ENVIRONMENTAL DISASTER ASSESSMENT USING GEOSPATIAL TECHNIQUES FOR HUNZA-NAGAR DISTRICT, GILGIT-BALTISTAN, PAKISTAN

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ABSTRACT: *Environmental disasters are common events across the globe due to climatic extremes. Historically, Hunza and Nagar districts in northern Pakistan experienced terrible natural disasters. Floods in 2010 became a leading destroyer of several traditional canal systems and hundreds of acres of cultivated land whereas several flora and fauna species had to face this attached risk. Similarly, Attabad landslide, on January 04, 2010, increased the vulnerability of all biota living in or beside and marginally aside of Hunza-Nagar river basin. Due to these natural disaster events, this region experienced tangible and intangible losses. This study has utilized geospatial and statistical techniques for disaster impact assessment. The climatic data from 2007 to 2013, disaster event data from 1999 to 2014 and calculated Land Surface Temperature (LST) using Landsat ETM+2010 have been used in the analysis. Statistical time series technique has been applied to observe the variability of climatic variables (temperature and precipitation) and environmental disaster events. Flood disasters resulted to be the most repeated events which struck the study area 102 times during 1999 to 2014 but landslide was observably low repeated event. There was an alarming level of flood disaster in Hunza and Nagar from 1999 to 2010. The overall trend line revealed that disaster events were considerably increased during the study period. Climatic variables (temperature and precipitation) causing floods played an important role increasing vulnerability. However, the usage of Satellite Remote Sensing technology (SRS) and Geographic Information Systems (GIS) has developed as a cohesive approach, fruitful tools for disaster assessment. This study enhances the understanding of disaster management technique using modern geospatial technologies.*

Keywords: GIS, SRS LST, Natural Disasters, NDVI, Time Series

1. INTRODUCTION

In 2011, global Environmental disasters caused deaths of 30773 people and made 244.7 million victims [1]. For the mitigation of natural disasters, it is really important to monitor these events using modern geospatial technology. The purpose of monitoring and preparedness is to reduce the residual risk through early warning system and mitigate the disaster effects [2]. Many regions in the world are exposed to several types of natural disaster, each with their own spatial characteristics [3]. Khan (1993) studied that approximately 90% of the world's natural disasters originate from the four types of hazards, i.e. flood, tropical cyclones, earthquakes and droughts [4]. Csavallo and Noy (2010) observed 96% people dead and 99% of the inhabitants affected by natural catastrophes during the years 1970-2008 in the Asia-Pacific Regions [5]. The landslides and flood disasters have increased in the Pacific-Asia regions from 1970 to 2000 and these events has been grown an average 11 events per country [6]. Pakistan also faced multiple disasters which caused severe damages. According to Qasim *et al.*, (2016) flood disasters affected an area of 613,721 km^2 and caused huge economic damages of more than 38.06 billion US$ in Pakistan [7]. Gilgit-Baltistan province is one of the remote areas with inadequate infrastructure where it is difficult to retain records of the events of various environmental disasters. In 1980 during the Karakorum Highway (KKH) construction, 339 disaster locations from Gulmit to Gilgit were identified [8]. According to observed records, there was an increased tendency in occurrence of environmental disasters in Hunza-Nagar Districts over the past four decades. The most apparent event was flood as per available records. However, author has analyzed the models on the basis of available data. This natural disaster analysis was conducted using 1996-2010 reported data comprising disaster damage areas of crop land, number of deaths, number of injured and direct tangible and intangible losses in the study area. There were three major devastating disaster events occurred in this region such as Phakar (Kota) in 1937, Shimshal in 1963 and recent catastrophic landslide disaster in Attabad during 2010 which created a lake with hundred-meter (100m) deep and one-kilometer (1km) width respectively [9]. In the northern part of Pakistan that 8 October Earthquake has triggered of landslides disaster which was the major impacts on our environment [10]. However, flood disasters are also one of the most important factors to increase the vulnerability. After the flood disaster, incorporated pending threats of a new hazard that is always expected in such mountainous areas are higher. The main objective of this manuscript is to unlock and suggest that how geospatial technology can minimize the impact of natural disasters and how much affect the climatic factors (temperature & precipitation) on disasters can trigger. However notable point about the Pakistan is an arid region [11] (Naheed & Rasul, 2011) including study area in which environmental disasters occur frequently in monsoon season.

2. STUDY AREA

The study was carried out in Hunza and Nagar districts of Gilgit-Baltistan shown in Figure 1. The geographical position of the study area is in between 76˚ 0' 45.354" E, 73˚ 59' 26.466" E, 36˚ 51' 38.359" N, 35˚ 55' 22.231" N. It is situated at an average altitude of 3000m from the mean sea level [7]. Hunza and Nagar cover an approximate area of 14305.07 km^2 with an estimated population of 98760 in 1998 census report. Most of the people settled along Hunza-Nagar River. Hunza and Nagar have thousands of streams, lakes and tons of glacier reserves provide fresh water to the low-lying Indus plain. River Hunza-Nagar is the major tributary of the mighty Indus River irrigation system which contributes almost one fifth to the Upstream Indus flow [12]. The snow cover area stretches to approximately 80% in winter season and decreases to 30% in summer [12]. The region has mountain climate with 18˚C mean maximum annual temperature while total annual precipitation is 840.8mm. The area has steep mountain slopes which may trigger debris flow, avalanches and landslides. River Hunza-Nagar basin is also having the effects of climatic variability in the form of swift melting down of glaciers, extension of the main lakes and development of some new lakes which could result in lake outburst a flooding risk to the downstream areas [8].

In the study area, cryosphere is the dominant land class with small portion of vegetation canopy. For agricultural activities, intensive farming is normally practiced across the both district.

