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**A**dvances in Science, Technology and Engineering Systems Journal (ASTESJ) is an online-only journal dedicated to publishing significant advances covering all aspects of technology relevant to the physical science and engineering communities. The journal regularly publishes articles covering specific topics of interest.

Current Issue features key papers related to multidisciplinary domains involving complex system stemming from numerous disciplines; this is exactly how this journal differs from other interdisciplinary and multidisciplinary engineering journals. This issue contains 2 accepted papers in civil engineering domain.

**Editor-in-chief**

*Prof. Passerini Kazmersk*

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## Compressive Strength of Cement Mortar blended with Coconut Fibers and Human Hair

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### ABSTRACT

Mortar is used all over the world for construction purpose. It consists of cement paste and fine aggregates and admixtures if required are also incorporated to modify some of its properties. In this study coconut fibers and human hair were used as an additive materials in the mortar and its effects on compressive strength of the mortar were investigated. Coconut fibers and human hair are waste materials which are produced in millions of tons every year which create not only biodegradability problems but also cause pollution. Coconut fibers and human hair were used as additive materials in mortar in 2, 4 and 6 % to prepare blended mortar. Mortar samples of coconut fibers and human hair were prepared and compared with each other and control samples. Cement to sand ratio was kept 1:3 with water cement ratio of 0.6 for all mixes. Cubes having dimensions of 2×2×2 inches were used in this project. All the mixes were cured at normal room temperature for 3, 7 and 28 days. Results revealed that mix with 4% coconut fibers showed higher compressive strength at 3 days and 6% higher compressive strength at 28 days. With increase of coconut fibers compressive strength increased. However, mortar with human hair initially shows higher strength when 2 % was incorporated but with increasing percentage of human hair, strength was reduced. With addition of mix fibers i.e. coconut fibers and human hair into the mix, the compressive strength initially increased at 3<sup>rd</sup> day of curing, showing higher compressive strength at 3 days for all percentages of mix compare to reference mortar, however with further increase of percentage of mix fibers into the mortar, the compressive strength was reduced showing lowest compressive strength at 28<sup>th</sup> days for 4% of mix fibers i.e. coconut fibers and human hair.

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### 1. Introduction

Several problems have evolved because of increasing temperature on the use of mortar and concrete in recent few years where it has sufficiently threaten the performance of mortar and concrete. Similarly some non-biodegradable wastes have also increased leading to un-hygienic conditions. Efforts are needed to educate public on the importance of fibers and its consequences both in short run and long run [1]. Fibers are waste materials which are obtained from various sources and hence treated as waste material because it is a major threat to environment.

Coconut fibers are long thread like structures which are obtained from outer shells of coconut. These fibers are very strong and tough. Coconut fibers have the highest toughness amongst natural fibers. Coconut fiber shows a great resistance to fungi attack. Coconut fibers act as excellent insulators against heat and sound. Coconut fibers are light in weight. Coconut fibers acts as a fire resistant material. Coconut fibers do not contain any kind of hazardous materials and so can easily be handled. They have rough structure and so form proper and strong bond with concrete. They have water absorption ability. Similarly human hair is also waste materials and as it is a non-biodegradable therefore it is also an environmental hazard, therefore its use in mortar can not only minimizes its environmental hazards but can also play an

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important role to increase compressive strength of mortar. It is easily and cheaply available throughout the world thus it can be used in concrete as the cheapest ingredient. It has got good tensile strength therefore it can play an important role to increase strength of mortar. Specific gravity ranges from 1.2 to 1.35 [2]. It is light in weight so mortar made of it will also be light. Density of coconut fibers ranges from 0.67-1 g/cm<sup>3</sup> [3]. Fibers used in mortar and concrete are environmental friendly and are also economical because these fibers are locally available [4].

## 2. Research Significance

Due to global warming the ozone layer is depleted due to which the temperature of earth is constantly increasing which has threaten the performance of concrete used in our structures. Year 2009 was declared as international year of natural fiber by United Nation General Assembly in order to highlight its importance to world and to make the world aware of its consequences [5]. More than 500,000 ton coconut fibers are produced throughout the world including Sri Lanka, Philippines, Nepal and Indonesia. Pakistan is also amongst those countries where sufficient quantity of coconut is cultivated in coastal areas [5]. Cementitious materials thus reducing environmental hazards along with increment of better concrete with useful properties. In present study mortar cubes were made with different percentages of coconut fibers and human hair fibers and cured up to 28 days. Compressive strength tests were carried out at different period to observe the performance of fiber reinforced mortar.

## 3. Physical Properties of Fibers

### 3.1. Physical Properties of Coconut Fibers

1. Length: length of coconut fibers usually ranges from 27 cm to 35 cm.
2. Diameter: Diameter of coconut fiber is almost same and ranges from 12-25 micron.
3. Density: Density of coconut fibers ranges from 0.67-1 g/cm<sup>3</sup> [3].
4. Strength: Coconut fibers has the ability to take additional strain of 4-6 times greater than other fibers.
5. Specific gravity: Specific gravity ranges from 1.2-1.35 [2].

### 3.2. Physical Properties of Human Hair

1. Lengthening of up to 5%, hair is elastic
2. Hair is the strongest, withstanding a weight of 100 grams and an elongation of 55%
3. Human hair has about 65-95% of its weight in proteins, more 32% of water, lipid pigments and other components. Chemically, about 80% of human hair is formed by a protein known as keratin [6].
4. Keratin has special affinity for water. This absorption depends on the air relative humidity rate and greatly interferes on all the proprieties of the hair, as: stretching ability, diameter and internal viscosity of the fibers.
5. Friction is higher in wet than in dry hair.
6. Hair tends also to be pervious to water in its liquid form. This absorption is followed by a swelling in the hair, with 15-10% increase in its thread diameter and 0.5-1.0% in its length.
7. It has a high tensile strength which is equal to that of a copper wire with similar diameter [7].

8. Human hair is nonhazardous but it is non bio degradable thus causing environmental threat. Every use of human hair does not reduce the human hair waste because, in some uses, the disposal of the hair after use can bring it back into waste streams. For example, even though wigs and hair extensions use human hair at large scale, the hair is not consumed during use, after which it is again thrown away in the solid waste.
9. The hair neither decay nor leave it intact for safe reuse or recycling. There are the applications that involve either contamination of the hair with toxic chemical or irreversible blending with certain non-biodegradable or ecologically unsafe materials. Hair contaminated with toxic organic pollutants is one such case. Other such use would be human hair composites with non-biodegradable resin. Recycling or safe disposal of these products require further processing to remove the specific contamination or separation of the other materials. For example, hair composites with non-biodegradable resin would need a method to separate the two materials or a method for safe decomposition such as combustion at very high temperatures to ensure safe destruction.

