dar-Rafi 2020). The Jhelum River consists on high mountain peaks in Himalayas and fertile plain in Punjab Pakistan. The Jhelum River is approximately 725 km long.

This region consists of steep slope valleys and high peaks such as Nanga Parbat and K2. Rising the temperature, changing in the precipitation pattern and other environmental threat are now common in this region (Sharma & Datta, 2023; Hashim et al., 2023). Due to global warming and climatic change precious glacial assets such as Siachen Glacier are melting (Nie & Pritchard, 2021; Qasim et al., 2024).

Figure: 1 Location of the Study Area

Materials and methods



This research is based on secondary data sources where the data met-stations in the study area are taken. Eight designated met-stations are located in the Jhelum River Basin. The Pakistan Meteorological Department provided the total annual and total monthly temperature data for each met-station. The study covers the temporal duration of 33 years from 1993 to 2023. Throughout the western Himalayas, met-stations are dispersed widely and at varying elevations. As a result, there are differences in the temperature intensity at various met stations. For the majority of the met-stations, temperature data has been collected since 1993.

Table 1 Geographical location of the Selected Meteorological Stations in the Study Area

Sr. #	Met Station	Period	Latitude (deg)	Longitude (deg)	Elevation (meters)
1.	Jhelum	1993-2023	32.94	73.74	287
2.	Kotli	1993-2023	33.50	73.90	614
3.	Rawlakot	1993-2023	33.87	73.68	1676
4.	Murree	1993-2023	33.91	73.38	2213
5.	Gharidupatta	1993-2023	34.22	73.62	814
6.	Muzaffarabad	1993-2023	34.37	73.48	702
7.	Balakot	1993-2023	34.55	73.35	995
8.	Athmuqam	1993-2023	34.90	73.65	2362

Source: (Pakistan Meteorology Department)

Results and Analyses

Table 2: Summary of monthly maximum, minimum, and normal temperature for the met stations in river Jhelum basin western Himalayas

Met stations	Temp	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jhelum	Max	18.9	22.4	27.8	33.9	39	40	36	34.9	34.7	32.7	27.3	21.8
	Min	5.8	8.7	13.3	18.7	23.6	26.1	26.2	25.8	23.7	17.7	10.8	6.5
	Normal	12.35	15.5	20.55	26.3	31.3	33.05	31.1	30.35	29.2	25.2	19.05	14.15
Kotli	Max	17.8	20.1	25.3	31	35.8	37.3	34	32.9	32.5	30.3	24.9	20.3
	Min	4.5	7.6	11.5	16.9	21.1	23.9	23.9	23.7	20.8	15.7	9.6	5.1
	Normal	11.15	13.8	18.4	23.95	28.45	30.6	28.95	28.3	26.65	23	17.25	12.7
Rawlakot	Max	11.8	12.7	17.6	22.1	26.2	28.4	27	26.4	25.9	23.2	18.9	15.4
	Min	1.8	0.5	3.4	7.1	10.1	13.3	16.4	16.4	13	7.3	1.8	0.9
	Normal	6.8	6.6	10.5	14.6	18.15	20.85	21.7	21.4	19.45	15.25	10.35	8.15
Murree	Max	8.8	9.8	14.4	19.3	23.8	25.7	23.5	22.9	22.4	20.4	16.3	12.5
	Min	1.7	0.4	4.5	8.9	12.9	15.2	15.9	15.8	13.8	10.2	6.1	0.6
	Normal	5.25	5.1	9.45	14.1	18.35	20.45	19.7	19.35	18.1	15.3	11.2	6.55
Gharidupatta	Max	15.3	17.5	22.3	27.7	33.3	36.2	34.7	33.7	32.9	29.1	22.6	17.6
	Min	2.4	4.8	8.4	12.6	16.8	20.1	21.9	21.9	18.8	12.5	6.6	3.1
	Normal	8.85	11.15	15.35	20.15	25.05	28.15	28.3	27.8	25.85	20.8	14.6	10.35

OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

Muzafarabad	Max	16.7	18.6	23.7	29.1	34.5	37.5	35.5	34.4	33.6	30.5	24	18.6
	Min	2.7	5.7	9.8	14.3	18.3	21.4	22.9	22.8	19.7	13.6	7.7	3.8
	Normal	9.7	12.15	16.75	21.7	26.4	29.45	29.2	28.6	26.65	22.05	15.85	11.2
Balakot	Max	14.6	16.4	20.7	27.5	31.1	33.6	32.6	31.6	30.9	28.2	20.7	17.5
	Min	2.1	4.4	8.4	12.7	17.6	20.4	21.4	20.8	17.3	11.6	6.5	3.1
	Normal	8.35	10.4	14.55	20.1	24.35	27	27	26.2	24.1	19.9	13.6	10.3
Athmuqam	Max	12.8	13.7	18.6	23.1	27.2	29.4	28	27.4	26.9	24.2	19.9	16.4
	Min	1.35	3.65	7.65	11.95	16.85	19.65	20.65	20.05	16.55	10.85	5.75	2.35
	Normal	7.08	8.68	13.13	17.53	22.03	24.53	24.33	23.73	21.73	17.53	12.83	9.38

Source: (Pakistan Meteorological Department)