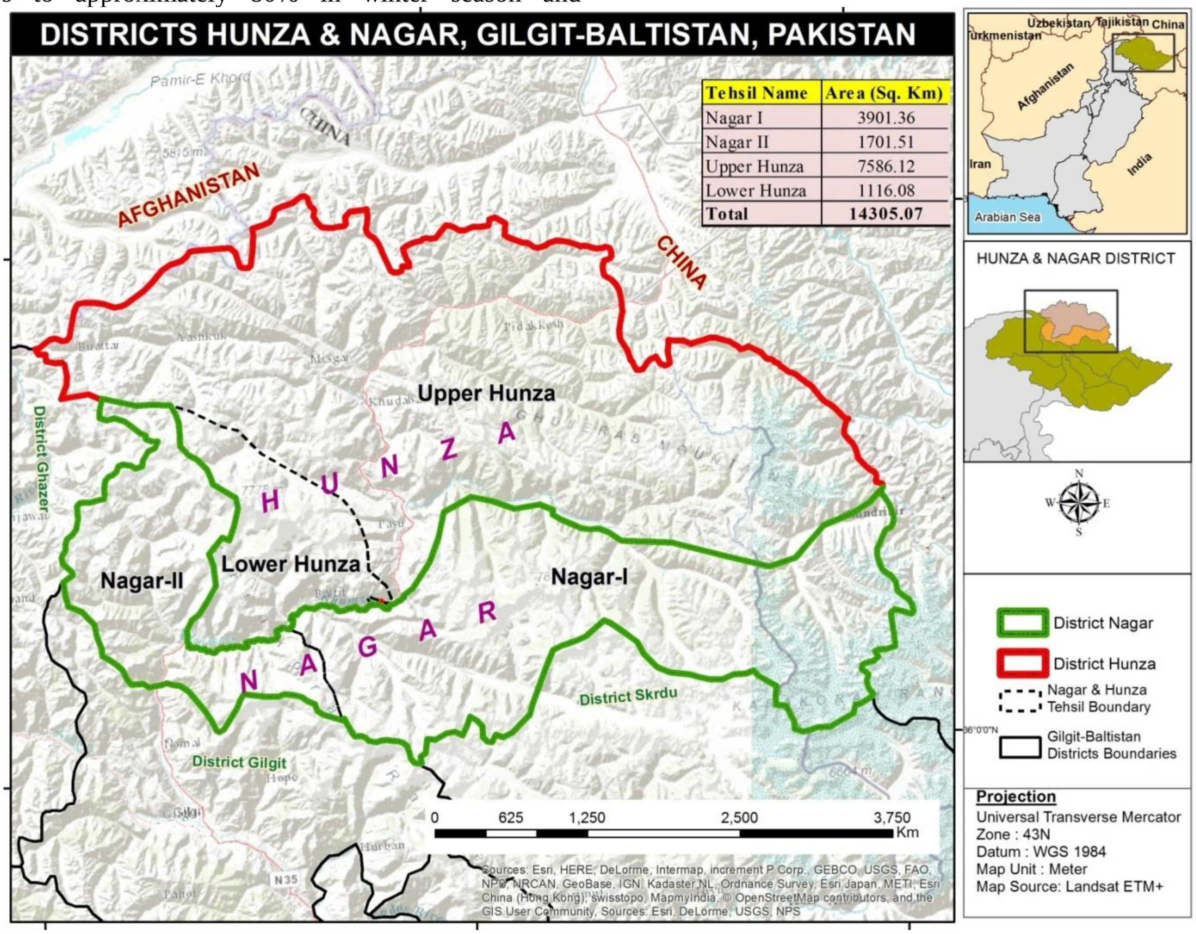

Figure 1: Study Area of Hunza and Nagar Districts, Province Gilgit-Baltistan

3. OBJECTIVES

a) To quantify the disaster risk zones using geospatial techniques.

b) To assess the tangible and intangible losses by natural disasters.

c) To explore the causes of natural disasters.

4. MATERIAL AND METHODS

4.1. Data sources: The methodological framework based on geospatial technology and available disaster and climatic data has been given in Figure 2. Temporal disaster data was used from 1996 to 2014 which was collected from reliable sources of Assistant Commissioner (AC) Office Nagar-II, Deputy Commissioner (DC) Office Nagar District and Gilgit-Baltistan Disaster Management Authority (GBDMA). Climatic data (2007 to 2013) including monthly mean maximum, monthly mean minimum temperatures and month based total of precipitation for the study area was collected from Pakistan Metrological Department (PMD) Karachi. Similarly, satellite images of Landsat ETM+ with 15m resolution for 2010 downloaded from USGS web sources.

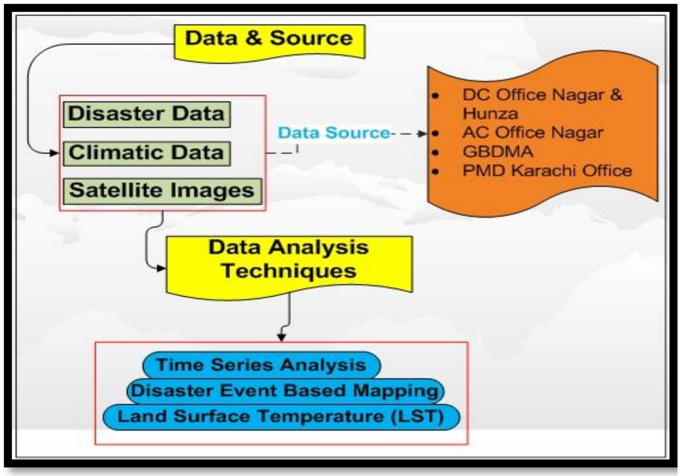

Figure 2: Methodological Framework

4.2. Techniques: Geospatial and statistical techniques were used to build geo-database for disaster events and mapping. GIS and Remote Sensing techniques can be used to enhance the capabilities of disaster management using digital mapping [13]. Remote Sensing (RS) techniques were applied to calculate surface temperature of the given study area using Land Surface Temperature (LST) technique The Land Surface Temperature has been calculated using satellite thermal infrared band of Landsat [14]. Mathematically, Land Surface Temperature (LST) model stated as;

Temp (k) = 209.831 + 0.834*DC – 0.00133*(DC)2

Where, Temp = Temperature, k = Kelvin Temp, DC = Thermal Band.

Hunza and Nagar districts were selected to analyze and extract village wise climatic data through zonal attribute analysis.

On the basis of temporal disaster database, authors developed disaster density map using grid techniques. This analysis was applied to explain the level of disaster risk locations in the study area. The statistical technique, correlation, trend line and time series analysis was applied.

A trend line in general is expressed in mathematics as; y = bo + b1*t. Where, b1 represents slope parameter and bo represents intercept parameter. If b1 is positive, a rise in ‘t’ will leads to an anticipated increase in response to y variable. Negative in b1 is considered to be an anticipated decline in response variable. The parameters i.e. ‘bo’ and ‘b1’ are estimated through least square method [15].