## 4. Experimental Program

The experimental was planned to find out the compressive strength of mortars using coconut fibers and human hair fibers in addition to cement as a waste materials. Fibers addition at various percentage levels were used in this research to investigate and observe the effects of different levels of fibers in mortar in contributing the compressive strength of mortars at various ages of curing.

### 4.1. Cement

ASTM Type-I Portland Cement conforming to ASTM C-150 was used as binding material. The physical properties and chemical compositions of OPC are given in Table-1 and Table-2 respectively.

Physical properties	ASTM Type-I Cement
%age fineness (Passing #200 sieve)	93
Initial setting time	30 minutes
Final setting time	45 minutes
3 days Compressive Strength	2233.581 Psi
7 days Compressive Strength	2886.251 Psi
28 days Compressive Strength	4380.14 Psi
Specific gravity	3.15

Oxides	Percentage (%)
Al <sub>2</sub> O <sub>3</sub>	21.24
SiO <sub>2</sub>	5.56
Fe <sub>2</sub> O <sub>3</sub>	3.24
CaO	65.53
MgO	0.93
SO <sub>3</sub>	2.55
LOI	1.24
IR	0.64
Free Lime	0.55

### 4.2. Sand

Locally available natural sand passing through 4.75 mm sieve and retained on 0.015 mm sieve was used in this research. Gradation of this sand is given in Table-3.

Table 3: Sieve Analysis of Sand

Sieve No	Sieve Size (mm)	Retained Mass (g)	Retained (%)	Passing (%)	Cumulative percentage retained
8	2.36	12.91	4.30	95.60	4.30
16	1.18	9.51	3.17	92.53	7.47
30	0.6	50.19	16.73	75.80	24.20
50	0.3	111.0	37	38.80	61.20
100	0.15	77.90	25.90	12.80	87.16
200	0.075	28.57	9.50	3.30	96.6
Pan		9.92			100

Fineness Modulus of sand is calculated as

$$F.M = \frac{(4.30 + 7.47 + 24.20 + 61.20 + 87.16 + 96.60)}{100} = 2.80$$

### 4.3. Mix Proportioning

Four different mix proportions of fiber cement mortar cubes (0%, 2%, 4% and 6%) were prepared having size of 50 mm x 50 mm x 50 mm. Cement to sand ratio was kept as 1:3 as a reference mortar for comparing the properties of mortar in addition of fibers, while the water to cement ratio was kept as 0.6. The fiber mortar means the mortar made by using cement and fibers as an additive material with sand and water. Details of mix proportion and materials are shown in Table 3.

Table 4: Mix Proportioning

S. No.	Material	Quantity
1	Fiber Length	50 mm
2	Cement	500 gram
3	Sand	1500 gram
4	w/c	0.6
5	Water	300

### 4.4 Washing of human hair

After sorting, the hair was washed using water with shampoo because washing of hair with only water is harmful to hair. It particularly accentuates the negative effects of sunlight, hair's other great enemy. Melanin degradation is encouraged and sun linked discoloration intensifies. Keratin itself is altered, making the hair fragile and easily damaged [8]. The hair was then dried under sun. After drying, the hair was used in cement mortar.

### 4.5 Curing Environment and Testing

Total of 140 mortar specimens were casted in the laboratory. After casting, the specimens were kept at 27°C temperature and 90% relative humidity for 24 hours. After removal from moulds, all the specimens were cured in water at room temperature for 3, 7 and 28 days. After specific exposure period, specimen was tested for compressive strength in accordance with test procedure (ASTM C109-87) [9].

## 5. Compressive Strength Test Results and Discussion

Cubes for all mortars were tested for compressive strength at 3, 7 and 28 days. The results for mortar MC, MH, MCH are shown in Table 4.

Table 5: Average Compressive Strength of Mortar Mixes

Mortar Type	Average Compressive Strength (Psi)		
	3 days	7 days	28 days
MC-0	843	1342	2315
MH-0	843	1342	2315
MCH-0	843	1342	2315
MC-2	1293	2150	2822
MH-2	1391	1506	2114
MCH-2	944	1471	2080
MC-4	1519	2334	3121
MH-4	745	1136	1523
MCH-4	908	1103	1530
MC-6	1439	2870	3270
MH-6	513	778	1209
MCH-6	1161	1583	1902

Figure 1 shows that with addition of coconut fibers into the mix, the compressive strength increased. However with further increase of percentage of coconut fibers into the mix, the compressive strength increased at 7 days.

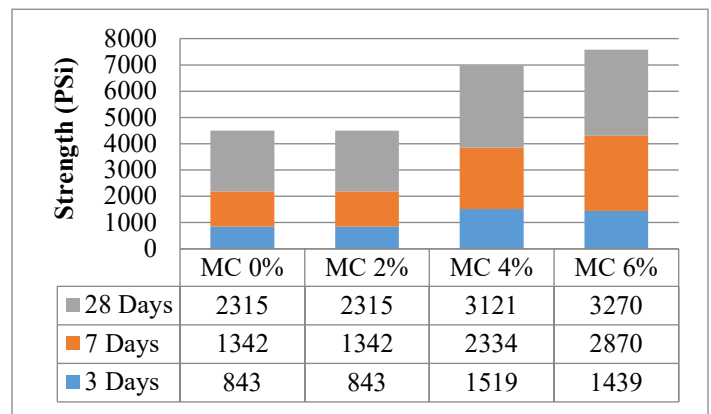


Figure 1: Compressive Test Result

However at 3 day of curing there was no difference in compressive strength of mortar between 4% and 6% of curing while at 28 day the compressive strength at 4% was higher than 2% and lower than 6% of coconut fibers.

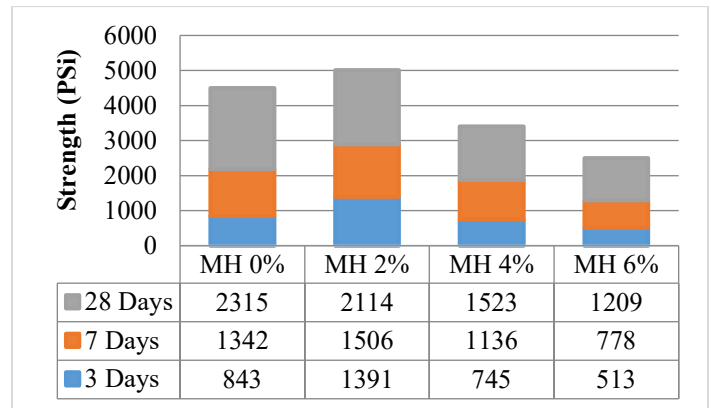


Figure 2: Compressive Test Result

Figure 2 shows that with addition of 2% human hair in the mix, the compressive strength increased. However with further increase of human hair beyond 2%, the compressive strength decreased progressively with the lowest values observed at the highest rate of 6% at all days of curing.

