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Extent and evaluation of flood resilience in Muzaffarabad City, Azad Jammu and Kashmir, Pakistan

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Abstract

Globally, high altitudes are more prone to a number of hazards. Mountains become more disastrous in regions where people's preparedness and response are weak. In such circumstances the risk and exposure of Governmental and non-governmental organizations as well as the indigenous community have been challenged to enhance the disaster resilience capabilities. The city of Muzaffarabad is exposed to hydro meteorological and geological hazards and producing damages to life, property and infrastructure. In this research an attempt has been made to explore the extent and evaluation of flood resilience in the mountainous environment of the study area. Climate Disaster Resilience Index (CDRI) was used to measure urban resilience in Muzaffarabad city. Questionnaire survey and Focus Group Discussions (FGDs) were conducted to investigate physical and socio-economic condition of the study area. Five dimensions including physical, social, economic, institutional and natural, have been quantified by applying Weight Measure Index (WMI) and Aggregate Weighted Mean Index (AWMI). Physical, socio-economic, institutional and natural dimensions were analysed on the basis of CDRI/AWMI index. Tools and techniques of Geographical Information System (GIS) and Remote Sensing have also been used for analysis and mapping. Analysis of the study revealed that the community has low resilience level to flood disaster and score for all five dimensions were less than 2, on the basis Climate Disaster Resilience Index. The contributing factors of low resilience level of Muzaffarabad city need to be properly investigated for the development of awareness programs and future developmental plans to enhance and improve the resilience level of the study area.

Keywords: Hazard; Disaster; Flood; Resilience; Climate Disaster Resilience Index; Aggregate Weighted Mean Index; Weight Measure Index; Geographical Information System.

1. Introduction

The occurrence of natural disasters and their adverse impacts are constantly escalating (Rahman and Khan 2013; Barnett et al. 2008). Hydro-meteorological disasters have been consistently escalated as compared to geo-physical hazards (IPCC 2011; UNISDR 2009). The magnitude and frequency of disasters have been increasing since the last three decades (Jabareen 2013; CRED 2014). It has also been estimated that by the end of the year 2050 human vulnerability to different disasters will be increased by two folds (Wilkinson and Brenes 2014). Risk to disasters exist in both developed and developing countries but the vulnerability of developing countries is high due to their low resilience capabilities (Rahman and Shaw 2015). In the year 2013, out of the total global destructive disasters, 80% have occurred in Asia (Caulderwood 2014). Similarly, it has also been estimated that only in South Asia about 246 million urban dwellers are severely exposed to various extremes of environment (World Bank 2009).

Pakistan is among one of the South Asian countries that has been susceptible to natural hazards (Shams 2006). In its history, multiple hazards such as earthquake, landslide, flood, drought, desertification, cyclones, storms, Glacial Lake Outburst Flood (GLOF) and extreme temperatures have severely struck the country along with human persuaded disasters (Sheikh 2004; Rahman 2010; Rahman and Shaw 2015). In disaster suffered nations, Pakistan is being declared at third and fifth position by German Watch and Centre for Research on the Epidemiology of Disasters (CRED), respectively (Kreft and Eckstein 2013; CRED 2014). The multiplying threats of fatalities and damages by the disasters have adversely affected the developmental policies of the country and it demands to focus specifically on environment related issues to uplift its economy (CDPM 2011). Floods are frequent hydro-meteorological hazards due to physiographic and climatic condition (Khan and Rahman 2003). So far, 26 major floods events have been occurred since 1950 (Mahmood and Razia 2018). In the densely populated region of Indus Plain more than 120 million people are involved in different economic activities. Among which agriculture is their main profession, however most of the people are poor leaseholder. Similarly, full-fledged Secondary and tertiary economic activities have also been practiced (Rahman and Khan 2013). The recent climatic variability, rapid population growth and anthropogenic activities in flood plain areas as well as environmental degradation has further intensified floods and increased vulnerability due to low resilience level.

Urban disaster resilience is the capacity of an urban area to resist, reduce, cope and get back proficiently against disasters (Pelling, 2003). The urban areas are centres of economic growth and need to be resilient against disasters (Rahman et al. 2015). There exists a strong relation between resilience and coping capacities of a community (Campanella 2006). At present, vulnerability is high against hydro-meteorological hazards due to ongoing global environmental change and climatic variability at regional scale (IPCC 2007). The CDRI Index developed by Joerin and Shaw in 2011 has made it easier to assess and evaluate the potentials of a city against natural disasters, and to investigate its vulnerable parts. The CDRI has been applied in many cities of Bangladesh and India with diverse geographical and environmental conditions (Joerin and Shaw 2011). Pervin et al. (2013) reported that CDRI has also been used at ward level (micro level) in cities of Dhaka (Bangladesh), Delhi and Chennai of India.