5. RESULTS AND DISCUSSION

Current study is based on two kinds of techniques i.e. geospatial and statistical techniques.

Figure 3 shows the variability of rainfall, minimum, maximum and mean temperature with respect to time. Maximum rainfall 244mm (in July 2007) recorded in the study area while maximum temperature 31°C and minimum temperature of -8.6ºC recorded. The disparity of temperature showed a cyclic pattern.

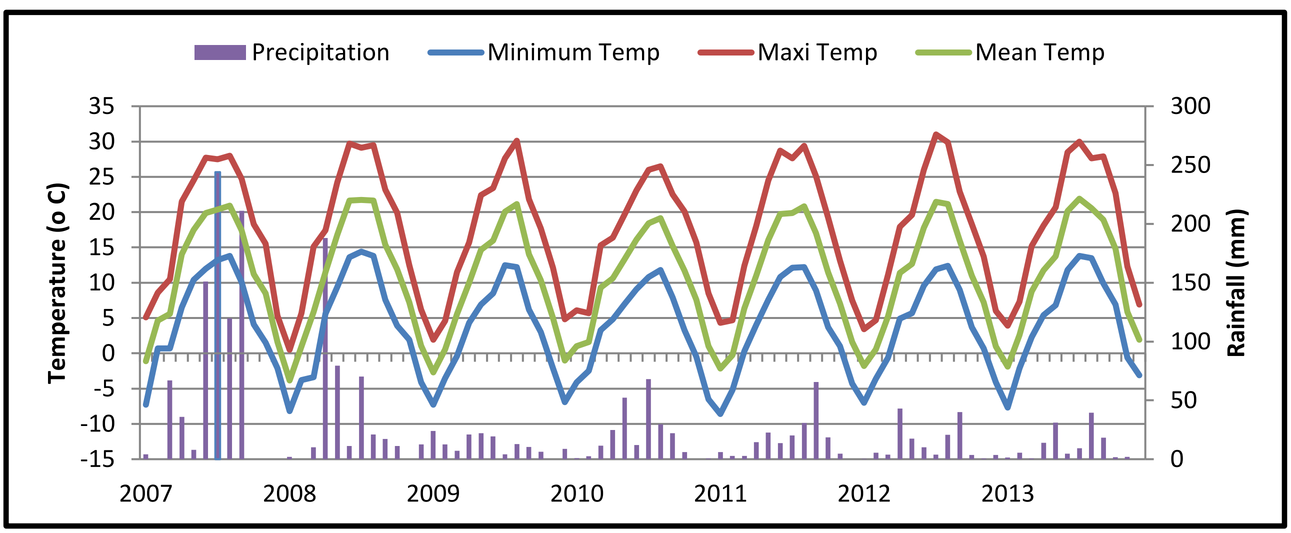

Figure 3: Time series of rainfall, minimum, maximum and mean temperature of Hunza-Nagar for 2007-2013

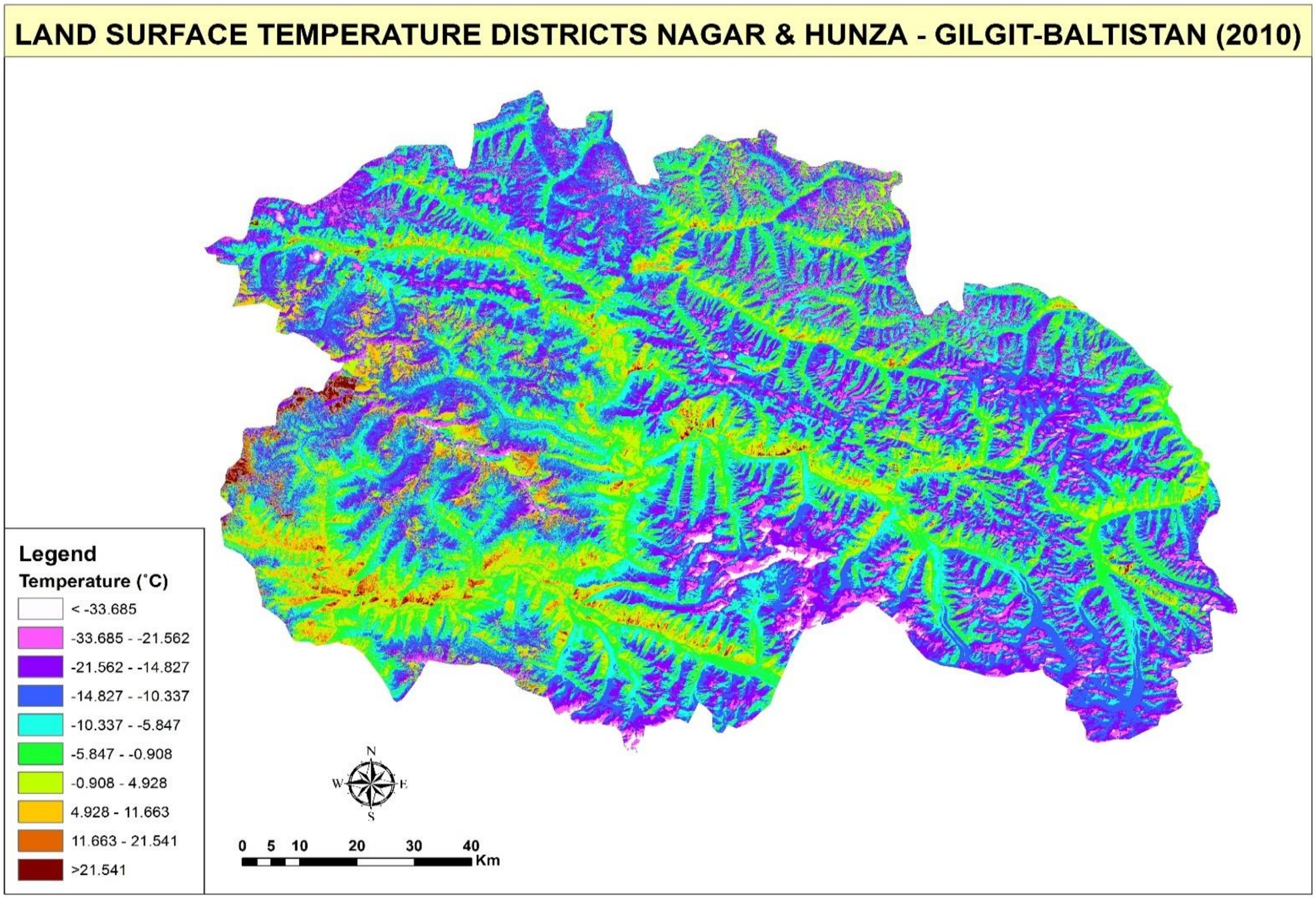

Figure 4: Land surface Temperature (LST) variation in Hunza-Nagar (2010)