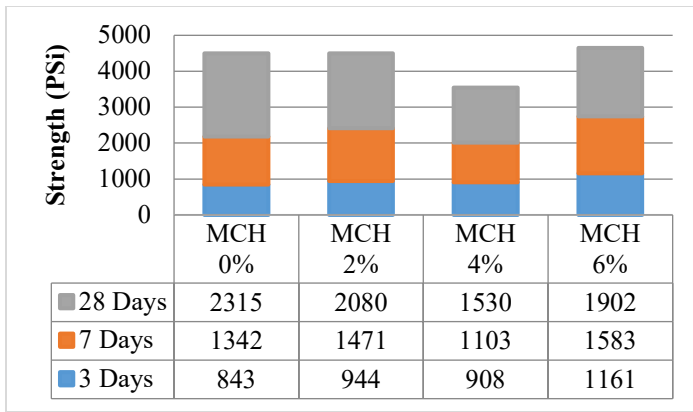


Figure 3: Compressive Test Result

Figure 3 shows that with addition of 2% mixed fibers (coconut fibers and human hair) into the mix, the compressive strength increased at 3, 7 and 28 days of curing. However with further increase of mixed fibers into the mix, the compressive strength is decreased progressively with the lowest value of 4% of mix fibers at 7<sup>th</sup> and 28<sup>th</sup> days of curing but compressive strength was higher at 3<sup>rd</sup> day for 4% of mix fibers than 0% at 3<sup>rd</sup> day of curing, while the compressive of 6% is increased at 3 day and 7 days of curing however at 28 day of curing, the compressive strength was lower for 6% than 2% of mixed fibers.

### Conclusions

This research work is further extension of the use of blended materials under the effect of using coconut fibers and human hair so that strength can be increased and also the adverse effects of these wastes materials can be reduced to keep our environment clean from the effects of such wastes.

- Coconut fibers of 4% into the mix gave high 3 days strength and 6 % gave high compressive strength at 28 days of curing at room temperature.
- By increasing the percentage of coconut fibers the strength of mortar increased at all days of curing.
- The use of human hair up to 2 % initially gave high strength. However with further increasing the percentage of human hair into the mix showed reduction in compressive strength of mortar at all days of curing.
- Addition of 6 % of mix fibers (coconut fibers and human hair) into the cement mortar showed higher compressive strength at 3<sup>rd</sup> day than 2% and 4%, while compressive strength of mortar was found higher for 2% at 28<sup>th</sup> day than compressive strength of mortar for 4% and 6% of mix fibers.

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## Temperature Trend Detection in Upper Indus Basin by Using Mann-Kendall Test

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### ABSTRACT

Global warming and Climate change are commonly acknowledged as the most noteworthy environmental quandary the world is undergoing today. Contemporary studies have revealed that the Earth's surface air temperature has augmented by 0.6°C - 0.8°C in the course of the 20<sup>th</sup> century, together with alterations in the hydrological cycle. This study focuses on detecting trends in seasonal temperature for the five selected stations in the Upper Indus Basin. The Mann-Kendall test was run at 5% significance level on time series data for each of the five stations during the time period, 1985 to 2014. The Standard Test Statistic ( $Z_s$ ) indicates the presence of trend and whether it is increasing or decreasing. The analysis showed an increasing trend in mean monthly temperature at Astore, Gilgit and Gupiz in March and a decreasing trend for Astore, Drosh, Gilgit and Skardu in September. Gilgit and Gupiz showed unexpected increasing trend in October. This study concludes that the temperature starts increasing in March and stays elevated till the month of June and starts rising again in October thus resulting in expansion of summer season and prolonged glacial melting.

## 1. Introduction

### 1.1 General

Temperature is a vital component of climate and vicissitudes in its pattern can clout ecosystems, plants, animals, human health and ecological diversity. Recent studies have shown that the Earth's surface air temperature has increased by 0.6°C - 0.8°C during the 20th century, along with changes in the hydrological cycle [1]. Scientific evidence shows that climate change has begun to manifest itself, globally, in the form of increased downpours and storms, rising temperature and sea level, retreating glaciers, etc [2]. An escalation in temperature can upshot heat wave incidents and trigger illness and death in predisposed populaces. An upsurge in Earth's temperature leads to more evaporation and cloud development to take place, which in turn, proliferates precipitation [3].

Pakistan is markedly susceptible to climate change for the reason that it has generally a volatile climate. It rests in a world region where the temperature escalations are presumed to be higher than the global averages. Its rivers are primarily supplied by the Hindu Kush-Karakoram-Himalaya (HKH) glaciers which are envisaged to be melting and retreating swiftly due to global warming [4]. Its economy is chiefly agrarian and consequently highly climate susceptible; so the country confronts increasingly larger risks of inconsistency in monsoon rains, large floods and protracted droughts [4]. Under the influence of all these factors the water security and the food security of the country are under serious threat. This study focuses on trend detection in seasonal temperature for five selected sub basins of Upper Indus Basin (UIB). Since flows influence of all these factors the water security and the food security of the country are under serious threat [13]. This study on trend detection in seasonal temperature for five selected sub basins of Upper Indus Basin (UIB). Since flows in upper Indus River, within KP, are directly affected by the waters-

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hed of these five sub basins. Using data from the Pakistan Metrological Department, study identifies the UIB temperature patterns from 1985 to 2014.

1.2 Recent Related Research

1- In view of a study conducted by [6] assessed the trend pattern of stream flow, rainfall, temperature and evaporation in River Kaduna. The difference in evaporation amount between 1980 - 1990 and 1991-2001 was 81 mm/day; this implies that there exists slight evaporation within the catchment area. Also, the difference in rainfall amount between 1980 -1990 and 1991-2012 was 14,619 mm. This implies that there are lots of climate change activities in the whole catchment area. Thus, the study confirmed that the increase in temperature causes more intense evaporation via relative humidity.

2- In a study conducted by [7] it was identified whether statistically significant changes in the spatio-temporal trends in the maximum and minimum temperatures and precipitation (amount and distribution) at different time scales occurred under climate change or not, in North Korea. They concluded that there are significant differences in meteorological elements, and particular locations and urbanized areas were affected by global warming.

3- In conclusion of a study led by [8] it was stated that primarily winter temperatures were increasing with increases also in spring and fall. They did not find clear increasing or decreasing trends in summer, though they found evidence of longer durations of periods with hot days. The analyses of datasets reveal clear temperature increases in summer, particularly for minimum temperatures and significant changes (decreasing) in precipitation in the summer and fall for nearly a quarter to a third of the country, depending on the season.

4- In a study led by [9] upon the possible impacts of climate change on the water resources of the Kunhar River basin, Pakistan. The overall conclusion of the study was that the Kunhar basin is likely to face more floods and droughts in the future due to the projected increase in high flows and decrease in low flows.