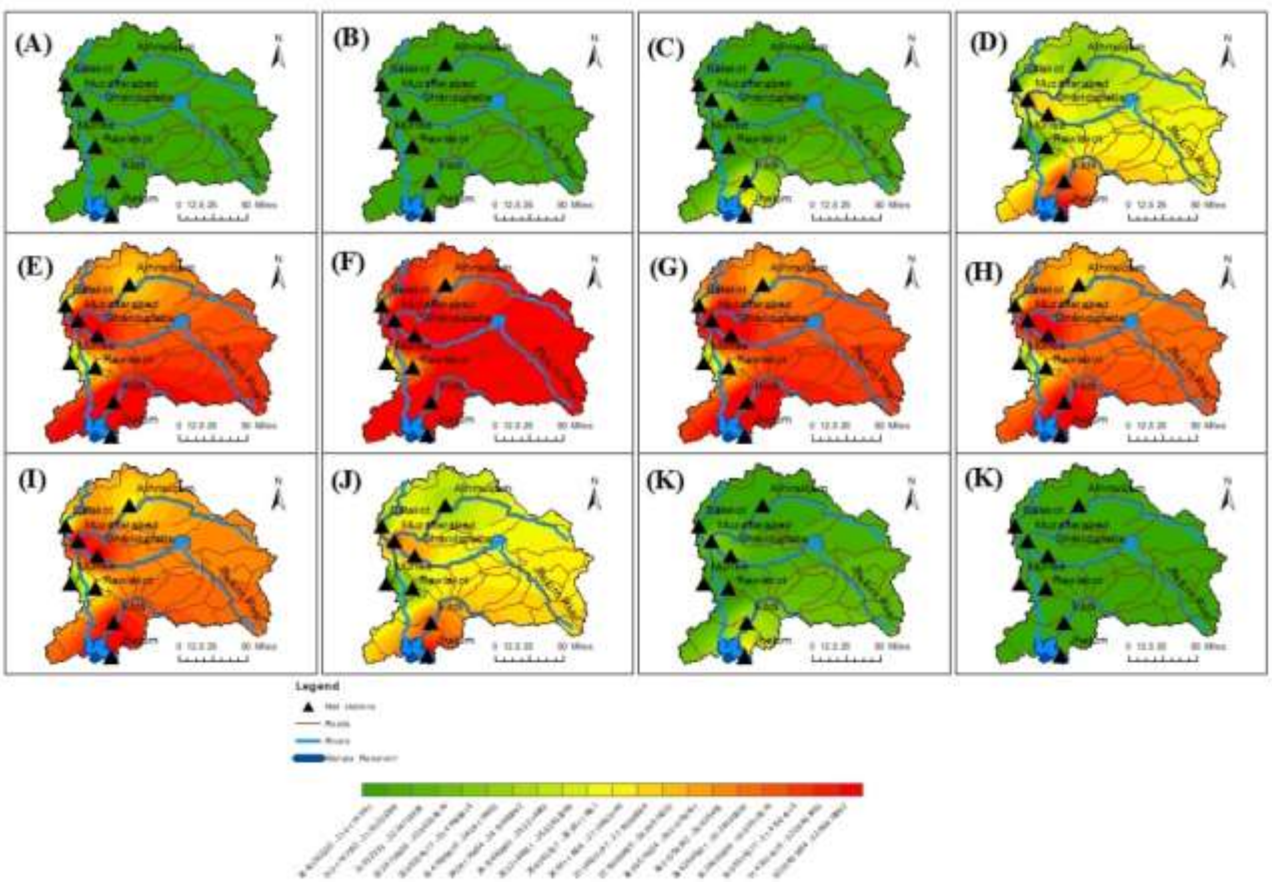


Figure II Interpolation of mean monthly maximum temperature [January (a)-December (l)] for all the met stations in river Jhelum Basin western Himalaya

OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

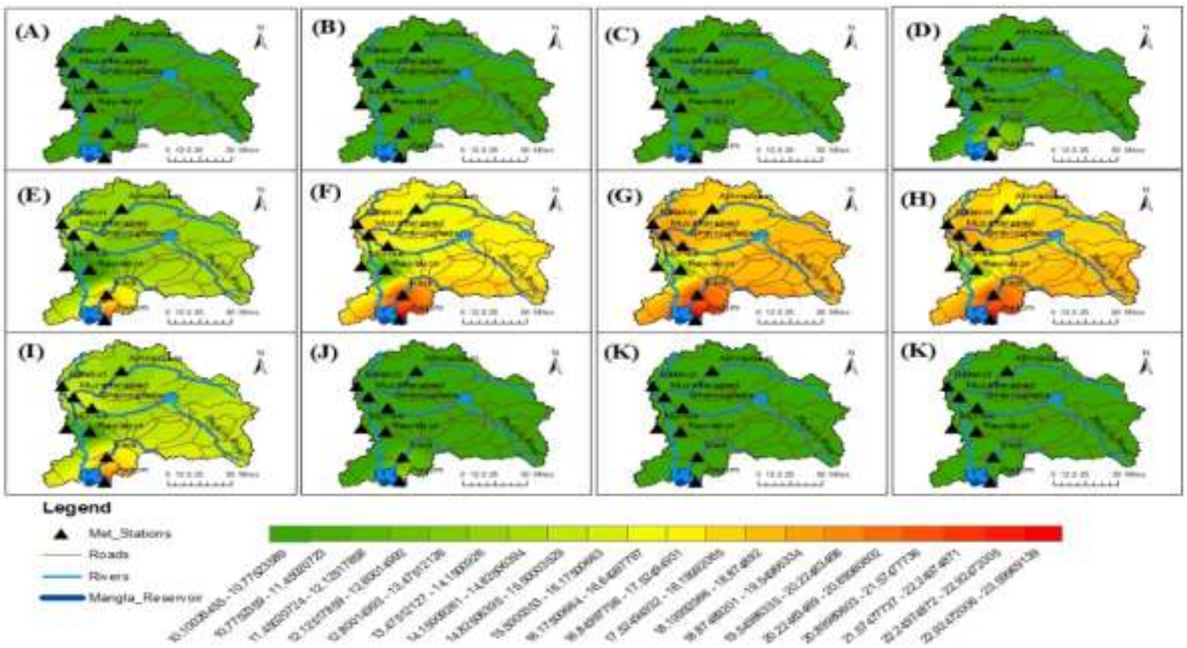
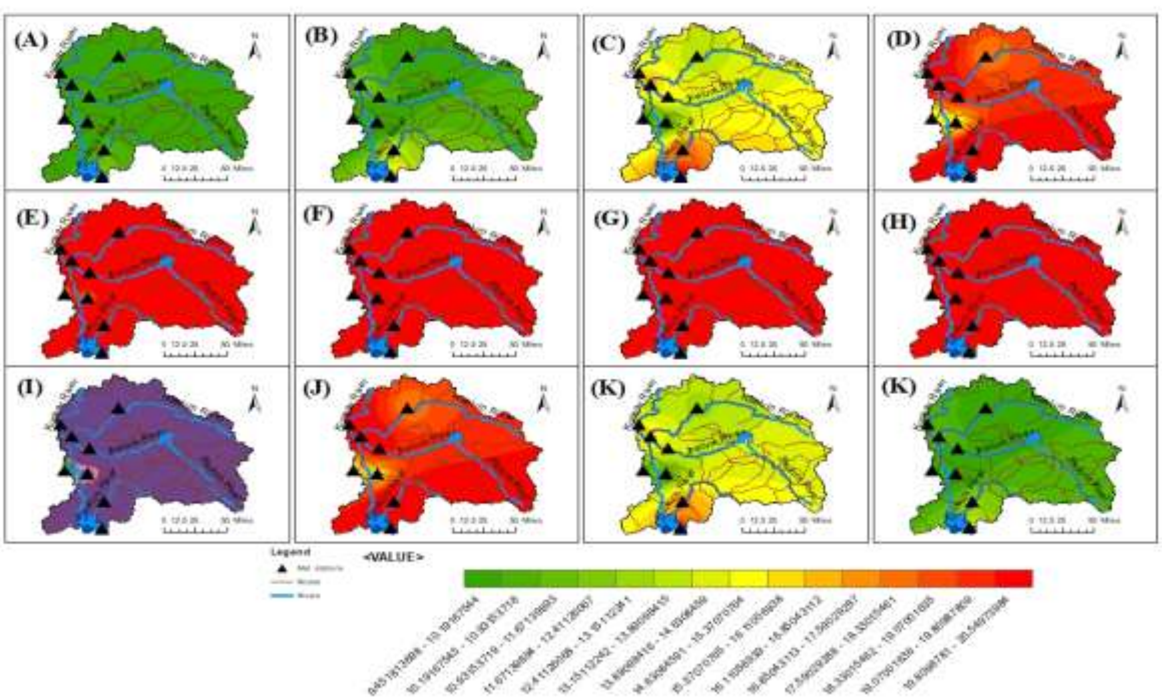