Figure 4 revealed the result of Land Surface Temperature (LST) in different villages of Hunza and Nagar districts. The contemporary scientific progression enables thermal sensors to monitor land surface temperature over ecosystems at a local and worldwide scales [16]. The outcome of LST model was compared the surface temperature data with atmospheric data (PMD Center Karachi) of mean monthly maximum and mean monthly minimum temperature (Table 1). It was observed that maximum temperature of LST model was about 21.54 ˚C (30 September 2010) that was closely corresponding to the observed mean temperature of Pakistan Metrological Department (PMD) which has recorded as 22.5 ˚C for the above-mentioned date of the study area. In contrast, minimum temperature was not closely correlated. Because LST techniques provide information pixel base values while PMD data is acquired from atmosphere and these technical differences might cause variation in these results. However, most of the minimum values were observed from the glaciated covered areas. During this study village, wise mean temperature for the districts of Hunza and Nagar had been extracted. **Figure 5** showed that seven villages had high mean temperature (4 to 7 ˚C) and minimum temperature (-5 to -2 ˚C). These villages included Bar Das, Chalt Paeen, Gulmit, SAS Valley, Ahmad Abad, Aynabad and Gulphan.

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Table 1: Comparison between LST and PMD Climatic Data (September 30, 2010) Hunza and Nagar

Temperature (˚C)	LST	PMD
Maximum Temp	21.54 ˚C	22.5 ˚C
Minimum Temp	-33.68 ˚C	-8.6 ˚C

5.1. Natural Disaster Assessment

It was evident that affected land is more than other physical features on the surface due to these natural disasters. For landslide and flood disaster assessment, Trend model was used on the basis of occurred events and their Intensity. Hayakawa *et al.,* (2015) studied the trend analysis with respect to time for the selected region [17].

Figure 6 shows numbers of total of disaster events in Hunza & Nagar districts from 1999 to 2014. The reported data indicated that the floods were the most repeated disasters while rockslide, debris flow and landslides events relatively remained lesser repeated. Study area had its environment affected highly by landslide events. There was a distressing level of flooding disaster in this area. The total observed events were (also) significantly high i.e. “102” in the selected time period.

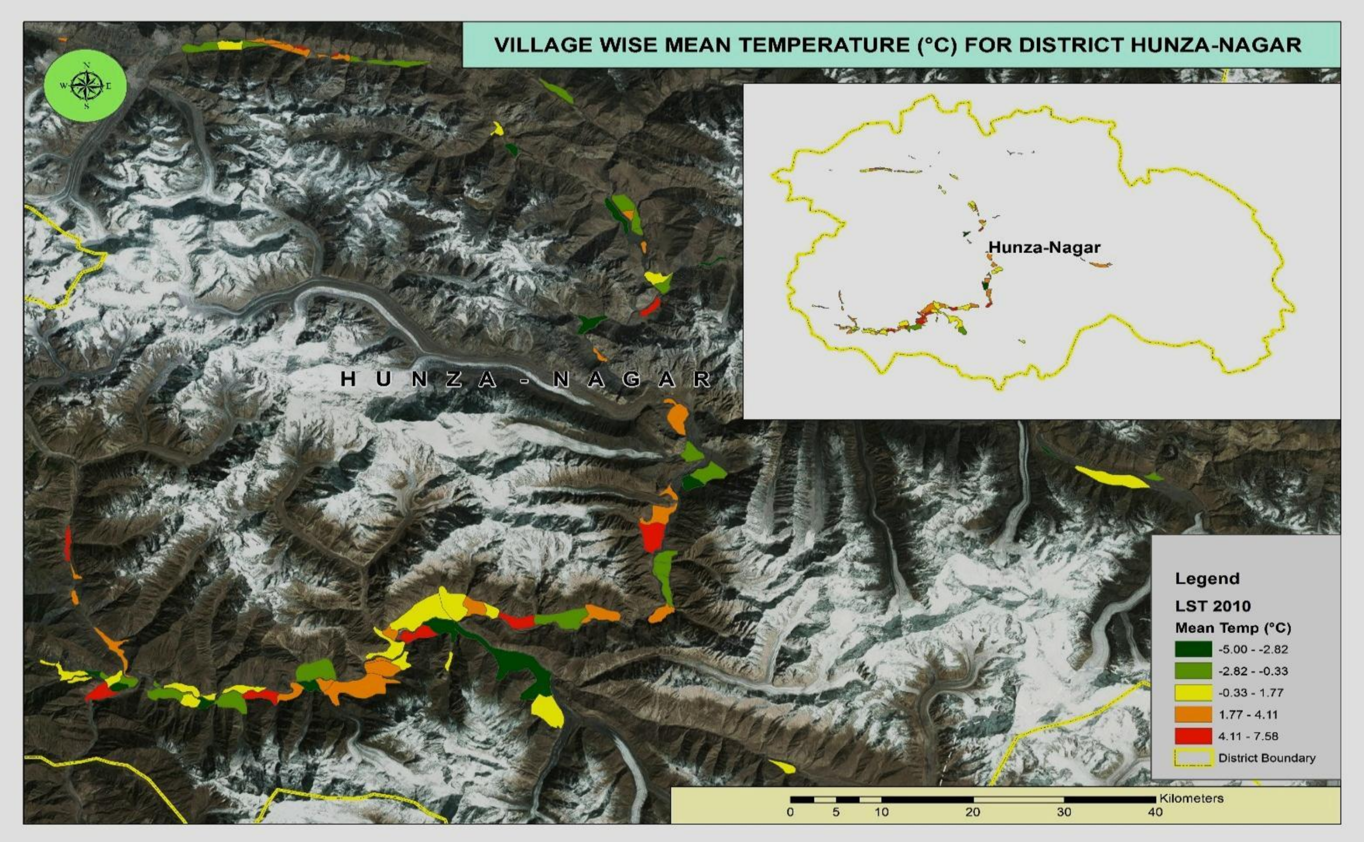

Figure 5: Village wise mean temperature analysis for districts Hunza-Nagar September 2010