5- The study conducted by [10] for annual precipitation and mean annual temperature in the state of Kentucky indicates that, over the period 1950–2010, both of these variables generally did not exhibit any statistically significant trends with respect to time. The relatively small number of significant trends detected. However all were in the positive direction, and all were associated with weather stations very close to the borders of the state.

6- According to a study conducted by [11] the mean minimum annual temperature has declined in most of the region of Upper Indus Basin for the period (1961 to 2011). Maximum and mean temperature has increased with increase in elevation while the minimum temperature and precipitation has more decreasing rate in higher mountainous catchments.

7- A report summarized by [12] about the potential future climate and hydrologic conditions based on the best available

datasets and data development methodologies, its characterization of future hydroclimate possibilities implicitly reflects several uncertainties. Trying to identify an exact climate change impact at a particular place and time remains difficult, despite advances in modeling efforts over the past half-century. U.S average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895. Most of this increase has occurred since about 1970. The Western U.S has warmed roughly 2°F in the basin considered here and is projected to warm further during the 21st century.

1.3 Study Area

The Indus River basin is one of the world’s largest basins, having an area of approximately 970,000 km<sup>2</sup>. However, this study is cramped only to Upper Indus River Basin (UIRB) that lies between the source of Indus river and Tarbela reservoir comprising a basin area of about 175, 000 km<sup>2</sup> [13].

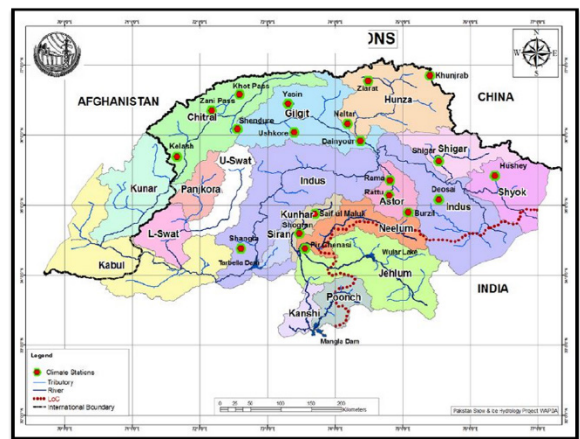


Figure 1: Climatic and River gauging stations in UIB [14]

1.4 Hydro Meteorological Network in Study Area

Twelve Climate stations are installed by Pakistan Meteorological Department (PMD), Islamabad, Pakistan in UIB of which eight are installed at five major sub basins.

Table 1: Particulars of five stations installed

ID	Station Name	Lat (°N)	Long (°E)	Elevation (m a.s.l.)
1	Astore	35.33	74.90	2394
2	Drosh	35.56	71.78	1465
3	Gilgit	35.91	74.33	1460
4	Gupis	36.01	73.40	2156
5	Skardu	35.30	75.68	2210

The maximum and minimum monthly temperature data of these five selected sub-basins was collected. The scope of this study was limited to a span of 30 years i.e., from 1985-2014.

2. Methods & Methodology

2.1 Trend Analysis

Trend analysis can be defined as the use of an empirical approach to quantify and explain changes in a system over a

period of time. The purpose of trend testing is to determine if the values of a random variable generally increase (or decrease) over some period of time in statistical terms.

### 2.2 Temperature Trends

The continuous increase or decrease in temperature over longer time periods depends upon spatial locality of the region. If the trend shows that the temperature is increasing than this means that the trend is positive, similarly if the trend shows that the temperature is decreasing than the trend is considered to be negative.

### 2.3 Methods for Trend Detection

Two major tests are used for the trend detection.

- i. Parametric Trend Tests
- ii. Non-Parametric Trend Tests

#### 2.3.1 Parametric Trend Tests

Parametric tests assume that the time series data and the errors (deviations from the trend) follow a particular distribution (usually normal distribution). Parametric tests are generally more powerful than non-parametric tests. For Linear and equally spaced data and cannot take into account any outliers.

There are two major parametric trend tests.

- i. Regression Analysis
- ii. Cumulative Deviation Test

#### 1- Regression Analysis

This is a parametric test that assumes that the data are normally distributed. It tests for the detection of linear trend by examining the relationship between time (x) and the variable of interest (y). The regression gradient “b” is estimated by:

$$b = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sum_{i=1}^n (X_i - \bar{X})^2}$$

and the intercept “a” is estimated as:

$$a = \bar{Y} - b\bar{X}$$

The test statistic “S” is:

$$S = \frac{b}{\sigma}$$

where

$$\sigma = \sqrt{\frac{12 \sum_{i=1}^n (Y_i - a - bX_i)^2}{n(n-2)(n^2-1)}}$$

The test statistic S follows a Student-t distribution with n-2 degrees of freedom under the null hypothesis. The linear regression test assumes that the data are normally distributed and that the errors (deviations from the trend) are independent and follows the same normal distribution with zero mean.

#### 2- Cumulative Deviation Test

This method tests whether the means in two parts of a record are different (for an unknown time of change). The test assumes that the data are normally distributed. The purpose of

this test is to detect a change in the mean of a time series after m observations:

$$\begin{aligned} E(X_i) &= \mu & i &= 1, 2, 3, \dots, m \\ E(X_i) &= \mu + \Delta & i &= m + 1, m + 2, \dots, n \end{aligned}$$

where  $\mu$  is the mean prior to the change and  $\Delta$  is the change in the mean. The cumulative deviations from the means are calculated as:

$$S'_0 = 0$$

$$S = \sum_{i=1}^k (X_i - \bar{X}) \quad k = 1, 2, 3, \dots, n$$

and the rescaled adjusted partial sums are obtained by dividing the  $S_k$  values by the standard deviation:

$$\ddot{S}_k = S'_k / D_x$$

$$D_x^2 = \sum_{i=1}^n \frac{(X_i - \bar{X})^2}{n}$$

The test statistic Q is:

$$Q = \max |S'_k|$$

and is calculated for each year, with the highest value indicating the change point. A negative value of  $S_k$  indicates that the latter part of the record has a higher mean than the earlier part and vice versa.

#### 2.3.2 Non-Parametric Trend Tests

Non-parametric tests are generally distribution-free. They detect trend/change, but do not quantify the size of the trend/change. They are very useful because most hydrologic time series data are not normally distributed. Less influenced by presence of outliers.