Figure III Interpolation of mean monthly minimum temperature January (a) to December (I) for all met stations

Figure IV Interpolation of mean monthly normal temperature [January (a)-December (l)] for all the met stations

The Western Himalayan region undergoes notable seasonal variations in climate. The lowest temperatures occur during the



winter months of December through February, particularly in Murree. Gradual warming occurs in the spring (March to May) and peaks in the summer (June to August), especially in lower areas like Jhelum and Kotli. Autumn, which lasts from September

OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

through November, marks the arrival of winter with its moderate temperatures. The region's dynamic and diversified nature is shown by the strong influence of elevation and proximity to water bodies on local temperature trends. Because of its varied topography and climatic effects, the Western Himalayan region suffers a wide variety of temperature fluctuations throughout the year. The following explains the seasonal variations in the climate that have been noted in this area

The region experiences its lowest temperatures in the winter. This time of year is especially frigid in Murree, a popular high-elevation hill station that is frequently used as a winter retreat because of its bitterly cold weather. The Himalayan mountain range and the high altitudes in the area affect the chilly weather by bringing in cooler air and occasionally snowfall. Spring brings with it a slow warming of the temperature. In March, April, and May, there is a consistent rise in temperature. By late April, the temperature has significantly increased throughout the region, especially in lower-lying places like Jhelum and Kotli. Before the hottest part of the summer, this time of year brings milder weather. The summer months provide the year's greatest temperatures, especially in lower-lying regions like Jhelum and Kotli. As you get closer to the plains, the heat gets even worse here, with record highs. Higher altitudes, such as Murree and Rawlakot, stay comparatively cooler despite the high temperatures, offering a break from the summer heat. Temperatures gradually drop in the autumn as the area moves from the hot summer months to the cooler winter months. The highs of the summer give way to more agreeable temperatures in September, October, and November. The winter season officially begins at this time.

Influences of Elevation and Proximity to Water Bodies

The elevation and the closeness to bodies of water, including rivers, have a considerable impact on the patterns of temperature in the Western Himalayan. The high areas such as Murree and Rawlakot faced the clod climatic situation throughout the years. As comparatively the others areas Muzaffarabad and Balakot have moderate temperature because these areas are situated near the river bank. Overall, the climate of Western Himalayan region has significant seasonal changes in winter cold weather in high altitude areas. Warm weather comes in spring season in low altitude areas. Climate varies due to topography of the region. Due to the topography of the region temperature also vary.

Sen's Slope Results Based on Mann-Kendall Trend Model

SSEM (Sen's slope Estimation magnitude) based on Mann Kendall trend model is applied on mean monthly maximum data. Temperature data is collected from the eight meteorological stations. The stations are Jhelum, Kotli, Rawlakot, Murree, Garapata, Muzaffarabad, Balakot, and Athmuqam. Temperature data which was collected from 1993-2022 showed Jhelum's SSEM value 0. 050. It also show that rising in temperature slowly. Kotli has 0. 124. It suggests stronger rising trend in temperatures.

Table 3 Sen's Slope Estimation Magnitude (SSEM) of selected met stations for temperature (Celsius)

Met Station	Time Period	SSEM(MM maximum Temp)	SSEM (MM Minimum Temp)	SSEM (MM Normal Temp)
Jhelum	1993-2022	0.050	0.367	0.032
Kotli	1993-2022	0.124	0.366	0.195

OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

Rawlakot	2003-2022	0.364	0.584	0.386
Murree	1993-2022	0.303	0.537	0.276
Gharidupatta	1993-2022	0.388	0.743	0.479
Muzaffarabad	1993-2022	0.367	0.621	0.513
Balakot	1993-2022	0.371	0.449	0.440
Athmuqam	1993-2022	0.364	0.449	0.514

Source: (Pakistan Meteorological Department)