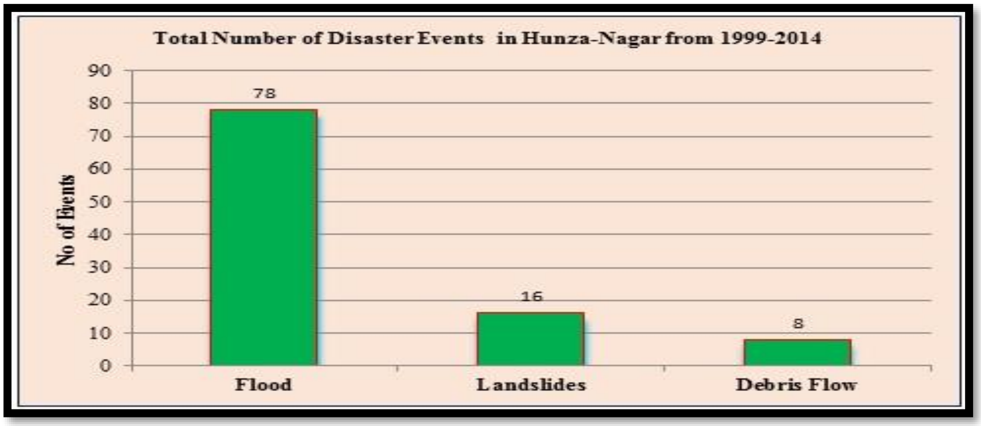

Figure 6: Histogram of total number of disaster events in Hunza-Nagar from the year 1999-2014

5.1.1. Hydrological Hazards

There is a main debate on the origins/causes of the disasters in our environment which can be numerous but time series which determines their severity should be known for better planning and management. Therefore, time series analysis has been undertaken. The time period here (for floods) divided into four intervals from 1999 to 2014. Figure 7 illustrates time plot of flood event with fitted line. The plot displays cumulative trend with positive (+) slope. Here sample data is comprised of four (04) intervals from 1999 to 2014 having total 78 events. So, this relationship could be denoted as $\hat{F} = 3.1 + 8.758*t$, Where F = Number of flood events, t = time, bo = 3.1 (intercept parameter), b1 = 8.758 (slope parameter) with correlation coefficient r = 0.3489, $R^2 = 59.079\%$. The slope value is very significant i.e. P-value < 0.05 at 5% level of significance whose confidence interval is 95%.

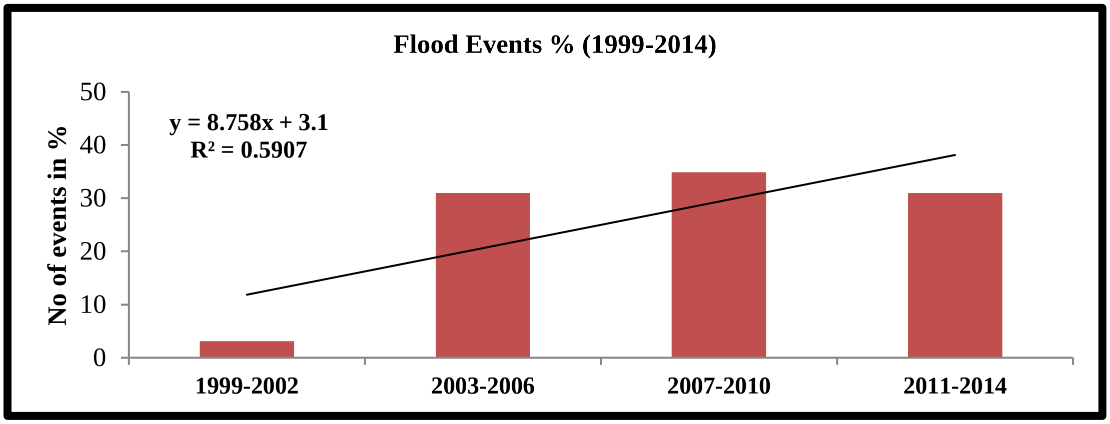

Figure 7: Time plot of flood disaster events with fitted liner trend line for Hunza-Nagar districts from 1999-2014

In flood level zones, noticeably, land use and land cover (LU and LC) types and the nature of the physical terrain were defining factors for existing flood localities [18]. Current study discusses extensive investigation on the basis of available data's increasing trend of natural disasters especially flood disaster between the years 1999 to 2014 which was found at alarming level in study area as indicated in figure 8. The figure highlights the flood event as repeated event mainly in 2010 when flood adversities were occurred in Nagar-Hunza. These natural disasters produced tangible and intangible losses specially from 2006 to 2010 when there was adverse situation of flooding. Total 795 houses were totally ruined, 14 houses moderately damaged, 565 Kanal (5.674 km^2) of cultivated land devastated and five irrigation channels destroyed by flood disaster in different villages of the study area in 2010. These flood disasters mostly occurred in dissimilar villages of Nagar-II i.e. Bar, Chaprote, Nelt and Jaferabad.