Muzaffarabad city is exposed to a number of hydro-meteorological hazards. However, Flood is not only a frequently occurring disaster in the study area but also causing loss of human lives and damages to properties and infrastructures. The rapidly expanding population of urban areas and deficit fertile soil in rugged topography has restricted the inhabitants to the floodplains of Neelum - Jhelum river system and has further aggravated the situation of the region. There is an urgent need to investigate and analyse flood disaster to reduce its adverse impacts. The current study is an attempt to explore and assess the disaster resilience of Muzaffarabad city against flood disaster by using the CDRI approach.

2. Study Area

This study has been conducted in Muzaffarabad city, which is not only the largest urban centre but also the capital of Azad Jammu and Kashmir state of Pakistan. The city of Muzaffarabad is located at the confluence of Neelum and Jhelum rivers which have been originated from Srinagar valley. The geographical location of the study area is 73°26′ E - 73°28′ E longitudes and 34°20′ N - 34°23′ N latitudes (Figure 1). The mean elevation of the study area ranges from 700 m - 4200 m and is mostly dominated by mountains (GoP 1999). Relatively, the District of Diamir (Gigit-Baltistan) is located in the north of Muzaffarabad district. In the south it is bordered by Poonch district and in the east by the Indian-held Jammu and Kashmir state. The districts of Abbottabad and Mansehra are situated to its west (GoP 1999; Kreutzmann 2008). The district of Muzaffarabad has a total area of 1,642 square kilometres while the city covers an area of 17 square kilometres. The study area has been facing multiple hazards in the form of landslides, earthquake and floods (Rahman et al. 2011). Torrential rainfall and earthquake are the causative factors for the landslides, while the city was severely hit by floods in 1992, 1995, 2010, 2011, 2012, and 2014 (JICA 2017; SDMA 2016). Moreover, the disastrous Kashmir earthquake in 2005 had triggered around 158 landslides in and across the city of Muzaffarabad (Kamp et al. 2010; Rahman et al. 2011; Shafique 2020).

3. Material and Methods

The study is based on mixed-methodology approach which involves both primary data collection through questionnaire survey and focus group discussions (FGDs).

Keeping in view the past flood history of the study area out of the total 20 wards, four wards were selected, which accounted 20 % sample size (Figure 2). For the collection of qualitative primary data, two focus group discussions were carried out per ward making a total of eight FGDs in the four selected wards. The focus group guide was prepared for the purpose based on the literature review of CDRI framework. Similarly, for the collection of quantitative primary field data, two types of questionnaires were designed. Key informant interviews were also conducted with officials of the concerned line agencies including, Water and Power Development Authority, Health Department, Planning and Development Department, Local Government and Rural Development Department, Urban Development unit, Muzaffarabad Development Authority, Education Department, Land use Planning Department, Public Health and Engineering Department, Industries and Labour Department, Pakistan Meteorological Department, Revenue Department, Muzaffarabad Municipal Corporation, Muzaffarabad Development Authority, District Disaster Management Authority, State Disaster Management Authority, Deputy Commissioner Office and Flood Forecasting Division, through Likert scale questionnaire. Questionnaire survey was also carried out in the urban community for those variables about which city officials had no adequate information. A total of two hundred questionnaires were filled by selecting fifty respondents through random sampling method from each of the four selected wards. Field observations through general and recorded techniques were also used for the collection of the required information. The parameters used for these observations included air, water, waste disposal, encroachment, life lines distribution and sanitation.

Secondary data was extracted from the SPOT images of 2009 and 2014 and topographical maps of 2001. SPOT images were acquired from Space and Upper Atmospheric Commission (SUPARCO), while Topographical maps of the study area were collected from Survey of Pakistan (SoP). The secondary data was also obtained from relevant academic researches, project reports of Government and Non-Governmental Organizations (NGOs) and published research works from the internet.