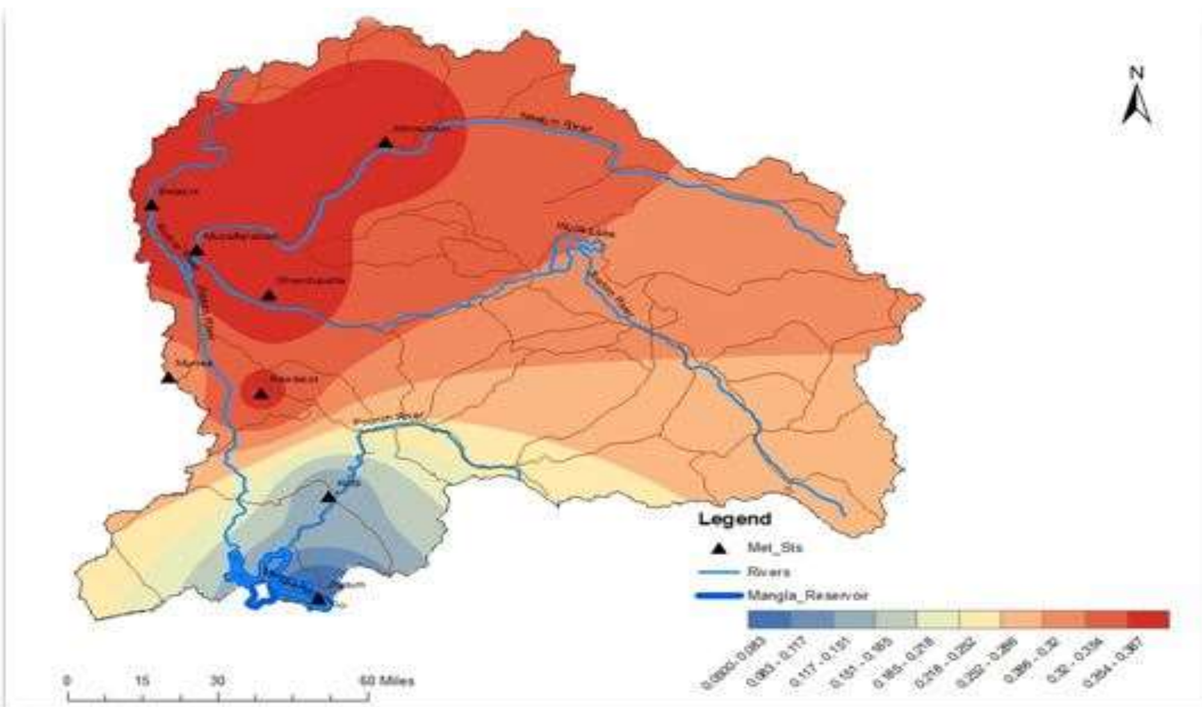


Figure V Sen’s Slope Estimation Magnitude (SSEM) of Eight Selected Met Sations for Mean monthly maximum Temperature

OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

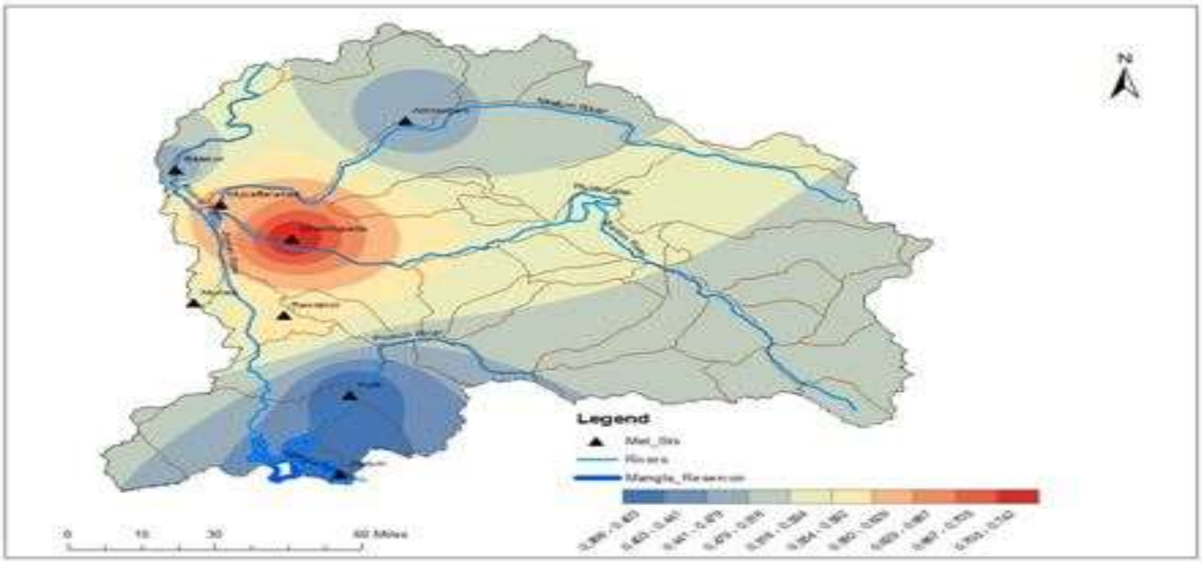


Figure VI Sen's Slope Estimation Magnitude (SSEM) of eight selected met stations for monthly mean minimum temperature