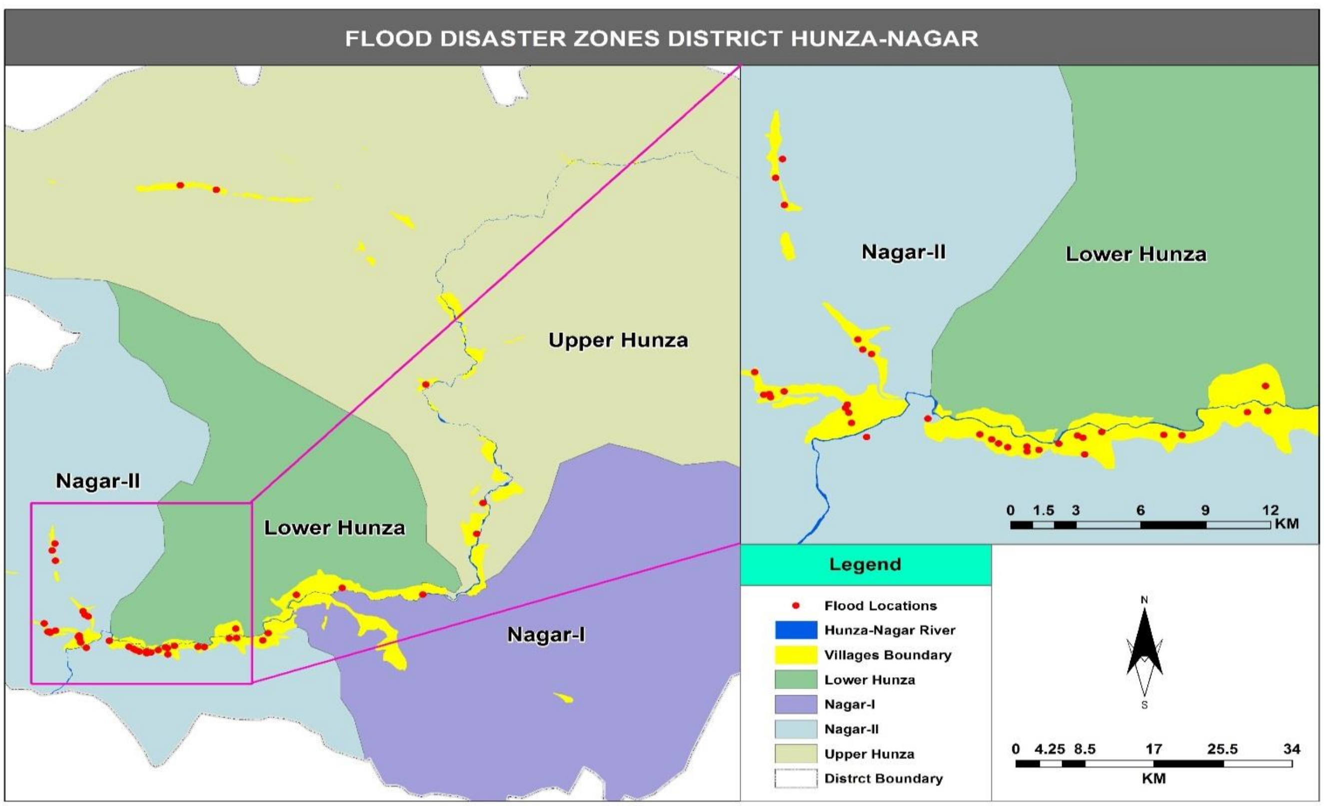

Figure 8: Flood disaster risk zones district Hunza -Nagar from 1999-2014

During this research, more than 56 flood locations were identified which were risk for human settlements. As a case study, two locations were highlighted, Chalt Nagar-II which was severely flood affected in 2010 and Shimshal valley affected by glacial outburst in 1963 as shown in figure 9. Shimshal disaster was a catastrophic event in the history that extended from Hunza-Nagar River to down areas of Pakistan. Passu village which is located 60 km downward faced devastating damages when flooding level reached 30m [19].

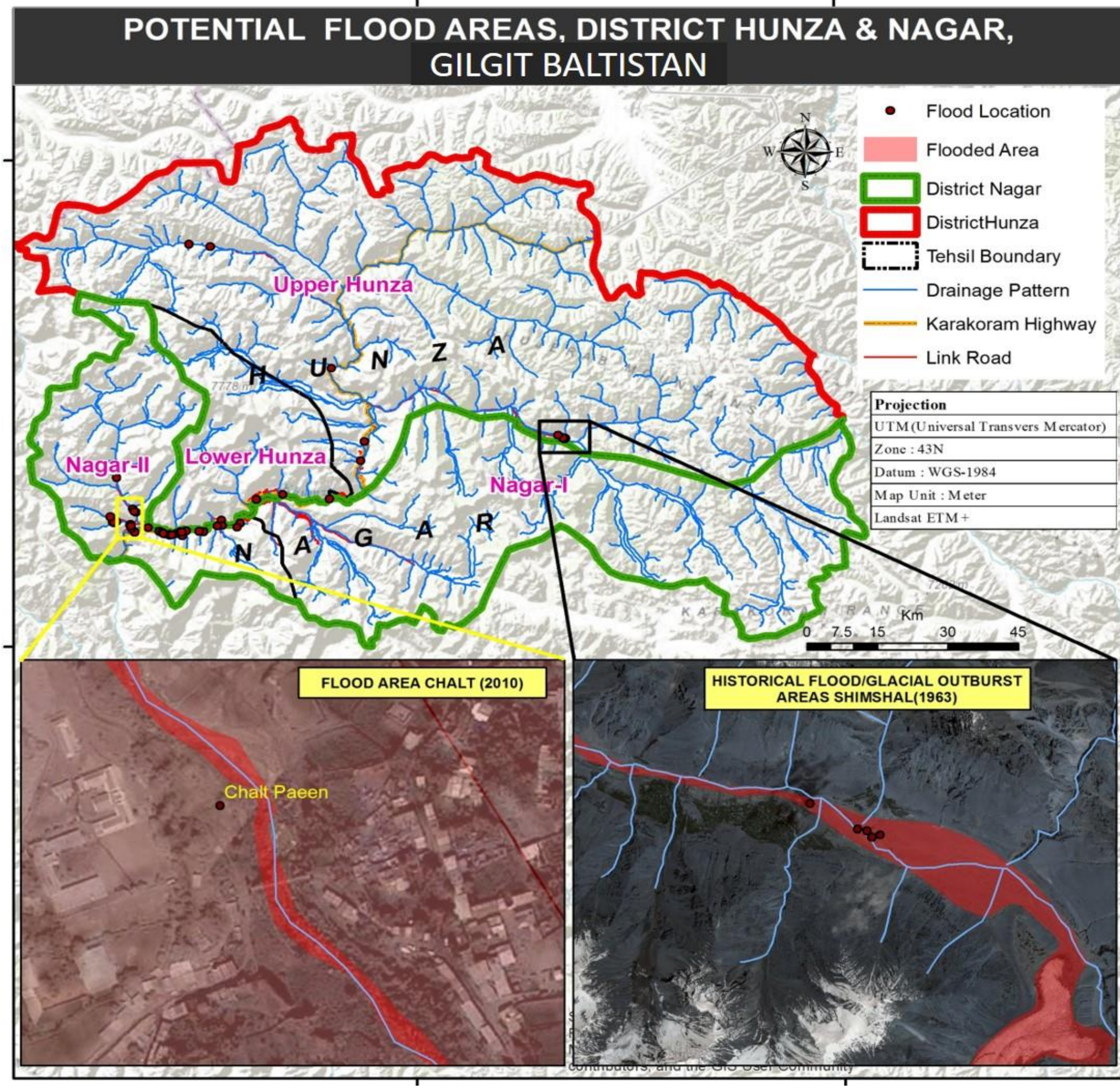

Figure 9: Flood affected areas of Hunza-Nagar districts, province Gilgit-Baltistan