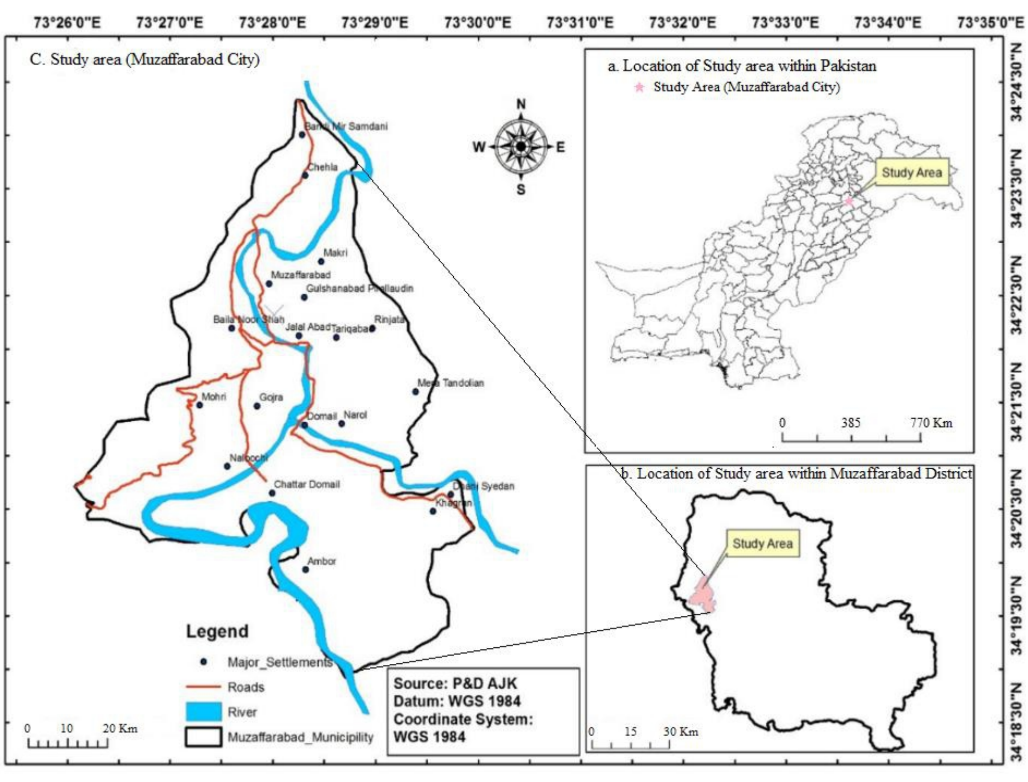

Fig. 1. Muzaffarabad city (The Study Area).

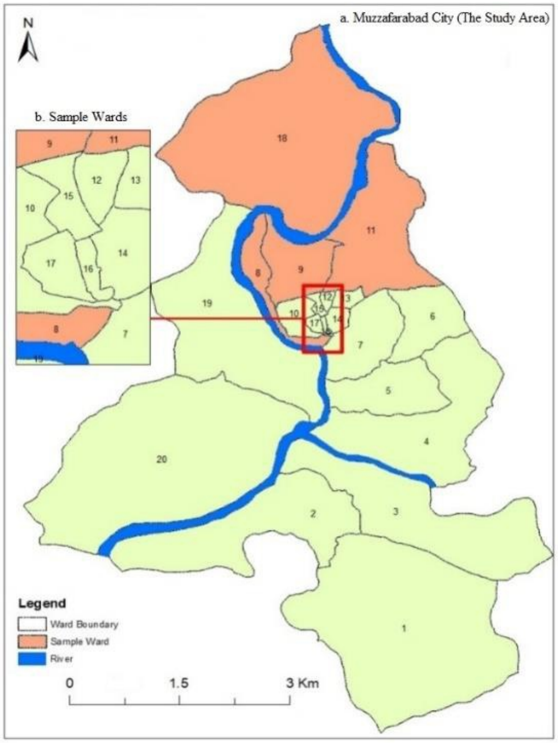

Fig. 2. Distribution of sample wards in Muzaffarabad city.

For better explanation of CDRI, weights were assigned to different dimensions including physical, social, economic, institutional, and natural. The CDRI values and scores for each dimension were calculated through Weight Measure Index (WMI). For each selected dimension of CDRI, its overall variable's values were also calculated. The variables of each dimension were ranked as not available/very low, low, medium, high and very high in the form of 1, 2, 3, 4, and 5, respectively (Eq. 1).

$$\mathbf{WMI} = \frac{\Sigma ni{=}1 \;\; w1x1w1x1{+}w2x2{+}w3x3{+}w4x4{+}w5x5}{\Sigma niw1{=}1 \;\; w1{+}w2{+}w3{+}w4{+}w5}$$

.... Eq. 1

Where, WMI = Weight Measure Index, ni = number of variables,
w1, w2, w3, w4 & w5 = weightage of variables and x1, x2, x3, x4 & x5= variables
The WMI for each dimension in the CDRI was calculated by the addition of weights (specified by the city officials) to each variable's index (obtained from the sum of rating scales under any given variable divided by the number of elements) and dividing the whole values by the number of variables in each dimension. ArcGIS 10.2 was used for mapping of weighted surfaces. The CDRI scores/values of the affected wards were assessed mutually. The average values of ratings for all the variables were calculated for flood affected wards. The strengths included the variables with 4.75 average rating out of 5 and the weaknesses comprised the variables with less than 2.00 average rating out of 5 for Muzaffarabad city. The CDRI values with their overall averages based on the AWMI scores of all five dimensions for four wards were analysed which signify Muzaffarabad city's resilience level. On the basis of CDRI framework the values ranges from 4.00 to 5.00, 3.01 to 3.99 and 1.00 to 3.00 indicating high, medium and low resilience, respectively.