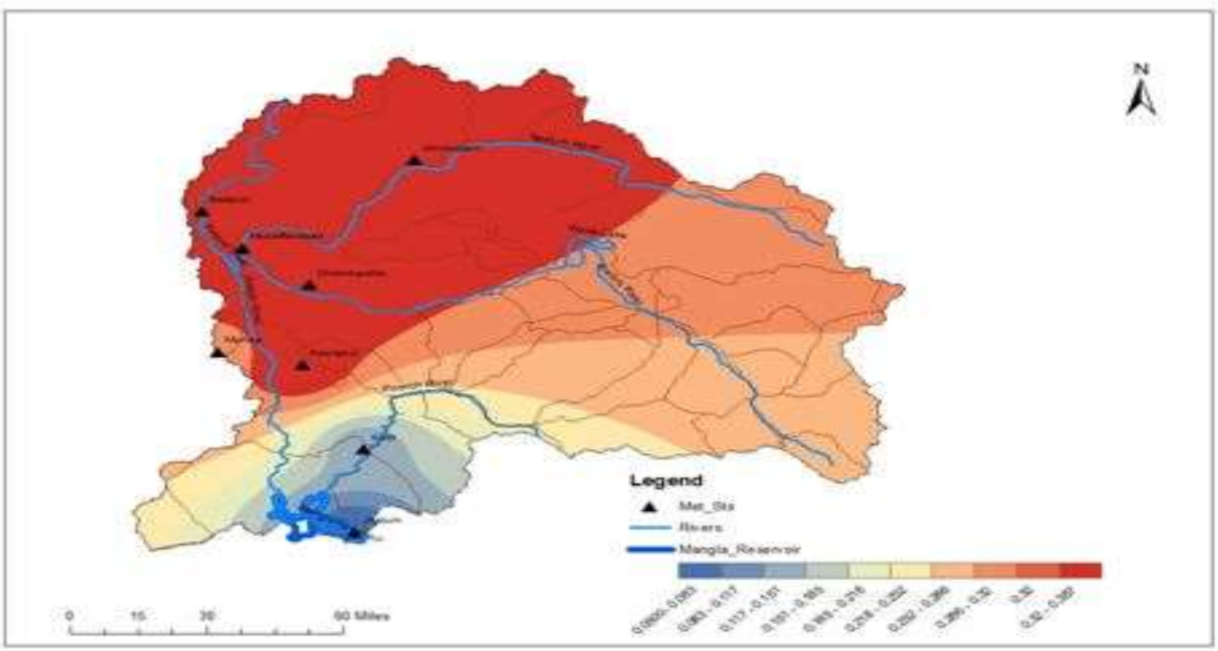


Figure VII Sen's Slope Magnitude 0f selected 8 met stations for mean monthly normal temperature

Rawlakot also have significant changes in temperature in given period the SSEM value is 0. 364. Murree and Balakot also indicating significance value of SSME 0.303 and 0.371. Muzaffarabad has 0.367 SSME value and Gharidupatta 0.388 value that mean these areas have significant temperature trend. Authmuqam also has significant change like Balakot and Rawlakot value of SSME is 0. 364. The result helps to identify the changing the in the climate in given area also help to mitigate effect of it in given areas.

Data of given data stations analyses thought Sen's slope estimation magnitude which analyses the mean monthly minimum temperature of given area of given time period. These meteorological stations are followings Jhelum, Kotli, Rawlakot, Murree, Gharidupatta, Muzaffarabad, Balakot, and Athmuqam. The Sen's slops Estimation Magnitude (SSEM) results show the variation in given time period. Jhelum SSEM value 0.367 indicates the rising trend in temperature. Kotli also have rising trend given time period SSEM value of kotli is 0. 366. Rawlakot's results of SSEM show more significant rising trend in temperature.0.584 the SSEM value of Rawlakot. Murree has 0.537 value of SSEM. Balakot has 0.449 that show the mild changing in temperature upward. Gharidupptta has 0.743 and Muzaffarabad has 0.621 value of SSEM which shows that increasing in temperature. Authmuqam also have mild increasing trend SSEM value of it is 0.449.

The Sen's slope Estimation Magnitude on base Mann-Kendall Trend test deducted mean monthly minimum temperate data of selected meteorological stations. That help to deduct the climatic variability and help to reduce its consequences.

SSEM (Sen's Slope Estimation Magnitude) base on Mann-Kendall Trend test deducted by using the temperature data of given time period mean monthly normal temperature. The results show the variations in climate in given time periods of selected areas. Authmuqam has highest variations the SSEM results value 0. 514. Gharidupta has 0.479 SSEM value. Muzaffarabad has 0.513 which shows the Significance change in temperature. Jhelum has 0. 032. Kotli has 0,195 SSEM value. Rawlakot and Murree also show the rising trend in temperature. SSEM of these stations is 0.386 and 0.276

The data from the SSEM values offer interesting insights into temperature variations and trends at meteorological stations. Analysis of data from 1993 to 2022 reveals significant warming trends in mean monthly maximum, minimum, and normal temperatures at stations like Rawlakot and Athmuqam. Meanwhile, stations such as Murree, Jhelum, and Kotli have shown varying degrees of temperature changes. These findings underscore the regional impact of climate change and emphasize the necessity of tailored adaptation strategies to address the challenges posed by shifting temperature patterns and their impact on ecosystems and human societies.

Winter (January): Coldest temperatures, especially in high-altitude areas like Rawalakot and Murree. Summer (June-July): Warmest temperatures, with Jhelum and Kotli experiencing significant warmth. Autumn (September-October): Transition to cooler temperatures.

Climate Change Implications

Sen's Slope Estimation: Notable trends of warming in Athmuqam and Rawalakot. Moderate rises in Kotli and Jhelum. Murree exhibits modest increases, especially for normal and minimum temperatures. The findings demonstrate the necessity of specific climate adaptation plans in these areas.

Table 4 Mann-Kendall model results of mean maximum temperature for all the met stations in the Western Himalayas

Met Stations	Mann-Kendall statistics	Kendall's Tau	Variance (S)	P-Value (two tailed test)	Model Interpretation
Jhelum	304.00	0.31	2017.6	0.021	Reject H_o (MSTD)
Kotli	9.00	0.11	212.1	0.720	Accept H_o (NSTD)
Rawlakot	279.00	0.36	5321.0	0.001	Reject H_o (MSTD)
Murree	99.00	0.23	3120.3	0.079	Accept H_o (STD)
Gharidupatta	-5.00	-0.33	0.00	0.469	Accept H_o (NSTD)

Muzaffarabad	164.00	0.24	0.00	0.032	Reject H_o (MSTD)
Balakot	2.00	0.20	243.0	0.817	Accept H_o (NSTD)
Athmuqam	384.00	0.41	2378.2	0.001	Reject H_o (MSTD)

More Significant Trend Detected (MSTD); **Significant Trend Detected (STD); *No Significant Trend Detected (NSTD)

Table 5 Mann-Kendall model results of mean minimum temperature for all the met stations in the Western Himalayas