5.1.2. Landslides Hazards

Landslide hazard assessment was significant parameter for prediction and management of natural disaster [15]. Figure 10 illustrates increasing trend of Landslide events having strong correlation with time. The sample data also consists of four (04) intervals (from 1999 to 2014) and has total Sixteen (16) events. The association (connection) characterized as, $\hat{L}$ = 10.00 + 6.00*t, Where L= no of Landslide events, t = time, bo = 10.00 (value of intercept), b1 = 6.00 (value of slope) with correlation coefficient r = 0.5184, R^2 = 72.00%. The positive slope (b1 = 6.00) showed sound significance because P-value < 0.05 at 5% level whose confidence interval is 95%.

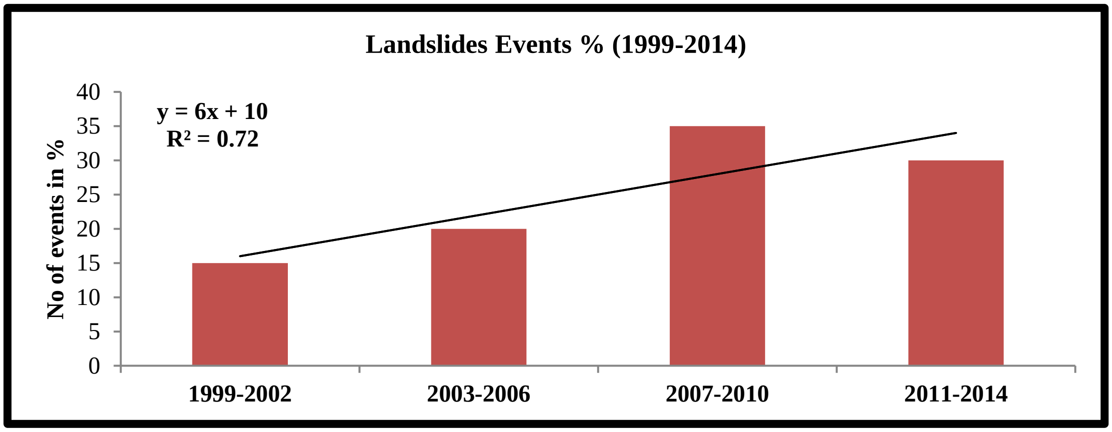

Figure 10: Time plot of Landslide disaster events with fitted liner trend line for Hunza-Nagar district from 1999-2014

Hunza and Nagar districts are considered as landslide prone areas due to steep and cut valleys. In 2010 (4th January) a huge mass of rock came down the slope at Attabad in Hunza that latter hit a small settlement close to the Hunza-Nagar River named Sarat village, killing 19 people [20]. After that Attabad landslide remained dangerous by the rising water level and hit five villages (Ayeenabad, Shishkat, Gulmit, Gulkin and Hussini). Because of Atabad landslide, Gilgit and downstream areas became highly vulnerable due to Lake Outburst flood hazards [21] and six villages were under high risk level. Approximately 3.05 km^2 of the village's area were under water while total lake extended 8.86 km^2 as shown in Figure11.