- i. Mann-Kendall Trend Test
- ii. Spearman Correlation
- iii. Rank-sum test

#### 1- Mann-Kendall Trend Test

This method tests whether there is a trend in the time series data. It is a non-parametric test. The n time series values ( $X_1, X_2, X_3, \dots, X_n$ ) are replaced by their relative ranks ( $R_1, R_2, R_3, \dots, R_n$ ) (starting at 1 for the lowest up to n). The test statistic S is:

$$S = \sum_{i=1}^{n-1} \left[ \sum_{j=i+1}^n \text{sgn}(R_j - R_i) \right]$$

Where

$$\text{sgn}(x) = 1 \text{ for } x > 0$$

$$\text{sgn}(x) = 0 \text{ for } x = 0$$

$$\text{sgn}(x) = -1 \text{ for } x < 0$$

If the null hypothesis  $H_0$  is true, then S is approximately normally distributed with:

$$\mu = 0$$

$$\sigma = \frac{n(n-1)(2n+5)}{18}$$

The z-statistic is therefore (critical test statistic values for various significance levels can be obtained from normal probability tables):

$$z = |S|/\sigma^{0.5}$$

A positive value of S indicates that there is an increasing trend and vice versa.

## 2- Spearman's Correlation

This is a rank-based test that determines whether the correlation between two variables is significant. In trend analysis, one variable is taken as the time itself (years) and the other as the corresponding time series data. Like the Mann-Kendall Test, the n time series values are replaced by their ranks. The test statistic  $\rho_s$  is the correlation coefficient, which is obtained in the same way as the usual sample correlation coefficient, but using ranks:

$$\rho_s = S_{XY}/(S_X S_Y)^{0.5}$$

$$S_X = \sum_{i=1}^n (X_i - \bar{X})^2$$

$$S_Y = \sum_{i=1}^n (Y_i - \bar{Y})^2$$

$$S_{XY} = \sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})$$

and xi (time), yi (variable of interest), x and y refer to the ranks (x, y, S<sub>x</sub> and S<sub>y</sub> have the same value in a trend analysis). For large samples, the quantity  $\rho_n$  is approximately normally distributed with mean of 0 and variance of 1 (critical test statistic values for various significance levels can be obtained from normal probability tables).

## 3- Rank-Sum Test

This method tests whether the medians in two different periods are different. It is a nonparametric test. To compute the rank-sum test statistic: Rank all the data, from 1 (smallest) to N (largest). In the case of ties (equal data values), use the average of ranks; Compute a statistic S as the sum of ranks of the observations in the smaller group (the number of observations in the smaller group is denoted as n, and the number of observations in the larger group is denoted as m); and compute the theoretical mean and standard deviation of S under H<sub>0</sub> for the entire sample

$$\mu = n(N+1)/2 \quad \sigma = [nm(N+1)/12]^{0.5}$$

The standardized form of the test statistic Z<sub>rs</sub> is computed as:

$$Z_{rs} = (S - 0.5 - \mu) / \sigma \quad \text{if } S > \mu$$

$$Z_{rs} = 0 \quad \text{if } S = \mu$$

$$Z_{rs} = |S + 0.5 - \mu| / \sigma \quad \text{if } S < \mu$$

Z<sub>rs</sub> is approximately normally distributed, and the critical test statistic values for various significance levels can be obtained from normal probability tables.

## 2.4 Methodology

For data of climatic nature non-parametric trend tests are preferred. The mean monthly temperature data was climatic in nature, since temperature is a climatic parameter. Thus Mann-Kendall Non-Parametric Trend Test was used for detection of trends in temperature in the selected sub-basins of Upper Indus River Basin.

## 2.5 Mann Kendall Trend Test

There are two advantages of using this test. First, it is a non-parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set. According to this test, the null hypothesis H<sub>0</sub> assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H<sub>1</sub>, which assumes that there is a trend [15].

## 2.6 Computational Procedure

The computational procedure for the Mann Kendall test considers the time series of n data points where T<sub>i</sub> and T<sub>j</sub> as two subsets of data where i = 1,2,3,..., n-1 and j = i+1, i+2, i+3, ..., n. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S [16].

## 2.7 Mann-Kendall, S Statistic

The Mann-Kendall S Statistic is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sign}(T_j - T_i)$$

$$\text{sign}(T_j - T_i) = \begin{cases} 1 & \text{if } T_j - T_i > 0 \\ 0 & \text{if } T_j - T_i = 0 \\ -1 & \text{if } T_j - T_i < 0 \end{cases}$$

where T<sub>j</sub> and T<sub>i</sub> are the annual values in years j and i, j > i, respectively. If n < 10, the value of |S| is compared directly to the theoretical distribution of S derived by Mann and Kendall. The two tailed test is used. At certain probability level H<sub>0</sub> is rejected in favor of H<sub>1</sub> if the absolute value of S equals or exceeds a specified value S<sub>α/2</sub>, where S<sub>α/2</sub> is the smallest S which has the probability less than α/2 to appear in case of no trend. A

positive (negative) value of S indicates an upward (downward) trend [16].

2.8 Variance ( $\sigma^2$ ) for the S-statistic

The variance ( $\sigma^2$ ) for the S-statistic is defined by:

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum_{i=1}^g t_i(t_i-1)(2t_i+5)}{18}$$

where  $t_i$  denotes the number of ties to extent  $i$  and  $g$  is the number of tied groups. The summation term in the numerator is used only if the data series contains tied values [17].

2.9 Standard Test Statistic  $Z_s$

The standard test statistic  $Z_s$  is calculated as follows:

$$Z_s = \begin{cases} \frac{S-1}{\sigma} & \text{for } S > 0 \\ 0 & \text{for } S = 0 \\ \frac{S+1}{\sigma} & \text{for } S < 0 \end{cases}$$

The test statistic  $Z_s$  is used as a measure of significance of trend.

In fact, this test statistic is used to test the null hypothesis  $H_0$ . If  $|Z_s|$  is greater than  $Z_{\alpha/2}$ , where  $\alpha$  represents the chosen significance level (e.g.: 5% with  $Z_{0.025} = 1.96$ ) then the null hypothesis is invalid implying that the trend is significant [17].

2.10 Sources of Error

No information available about the number of precipitation gauges and temperature sensors used in each sub-basin to record precipitation and temperature data. Also, the exact location of these gauges and sensors is unknown. The lack of uniformity in precipitation gauges and temperature sensors can influence the quality of recorded data [18]. It is mentioned on the website of data center of Pakistan Meteorological Department (PMD) that probability of collecting 100% correct data is very low due to data transmission problems which occur while the data is transmitted from stations to the data center.

3. Analysis & Results

The value of  $Z_s$  for all five substations is shown in the Table-2. Now Table 2 shows the value of  $Z_s$  calculated for all twelve months for all five stations respectively, using mann-kendall trend test.