4. Results and Discussion

The resilience against flood disaster in Muzaffarabad City is categorized into physical, social, economic, institutional, and natural. The detail of each dimension is given in the following sections.

4.1 Physical Resilience

The physical, social, economic, institutional and natural dimensions of CDRI along with 5 parameters and 25 variables in each dimension were calculated and analysed for the study area. The ward 8 with physical dimension's CDRI scores of 3.05 designate the moderate level of physical resilience. In spite of nearness to the river, ward 8 has moderate resilience due to well-developed infrastructure. However, Ward 9, 11 and 18 have been ranked by low resilience status having CDRI scores of 2.41, 2.14 and 2.35 respectively. However, the overall resilience of all these four wards is low with an average value of 2.48, (Table 1; Figure 3; Figure 4).

4.2 Social Resilience

Considering the resilience status for social dimension particularly in four flood affected wards and generally in Muzaffarabad city. The social dimension's CDRI score of 2.53 at ward 8 displays low social resilience. The ward 9 with CDRI score of 2.38 also discloses its low social resilience capabilities against flood disaster.

The social dimension's CDRI score of 1.95 in case of ward 11 points towards the low social resilience. Whereas the ward 18 with a CDRI score of 2.54 describe its low resilience of social dimension. Thus the overall CDRI score of 2.35 unveil the low social resilience for Muzaffarabad urban area (Table 2; Figure 5; Figure 6).

Table 1. Ward Wise CDRI Scores for Physical Dimensions

Ward Wise CDRI Score for Physical Dimension				
Ward No.	8	9	11	18
CDRI Score	3.05	2.41	2.14	2.35
Average Score (CDRI) = 2.48				

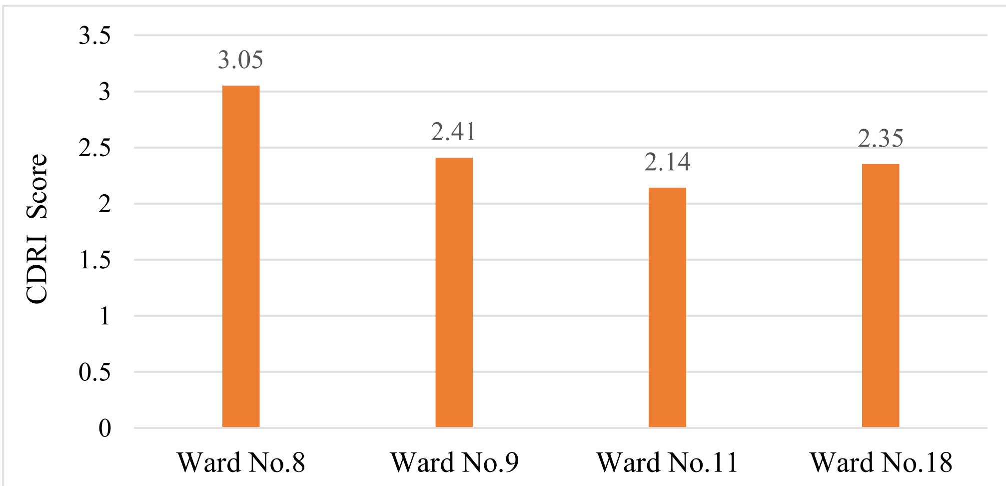

Fig. 3. Ward Wise CDRI Scores of Physical Dimension.

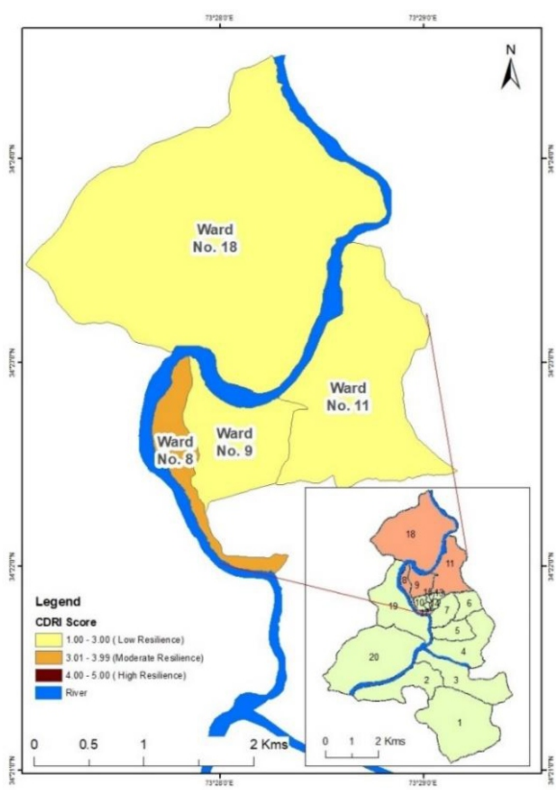

Fig. 4. Physical Dimension's Resilience level map.