Met Stations	Mann-Kendall statistics	Kendall's Tau	Variance (S)	P-Value (two tailed test)	Model Interpretation
Jhelum	-169.00	-0.15	207.6	0.141	Accept H_o (NSTD)
Kotli	16.00	0.03	212.1	0.506	Accept H_o (NSTD)
Rawlakot	-104.00	-0.15	6321.0	0.233	Accept H_o (NSTD)
Murree	0.00	0.00	5120.3	0.615	Accept H_o (NSTD)
Gharidupatta	-4.00	-0.40	0.00	0.258	Accept H_o (NSTD)
Muzaffarabad	-176.00	-0.26	0.00	0.034	Reject H_o (MSTD)
Balakot	-10.00	-1.00	343.0	0.009	Reject H_o (MSTD)
Athmuqam	-176.00	-0.26	2378.2	0.029	Reject H_o (MSTD)

More Significant Trend Detected (MSTD); **Significant Trend Detected (STD); *No Significant Trend Detected (NSTD)

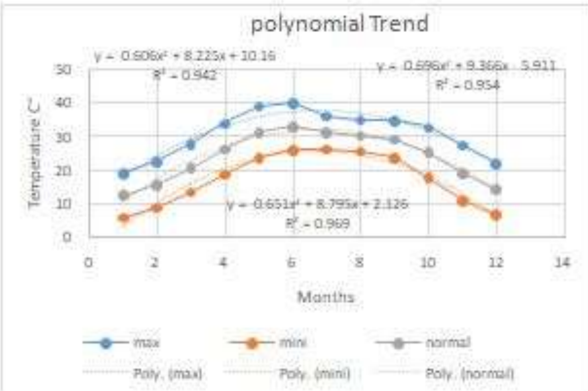
Table 6 Mann-Kendall model results of monthly normal temperature for all the met stations in the Western Himalayas

Met Stations	Mann-Kendall statistics	Kendall's Tau	Variance (S)	P-Value (two tailed test)	Model Interpretation
Jhelum	121.00	0.13	12635.3	0.21	Accept H_o (NSTD)
Kotli	91.00	0.16	3134.3	0.11	Accept H_o (NSTD)
Rawlakot	94.00	0.19	6326.00	0.071	Accept H_o (NSTD)
Murree	0.00	0.00	0.00	0.851	Accept H_o (NSTD)
Gharidupatta	4.5	0.00	14.66	1.29	Accept H_o (NSTD)
Muzaffarabad	20.00	0.03	0.00	0.550	Accept H_o (NSTD)
Balakot	-9.00	-0.60	0.00	0.136	Accept H_o (NSTD)
Athmuqam	34.00	0.04	1.11	0.615	Accept H_o (NSTD)

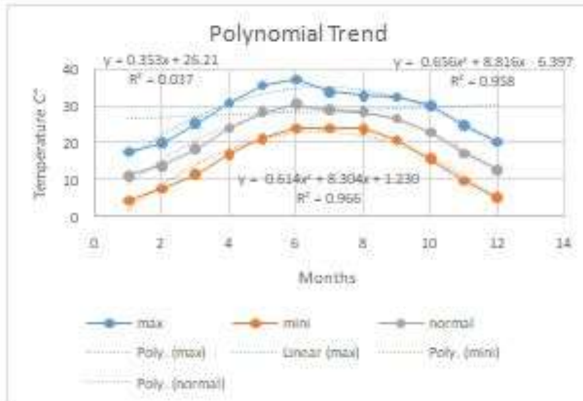
More Significant Trend Detected (MSTD); **Significant Trend Detected (STD); *No Significant Trend Detected (NSTD)

OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

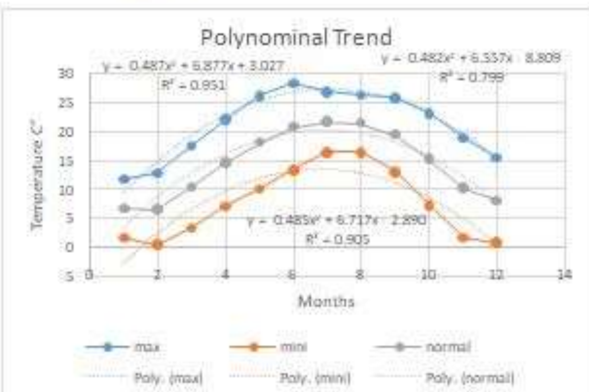
Trends in the Jhelum River Basin and Western Himalayan Region Temperature



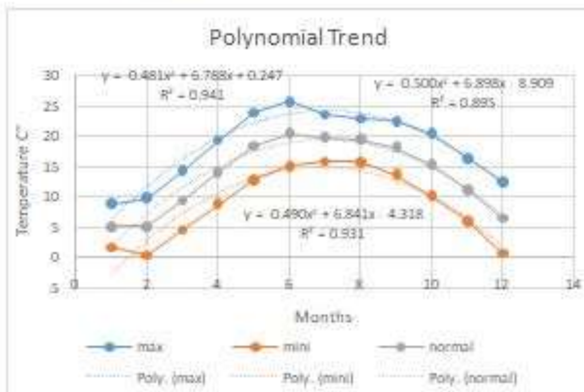
Jhelum



Kotli



Rawlakot



Murree

Figure VIII TMMMax, TMMMin, and TMMNor polynomial Trend (1993-2022)

OEconomia
oeconomiajournal.com
Volume: 07, No: 2 (2024)
ISSN: **2269-8450,2113-5207**