Station	Statistics	January	February	March	April	May	June	July	August	September	October	November	December
Astor	Z	0.85	1.42	2.25	1.63	1.73	3.24	0.82	0.97	-1.98	1.48	0.81	-0.14
	Critical Z Value, $\alpha=5\%$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$
	H. hypothesis	Accept	Accept	Reject	Accept	Accept	Reject	Accept	Accept	Reject	Accept	Accept	Accept
	Trend, $\pm$	No	No	Yes(+)	No	No	Yes(+)	No	No	Yes(-)	No	No	No
Drosh	Z	0.00	-1.36	1.55	-0.64	0.45	-1.20	-2.25	-1.96	-2.56	0.00	-2.62	-1.36
	Critical Z Value, $\alpha=5\%$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$
	H. hypothesis	Accept	Accept	Accept	Accept	Accept	Accept	Reject	Accept	Reject	Accept	Reject	Accept
	Trend, $\pm$	No	No	No	No	No	No	Yes(-)	No	Yes(-)	No	Yes(-)	No
Gilgit	Z	0.82	1.34	2.74	2.17	1.49	2.00	-0.49	0.00	-2.23	2.72	2.06	0.08
	Critical Z Value, $\alpha=5\%$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$
	H. hypothesis	Accept	Accept	Reject	Reject	Accept	Reject	Accept	Accept	Reject	Reject	Reject	Accept
	Trend, $\pm$	No	No	Yes(+)	Yes(+)	No	Yes(+)	No	No	Yes(-)	Yes(+)	Yes(+)	No
Gupis	Z	0.54	0.47	2.27	0.89	1.22	1.22	-0.64	-1.20	-1.53	2.44	0.21	0.29
	Critical Z Value, $\alpha=5\%$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$
	H. hypothesis	Accept	Accept	Reject	Accept	Accept	Accept	Accept	Accept	Accept	Reject	Accept	Accept
	Trend, $\pm$	No	No	Yes(+)	No	No	No	No	No	No	Yes(+)	No	No
Skurdu	Z	0.25	0.49	0.99	0.23	0.64	-0.12	-1.40	-1.09	-2.97	-0.56	-1.96	-1.57
	Critical Z Value, $\alpha=5\%$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$	$\pm 1.96$
	H. hypothesis	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Reject	Accept	Reject	Accept
	Trend, $\pm$	No	No	No	No	No	No	No	No	Yes(-)	No	Yes(-)	No

Table 2: Tabulated value of  $Z=Z_s$  against  $Z_{cr}$

### 3.1 Tabulated Result

This value of  $Z_s$  is than compared with the value of critical  $Z$  or  $Z_{cr}$  for the significance level of 5%, which comes out to be  $\pm 1.96$ .

- If the value of  $Z_s$  is greater than +1.96 than this will imply that there is an increasing trend.
- If the value of  $Z_s$  is smaller than -1.96 than this will imply the presence of a decreasing trend.
- For all values between +1.96 and -1.96; it is considered that there is no significant trend. Neither increasing nor decreasing.
- For values of  $Z_s$  greater than +1.96 and smaller than -1.96 the null hypothesis is rejected.
- For all values of  $Z_s$  in between  $\pm 1.96$ , null hypothesis is accepted.

When the null hypothesis is rejected, trend is accepted and similarly if null hypothesis is accepted than trend is rejected. Using this approach Table 2 shows 3 accepted trends in March, June and September for Astore station.

### 3.2 Graphical Representation of Results

#### 1- Astore Standard Test Statistic Graph

The results from the trend analysis of mean monthly temperature data of Astore station shows that for Astore station, the  $Z_s$  test statistic plotted in Figure 2 for the month of March ( $Z_s = 2.25$ ) and for the month of June ( $Z_s = 3.24$ ) is higher than the critical value of 1.96 at ( $\alpha = 5\%$  or 0.05) significance level.

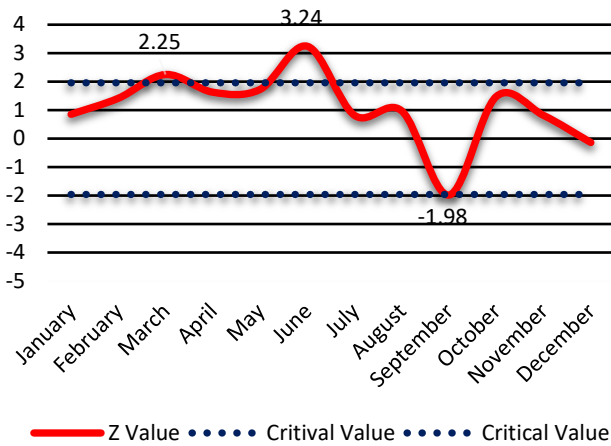


Figure 2: Graph plotted for Astore station between  $Z_s$  calculated and  $Z$  critical at Significance level  $\alpha = 0.05$

This shows increasing trend which indicates higher temperature during summer and early arrival of summer season. The results also show the  $Z_s$  test statistic for month of September ( $Z_s = -1.98$ ).

#### 2- Drosh Standard Test Statistic Graph

The results from the trend analysis of mean monthly temperature data of Drosh station shows no considerable variation in trend for summer season. Whereas the results show the  $Z_s$  test statistic plotted in Figure 3 for month of July ( $Z_s = -$

2.25), September ( $Z_s = -2.56$ ) and November ( $Z_s = -2.62$ ) there is a considerable decreasing trend which indicates lowering of temperature and early arrival of winter season.

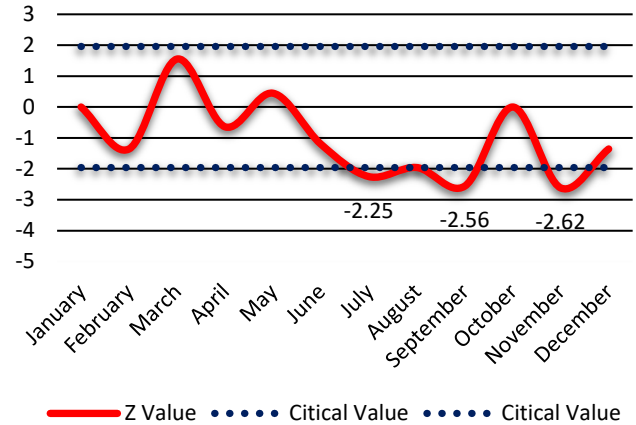


Figure 3: Graph plotted for Drosh station between  $Z_s$  calculated and  $Z$  critical at Significance level  $\alpha = 0.05$

#### 3- Gilgit Standard Test Statistic Graph

The results from trend analysis of mean monthly temperature data of Gilgit station show that for Gilgit station, the  $Z_s$  test statistic plotted in Figure 4 for the month of March ( $Z_s = 2.74$ ), April ( $Z_s = 2.17$ ) and June ( $Z_s = 2$ ) is higher than the critical value of 1.96 at ( $\alpha = 5\%$  or 0.05) significance level. This shows increasing trend which indicates higher temperature during and early arrival of summer season.