Table 2. Ward Wise CDRI scores for Social Dimensions

Ward Wise CDRI Score for Social Dimension				
Ward No.	8	9	11	18
CDRI Score	2.53	2.38	1.95	2.54
Average Score (CDRI) = 2.35				

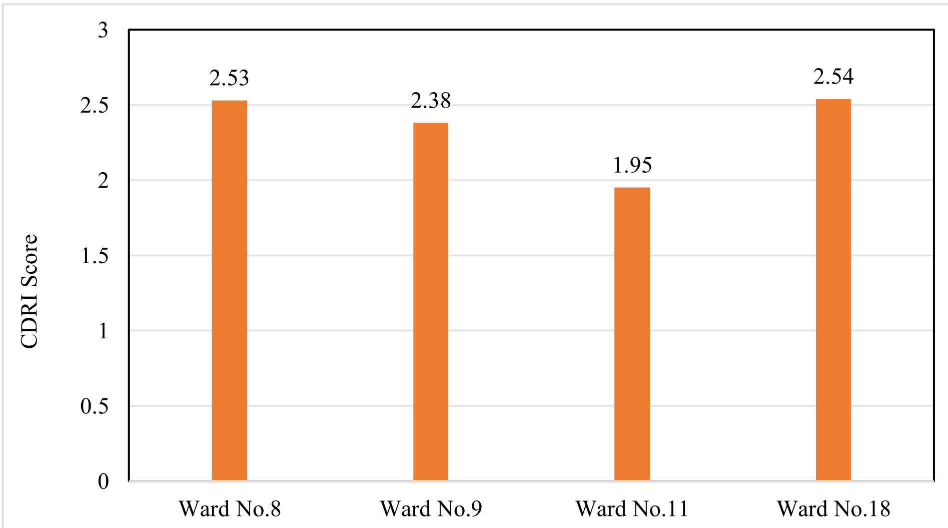

Fig. 5. Ward Wise CDRI Scores of Social Dimension.

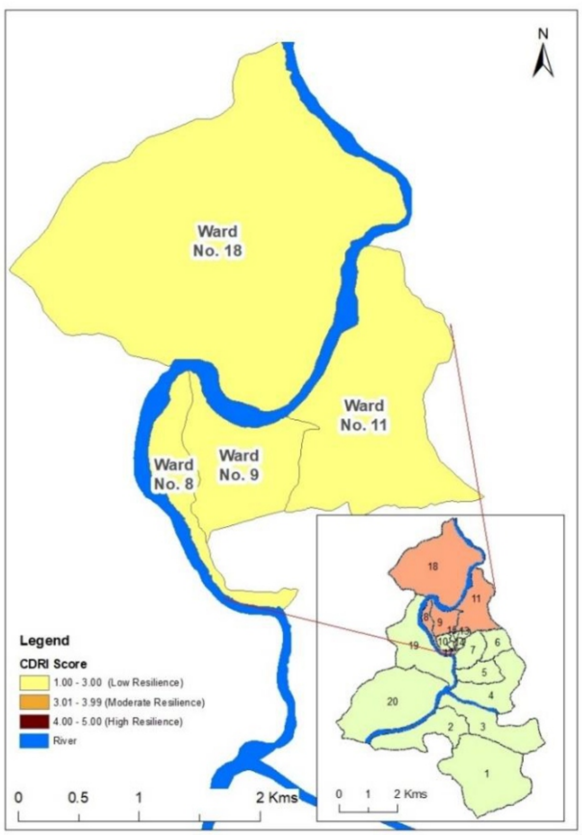

Fig. 6. Social Dimension's Resilience level map.

4.3 Economic Resilience

Considering the economic dimension's resilience level based on the CDRI scores for the study area. It has been observed that low economic resilience is depicted by a CDRI score of 2.47 for ward 8 of the study area. The ward 9 with CDRI score of 1.99 represents low economic resilience. Similarly, ward 11 and ward 18 with CDRI scores of 1.87 and 2.12 points to the low economic resilience of these wards against flood disaster. Thus the low economic resilience is characterised by an overall CDRI of 2.11 in Muzaffarabad city (Table 3; Figure 7; Figure 8).