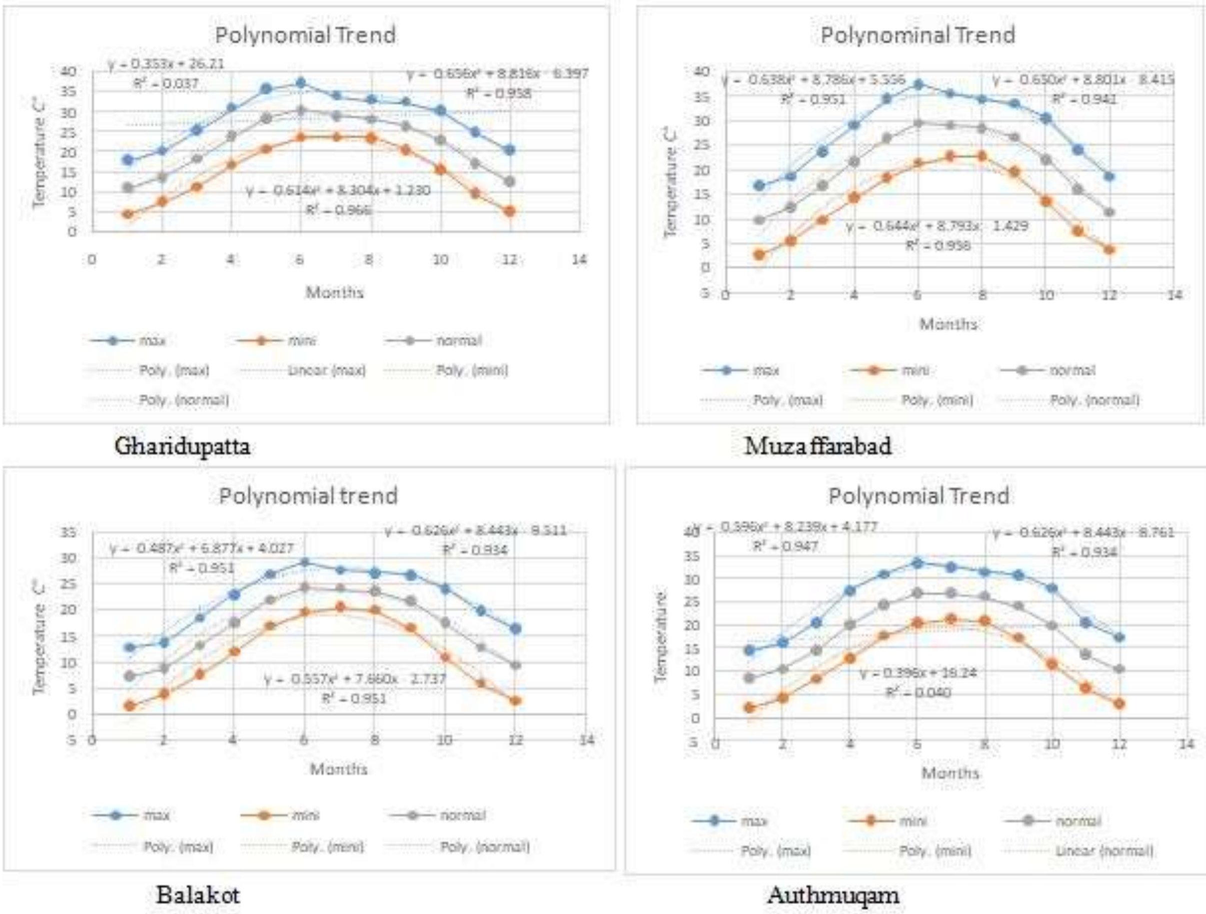


Figure IX

TMMMax, TMMMin, and TMMNor polynomial Trend (1993-2022)

The polynomial regression analyses across eight cities show a consistent pattern of temperature increases that gradually decrease over time. Strong fits are indicated by high R^2values for the majority of the cities, indicating how well these models capture the dynamics of temperature in the area. Given the various climatic conditions and trends seen across various altitudes and geographic regions, this knowledge is essential for urban planning, agriculture, and the development of climate adaptation techniques.

Conclusion

Temperature variability is common global issue in modern era which is considered the main instigating factor behind global warming. It's not only effecting rising temperature but also effect the precipitation pattern along with melting of the glacier. The study area Jhelum River basin is also facing such type of issues. This study area has amazing landscapes such as lakes highlands and lush green valleys. The proximities of Jhelum River and its tributaries flow and adds water in an artificial water reservoir namely Mangla. It covers about 725 km area. This basin is facing challenges such as sedimentation habitat loss and water quality degradation. Due to the temperature variability precipitation pattern also changed that is alarming situation for Jhelum River basin Western Himalaya (JRBWH).

The climatic data of given station is collected from secondary data source, Pakistan Meteorological department. For analyzing the temperature variability 8 meteorological stations selected. 30 years data of the meteorological station was analyzed for deducting climate change and temperature variability. The data is analyzed in three different parts first on mean monthly maximum temperature of selected meteorological station was analysis for deduct the temperature variability. The results showed that Jhelum city has maximum mean monthly highest temperature recorded in June as 40 C. in second part mean minimum monthly data analyses which show the coldest point is Murree minimum values of temperature recoded 0.4 C. At the end mean monthly normal data analyses which show the mean of 30-year weather stations data maximum temperature mean of time period is noted 33.05 C which is recoded in Jhelum city. Minimum temperature means monthly normal temperature recorded Murree city 5.1 C. The results show that cold city is Murree and hot city is Jhelum. Polynomial trend of the given met stations is also deducted. The poly lines of given 8 met stations showed curved lines. The results indicate the hottest months are the middle month of the years. Temperature of June is high and on January and December temperature decreased. However, the study area is continuously facing the deforestation and other issues which lead to high temperature.

References

Alemu, Z. A., & Dioha, M. O. (2020). Climate Change and Trend Analysis of Temperature: The case of Addis Ababa, Ethiopia. *Environmental Systems Research,* 9(27) 1-15

Amrutha, K., & Patnaik, R. (2023). *Climate Change Impact on Major River Basins in the Indian Himalayan Region : Risk Managent and Sustainable Practices in the Himayas,* Springer

Bhat, M., & Tali, P. (2021). Seasonal spatio-temporal variability in temperature over north Kashmir Himalayas using sen slope and Mann-Kendall Test. *Journal of Climatology and Weather Forecast,* 9(5), 288.

Dar-Rafi, R. (2020). Assessing catchment area and morphometric dynamics and its impact on the water chemistry of Wular Lake, Kashmir. *International Journal for Environmental Rehabilitation and Conservation, XI*(SP2) 404 - 413

Dong, Z., & Jia, W. (2020). "Innovative trend analysis of air temperature and precipitation in the jinsha river basin, china." *Water,* 12(11): 3293.