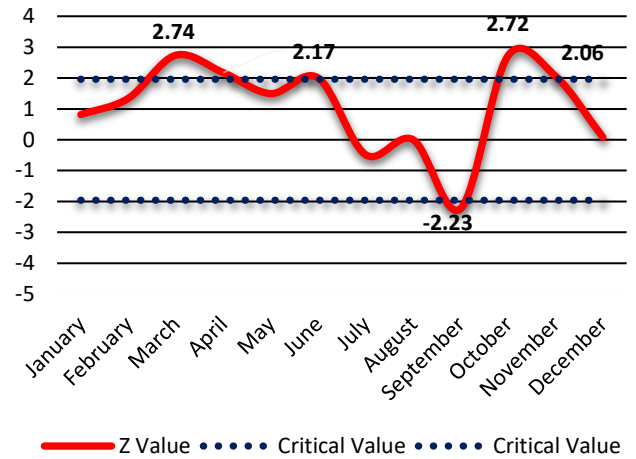


Figure 4: Graph plotted for Gilgit station between  $Z_s$  calculated and  $Z$  critical at Significance level  $\alpha = 0.05$

The results also show the  $Z_s$  test statistic for month of September ( $Z_s = -2.23$ ) there is a considerable decreasing trend which indicates lowering of temperature and early arrival of winter season. But the months of October ( $Z_s = 2.72$ ) and November ( $Z_s = 2.06$ ) show complex increasing trends (may be due to errors in data observation) which indicate increase of temperature during winter season.

#### 4- Gupiz Standard Test Statistic Graph

The results from the trend analysis of mean monthly temperature data of Gupiz station show that for Gupiz station,

the  $Z_s$  test statistic plotted in Figure 5 for the month of March ( $Z_s=2.27$ ) is higher than the critical value of 1.96 at ( $\alpha=5\%$  or 0.05) significance level. Which shows increasing trend which indicates higher temperature during and early arrival of summer season. But the months of October ( $Z_s=2.44$ ) show unexpected increasing trends which indicate increase of temperature during winter season.

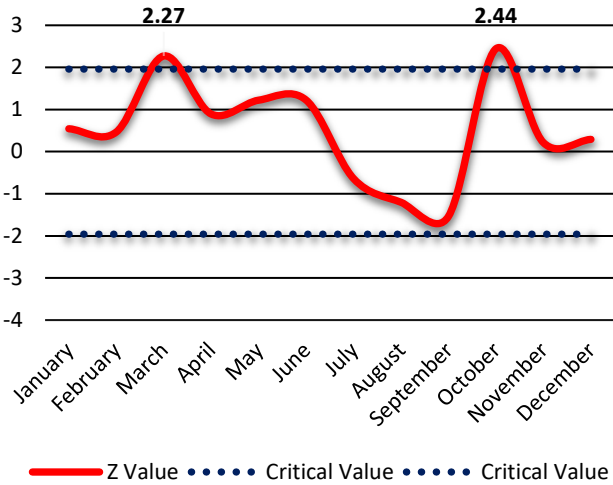


Figure 5: Graph plotted for Gupiz station between  $Z_s$  calculated and  $Z$  critical at Significance level  $\alpha = 0.05$

### 5- Skardu Standard Test Statistic Graph

The results from the trend analysis of mean monthly temperature data of Skardu station show that for Drosh station, the  $Z_s$  statistic plotted in Figure 6 shows no considerable variation in trend for summer season. Whereas the results show the  $Z_s$  test statistic for month of September ( $Z_s = -2.97$ ), November ( $Z_s = -1.96$ ) there is a considerable decreasing trend which indicates lowering of temperature and early arrival of winter season.

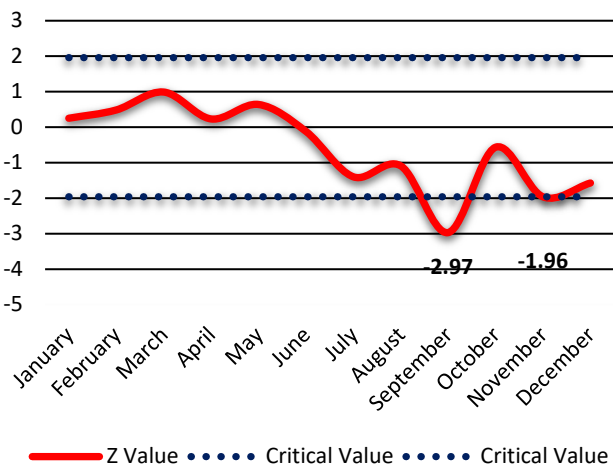


Figure 6: Graph plotted for Skardu station between  $Z_s$  calculated and  $Z$  critical at Significance level  $\alpha = 0.05$

### 3.3 Seasonal Comparison

1- For Winter Season plotted in Figure 6:

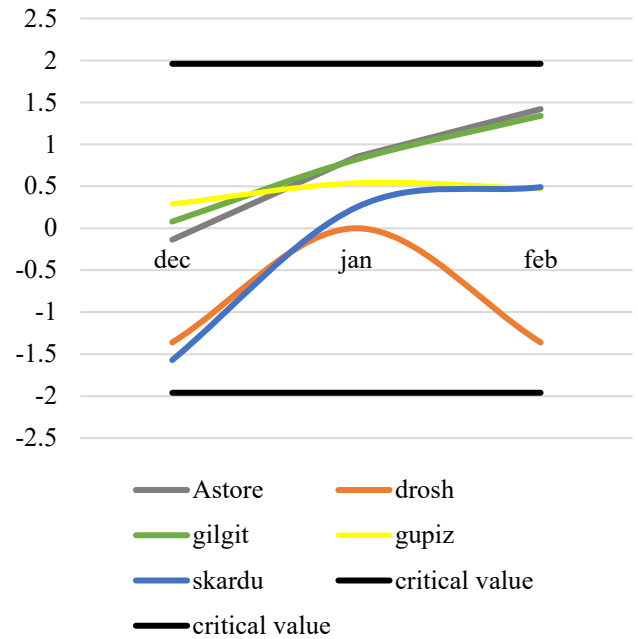


Figure 7: No increasing or decreasing trend in winter

2- For Spring Season plotted in Figure 7:

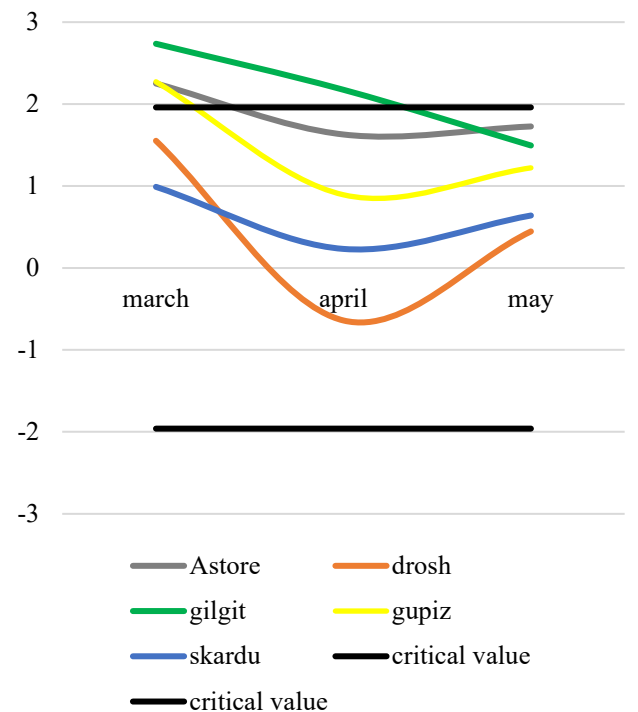


Figure 8: Increasing trend detected in Gupiz, Astore & Gilgit (Temperature starts increasing from March)

3- For Summer Season plotted in Figure 8:

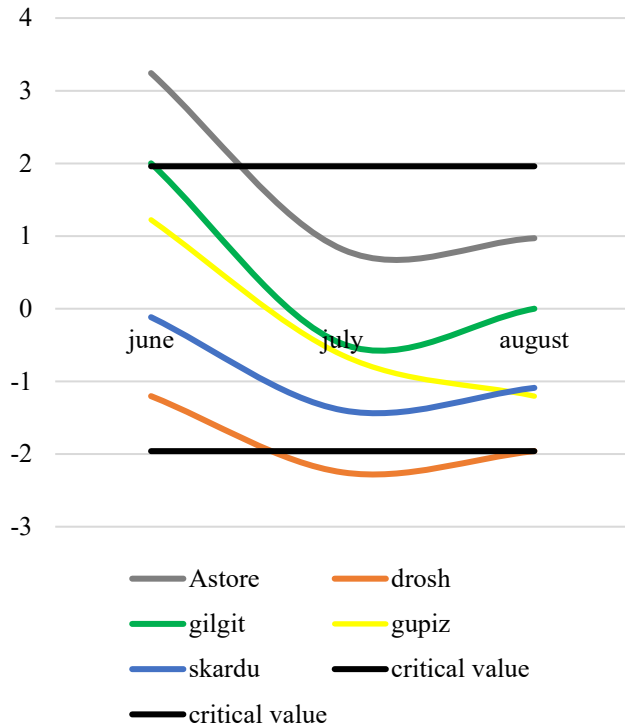


Figure 9: Increasing trend detected in Astore and Gilgit for June and abnormal decreasing trend in Drosh for July

4- For Autumn Season plotted in Figure 9:

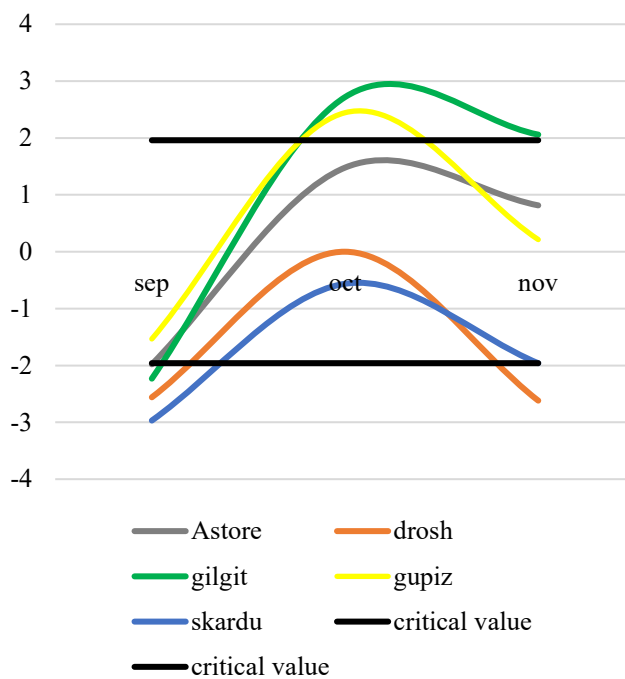


Figure 10: Decreasing trends in Skardu, Drosh & Gilgit for September; Increasing trend in Gupiz & Gilgit for October

4. Conclusions & Recommendations

4.1 Conclusions

The main aim of this study was to detect trends in mean monthly, seasonal and annual temperature resolution in Upper Indus River Basin (UIRB), KP, Pakistan for five selected meteorological stations using Mann-Kendall Trend Test. The study revealed the following findings:

- i. A generalized increase was noted in mean monthly temperature at most time scales and particularly in winter, pre-monsoon, and at the annual resolution. The maximum increase in temperature was found in March and in the pre-monsoon season.
- ii. There were numbers of locations showing significant increasing trends (Positive) than decreasing trends (Negative) in different seasons.
- iii. A generalized cooling was observed in mean monthly temperature in study region in the monsoon, post-monsoon and on the annual time scale. While mean monthly temperature increased significantly in these areas in winter, pre-monsoon, post-monsoon and on an annual basis.
- iv. Mean monthly temperature increased abruptly from February to May (especially in March); July, August, and October; winter and the pre-monsoon season; and at the annual resolution. Rate of increase in mean monthly temperature during pre-monsoon period was found higher as compared to the rate of decrease in mean monthly temperature during post-monsoon period.
- v. A significant increasing trend in mean monthly temperature was noted at Astore, Gilgit and Gupiz during the month of March and a considerably decreasing trend in mean monthly temperature for the Astore, Drosh, Gilgit and Skardu stations in the month of September.
- vi. Gilgit and Gupiz showed unexpected increasing trend in mean monthly temperatures in the month of October.
- vii. Temperature starts increasing in March and stays elevated till the onset of winter and starts rising again in October thus expansion of summer season and prolonged glacial melting.

4.2 Recommendations

1- Control Global Warming

All preventive measures for control of global warming should be given serious thought and standard operating procedures should be implemented. Such as:

- Deforestation should be discouraged.
- Use of fossil fuels should be minimized. etc.

2- Store Excess Water

- Preparations should be made to increase storage capacity of reservoirs.
- Building new reservoirs must be prior consideration.

3- Reforms in Agriculture

Time of harvesting of summer crops and time of sowing of winter crops should be managed.



#### 4- Flood Control

Studies should be carried out for mapping of endangered settlements in flood prone areas.

#### 5- Further Research

The scope of this study was curbed to only five sub basins of Upper Indus Basin (UIB) and to only 30 years of data. More comprehensive studies should be carried out using data of more than 30 years and by increasing the area of interest (AOI) i.e., number of sub basins of Upper Indus Basin (UIB). Large scale studies will give a comprehensible and broader image of the temperature trends in the Upper Indus Basin (UIB). Furthermore the studies conducted for temperature trends should be compared with the studies conducted for other climatological parameters such as precipitation and humidity to investigate the climatic patterns in depth.

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