Table 3. Ward Wise CDRI scores for Economic Dimensions

Ward Wise CDRI Score for Economic Dimension				
Ward No.	8	9	11	18
CDRI Score	2.47	1.99	1.87	2.12
Average Score (CDRI) = 2.11				

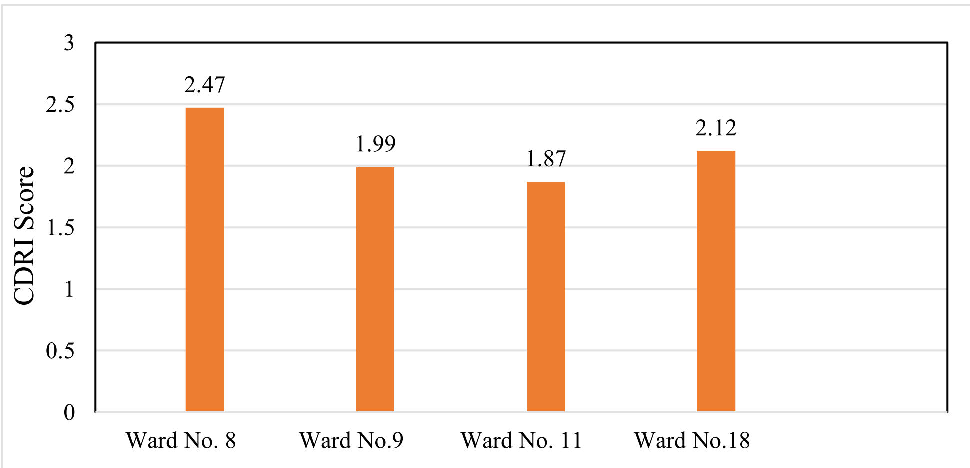

Fig. 7. Ward Wise CDRI Scores of Economic Dimension.

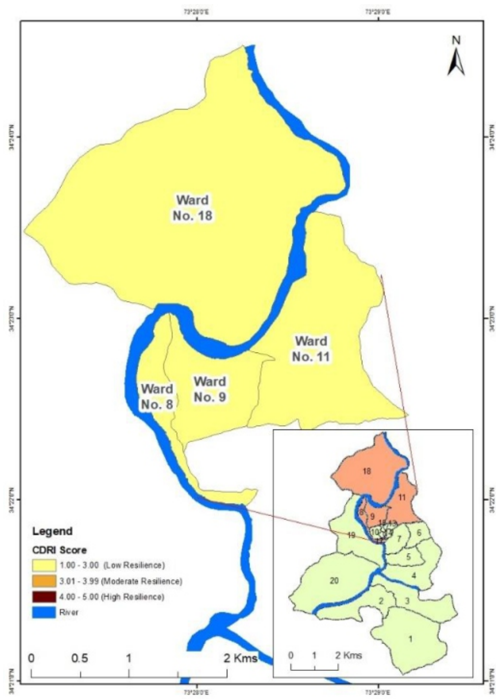

Fig. 8. Economic Dimension's Resilience Level map.

4.4 Institutional Resilience

The Muzaffarabad city also displays low institutional resilience. Ward 8 with 2.67 CDRI score indicates low institutional resilience. CDRI score of 2.78 points towards low institutional resilience in case of ward 9. Low resilience is also described by a CDRI score of 2.22 for ward 11 of the city. Similarly, 2.43 CDRI score of institutional dimension depicts the fact of low institutional capabilities of ward 18 against the flood disaster. Hence, an overall CDRI score of 2.52 demonstrate low institutional capabilities of Muzaffarabad city against hydro-meteorological disaster of flood (Table 4; Figure 9; Figure 10).

Table 4. Ward Wise CDRI scores for Institutional Dimensions

Ward Wise CDRI Score for Economic Dimension				
Ward No.	8	9	11	18
CDRI Score	2.67	2.78	2.22	2.41
Average Score (CDRI) = 2.52				

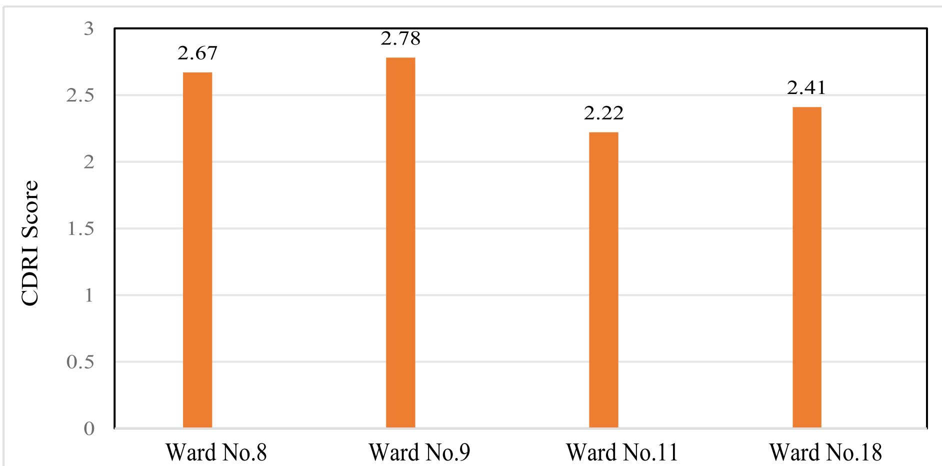

Fig. 9. Ward Wise CDRI Scores of Institutional Dimension.