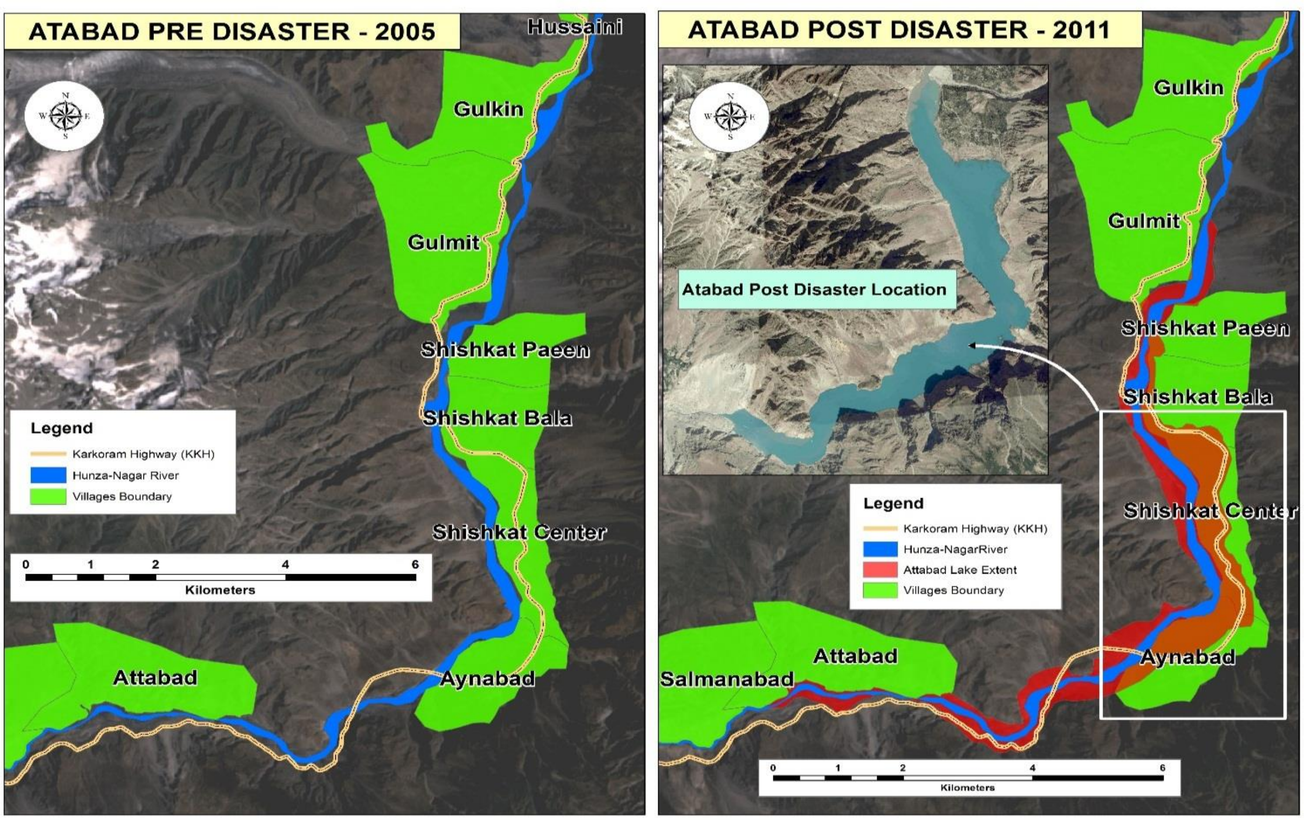

Figure 11: Landslide Area of Hunza District, Province Gilgit-Baltistan

Figure 12 explained the time plot of multiple disasters with fitted line (Landslides / Debris Flow / Floods) from 1999-2014 with total 102 events. The trend line stated as $\hat{\mathbf{D}} = 4.02 + 8.39*t$, (Where D= no of Disaster events, t = time, bo = 4.02 (value of intercept), b1 = 8.39 (value of slope) and coefficient of determination R^2 = 62.2%). This confirmed a good correlation (r = 0.622) as p-value < 0.05 at confidence interval 95%.

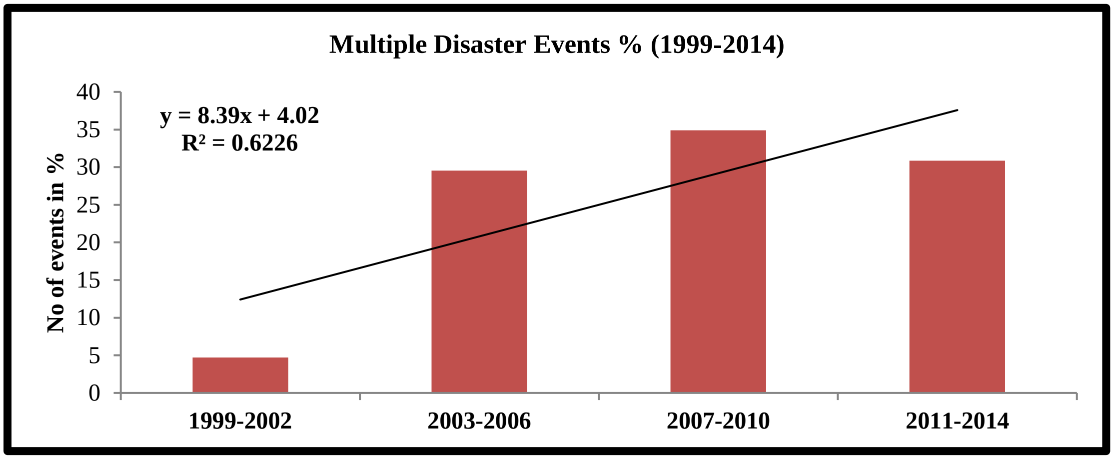

Figure 12: Time plot of multiple disaster events with fitted trend line for Hunza &Nagar districts from 1999-2014

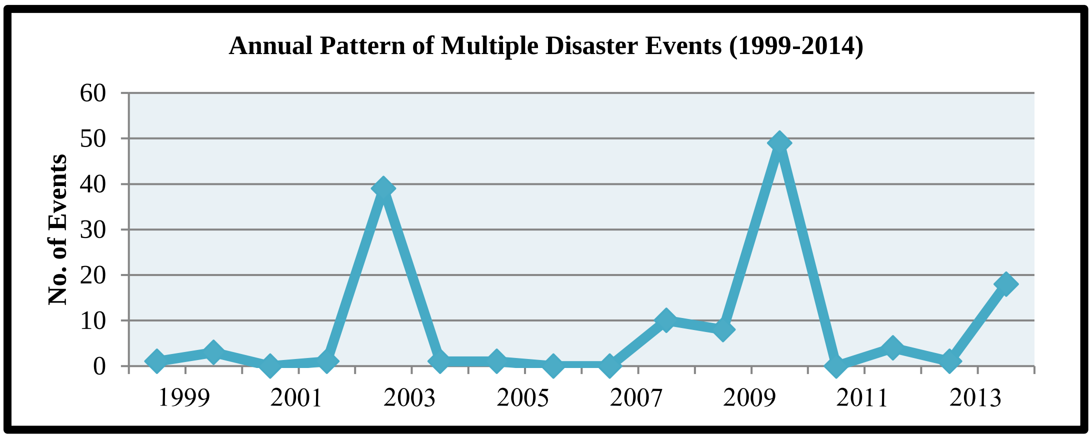

Figure 13: Time series of annual pattern of multiple disasters events (1999-2014) in district Hunza and Nagar

Finally, yearly situation of natural disasters (events) (from 1999 to 2014) revealed remarkable fluctuations in dissimilar years as indicated in figure 13. Maximum events occurred in 2003 and 2010. These natural disasters brutally affected the ecosystem and other parts of environmental locations.

6. CONCLUSION

Disaster assessment and climatic data analysis with geospatial risk management is a great debate in the world. Hunza-Nagar is highly vulnerable to natural disasters. A geospatial database of disaster locations was developed and climatic data was used to investigate the hydrological regime in the area. The trend of natural disaster events showed increasing trend in the region. However, results revealed that the climatic variables such as temperature increased while precipitation decreased in the study area. According to reported data, nearly 204.73 km^2 (20,386 kanal) land was destroyed, 81 people lost their lives and almost 4,005 forest trees got demolished by such environmental disasters. The study recognized more than 56 flood locations at risk (as risk zones) for humans and their activities. Unexpectedly, overall resulting trend of natural disasters showed that the region would be in alarming level of risk.

This sort of research calls for swift measures to mitigate the impact of natural disaster and will be useful for improvement of town planning through the use of the modern technologies including space related technologies (GIS & SRS) and can minimize the impact of natural disasters. Optimistically, this study will be helpful to understand the status of disasters and importance advanced approaches enabling us to prepare geospatial assessment plans for disaster prone areas.

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