Ekwueme, B. N. & Agunwamba, J. C. (2021). "Trend analysis and variability of air temperature and rainfall in regional river basins." *Civil Engineering Journal,* 7(5): 816-826.

El-Sayed, A. & M. Kamel (2020). "Climatic changes and their role in emergence and re-emergence of diseases." *Environmental Science and Pollution Research*, 27(18): 22336-22352.

Farooq, M. U., Rahman, A., Qasim, M., Hashim, M., and Batool, S. (2023). Evaluation of Physical Expansion of Built Environment in District Sargodha Pakistan. *Journal of Asian Development Studies*, 12(3) 1223-1235.

Farooq, M. U., Rahman, A., Qasim, M., Hashim, M., and Batool, S. (2023). Monitoring the Impact of Built-up Area Expansion on Agricultural Land of District Sargodha, Pakistan. *Central European Management Journal*, 31(4) 285-296.

Gao, C., & Booij, M. J. (2020). "Assessment of extreme flows and uncertainty under climate change: disentangling the uncertainty contribution of representative concentration pathways, global climate models and internal climate variability." *Hydrology and Earth System Sciences*, 24(6): 3251-3269.

Hashim, M., Rahman, A., Nadeem, B., Aziz, F., Dawood, M., Qasim, M., Farooq, M. U., and Muneer, S. (2024). Spatio-Temporal Analysis of Land Use Land Cover Changes and Spectral Normalized Difference Indices in Multan City, Pakistan. *Al-Qantara*, 9(4) 685 699.

Hashim, M., Rahman, A., Qasim, M., Farooq, M. U., Muneer, S. and Ahmed, Z. (2023). Spatio Temporal Analysis of Land use Land Cover Changes in Multan City, Pakistan. *Natural and Applied Sciences International Journal,* 4(1) 120-134.

Hashim, M., Rahman, A., Qasim, M., Farooq, M. U., Nadeem, B., and Muneer, S. (2023). Determination of Demographic Change and Urban Settlement Pattern in Multan City, Pakistan. *Journal of Positive School Psychology*, 7(6) 1243-1253.

Hu, J., & Wu, Y. (2021). "Predicting long-term hydrological change caused by climate shifting in the 21st century in the headwater area of the Yellow River Basin." *Stochastic Environmental Research and Risk Assessment*, 1-18.

Jia, T., & Yang, K. (2022). "Review on the change trend, attribution analysis, retrieval, simulation, and prediction of lake surface water temperature." *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 15: 6324-6355.

Joakim, E. P., & L. Mortsch, L. (2021). Using vulnerability and resilience concepts to advance climate change adaptation. *Environmental Hazards and Resilience, Routledge:* 13-31.

Loukas, A., & Garrote, L. (2021). Hydrological and Hydro-Meteorological Extremes and Related Risk and Uncertainty, *MDPI*. 13: 377.

Mantoo, S. (2020). "Indus Water Treaty: Past Present and Future." *Journal of Global Economy*, 16(4): 65-87.

Murad, A. G. B. (2023). "Geo-statistical analysis for the natural conditions of temperature in Iraq." *Tikrit Journal of Administration and Economics Sciences*, 19 (Special Issue part 5).

Nagendra, H. & S. Mundoli (2023). *Shades of Blue: Connecting the Drops in India's Cities.* Penguin Random House India Private Limited.

Nie, Y., & Pritchard, H. D. (2021). "Glacial change and hydrological implications in the Himalaya and Karakoram." *Nature Reviews Earth & Environment*, 2(2): 91-106.

Qasim, M., Ali, N., and Aqeel, M. (2023). Trends and Patterns of Temporal Urban Population Growth in Pakistan. *Pakistan Social Sciences Review,* 7(3) 551-564.

Qasim, M., Ali, N., Haider, S., S., Zainab, I., and Ali, M. (2024). Socio-Ecological Dynamics in Gilgit Baltistan: Insights of Human Geographic Perspectives. *Journal of Education and Social Studies,* 5(2) 372-385.

Qasim, M., Ali, S., and Aqeel, M. (2024). Geographic Diversity and Landscape in Transition: Analyzing the Physical Features of Gilgit Baltistan Region. *Journal of Social Sciences Development,* 3(2) 154-169.

Sam, M. G., & Nwaogazie, I. L. (2022). "Climate change and trend analysis of 24-hourly annual maximum series using Mann-Kendall and Sen slope methods for rainfall IDF modeling." *International Journal of Environment and Climate Change,* 12(2): 44-60.

Shah, S., & Sen, S. (2024). "State of Indian Northwestern Himalayan lakes under human and climate impacts: A review." *Ecological Indicators*, 160: 111858.

Sharafati, A., & Pezeshki, E. (2020). "Quantification and uncertainty of the impact of climate change on river discharge and sediment yield in the Dehbar river basin in Iran." *Journal of Soils and Sediments*, 20: 2977-2996.

Sharma, A., & Batish, D. R. (2020). "Documentation and validation of climate change perception of an ethnic community of the western Himalaya." *Environmental Monitoring and Assessment*, 192: 1-22.

Sharma, N. & Kala, C. P. (2022). "Patterns in plant species diversity along the altitudinal gradient in Dhauladhar mountain range of the North-West Himalaya in India." *Trees, Forests and People* 7: 100196.

Sharma, U., & Datta, M. (2023). Geology of Himalayan Soils. Soils in the Hindu Kush Himalayas: Management for Agricultural Land Use. *Springer*, 95-115.

Siddha, S., & Sahu, P. (2022). Impact of climate change on the river ecosystem. Ecological significance of river ecosystems. *Elsevier*, 79-104.

Upadhyay, R. K. (2020). "Markers for global climate change and its impact on social, biological and ecological systems: A review." *American Journal of Climate Change*, 9(03): 159.

Zhang, Q., & Chen, Y. (2020). "Recent changes in water discharge in snow and glacier melt-dominated rivers in the Tienshan Mountains, central Asia." *Remote Sensing*, 12(17): 2704.