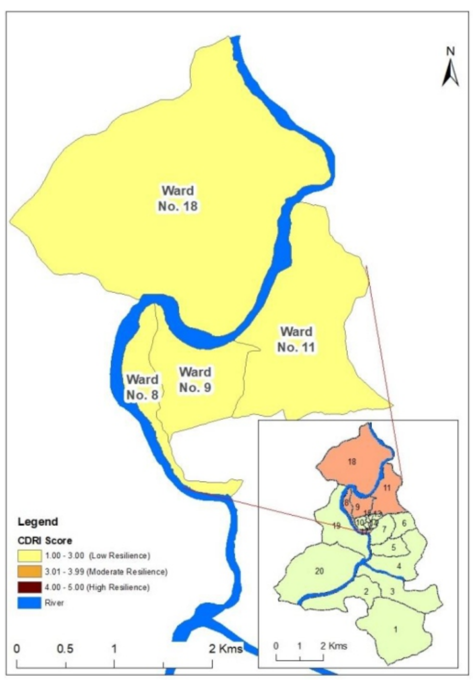

Fig. 10. Institutional Dimension's Resilience Level map.

4.5 Natural Resilience

The natural dimension's resilience for the selected wards in particular and Muzaffarabad city in general was illustrated by low resilience. Low resilience is described by a CDRI score of 2.83 for ward 8 of the study area. Ward 9 with CDRI score of 2.91 is depicted by low resilience level. The CDRI score of 2.58 also shows low resilience as well for ward 11 of the city. Still low resilience is illustrated by a CDRI score of 2.43 in case of ward 18 of the study area (Table 5; Figure 11; Figure 12). However, an overall CDRI score of 2.68 points towards the low resilience status of the city.

Table 5. Ward Wise CDRI scores for Natural Dimensions

Ward Wise CDRI Score for Economic Dimension				
Ward No.	8	9	11	18
CDRI Score	2.83	2.91	2.58	2.43
Average Score (CDRI) = 2.68				

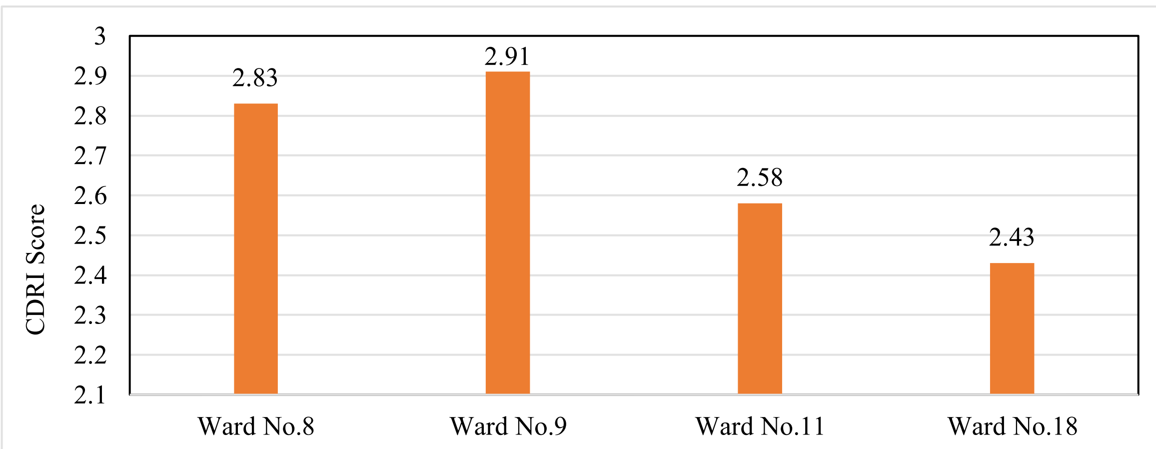

Fig. 11. Ward Wise CDRI Scores of Natural Dimension.

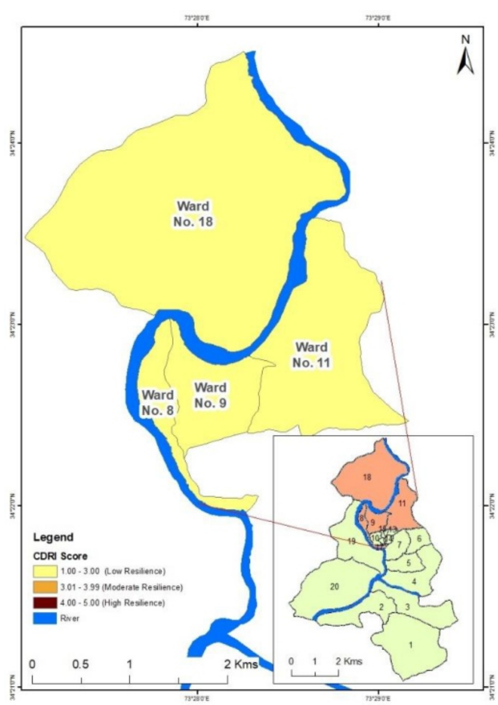

Fig. 12. Natural Dimension's Resilience level map.

4.6 Ward-wise Comparison of Resilience

An in-depth and extensive analysis was carried out for each dimension through the comparison of CDRI scores for Muzaffarabad city. The overall CDRI score of 2.71 in case of ward 8 reveals its low resilience potential. The low resilience is also indicated by an overall CDRI score of 2.49 at ward 9 of the study area. Similarly, ward 11 and ward 18 with their respective overall CDRI scores of 2.15 and 2.37 indicated low resilience capabilities of Muzaffarabad city (Table 6; Figure 13).

4.7 Parameter-Wise Average CDRI Score

Based on extensive analysis of calculating the average CDRI scores of all 25 parameters of CDRI amongst highest taken values for all the selected four wards of Muzaffarabad city (Table 7). Among all the values, the highest value average 4.73 was assigned to household assets while finance and saving attains 1.46 being the lowest value.

4.8 Strengths of the Study area against Flood Disaster

The strengths of the city based on the calculations of average ratings of variables for all the four wards include those variables which possess average rating of 4.75 or more out of 5 from the CDRI Likert scale questionnaire (Table 8).

4.9 Weaknesses of the Study area against flood disaster

Analysis of the study revealed that the variables having low, average values of less than 2.00 out of the total rating of 5 (Table 9). The weaknesses include the lack of alternate provision of electricity and water supply to the city. Similarly, general public has lesser access to clean and hygienic environment. Likewise, inadequate public sewerage connections to aseptic tank, lack of solid waste treated before dumping and solid waste recycling is also a serious issue. High dependent age groups, lack of organised public awareness programs/disaster drills, insurance and credit facilities for urban dwellers are also threatening the situation. Governmental and non-governmental organizations are not taking keen interests to provide subsidies and incentives to urban dwellers in rebuilding houses after disaster. There is lack of incorporation of disaster risk reduction and climate change adaptation in educational institution curriculum. Inadequate availability and efficiency of trained emergency workers during and after a disaster is also triggering the situation. Regular flood disaster training programs regarding high frequency flash floods in the study area is also needed.

Table 6. Dimension wise and overall CDRI scores for all wards

Ward No.	Physical	Social	Economic	Institutional	Natural	Ward-wise average
08	3.05	2.53	2.47	2.67	2.83	2.71
09	2.41	2.38	1.99	2.78	2.91	2.49
11	2.14	1.95	1.87	2.22	2.58	2.15
18	2.35	2.54	2.12	2.41	2.43	2.37
Average	2.48	2.35	2.11	2.52	2.68	-
Resilience Level: Low						

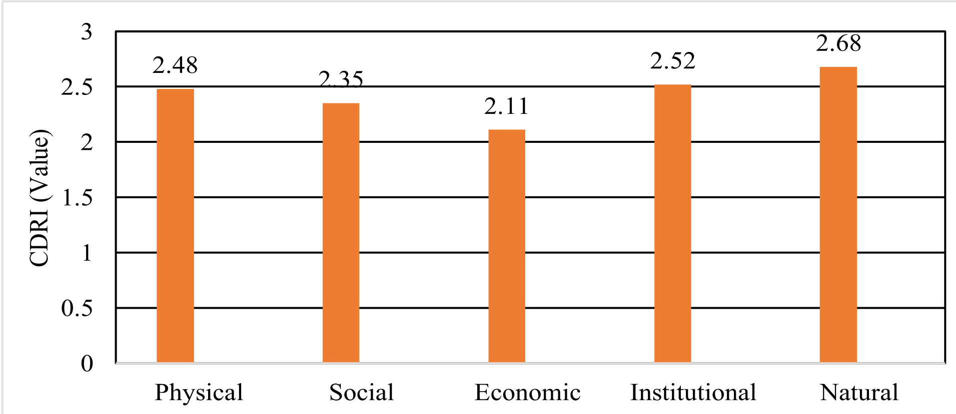

Fig. 13. Dimension wise CDRI scores for all wards.

Table 7. Parameter-Wise Average CDRI Scores (from highest to lowest) for All the Wards

Parameter	Higher to Lower (Value)	Parameter	Higher to Lower (Value)
Household (Assets)	4.73	Accessibility of roads	2.86
land-use & Housing	4.26	Social capital	2.80
Water	3.93	Good Governance	2.73
Preparedness &Social cohesion	3.66	Population	2.66
Institutional collaboration	3.60	Electricity	2.60
Health	3.40	Mainstreaming of CCA & DRR	2.53
eco-system services & Vulnerability	3.26	Effectiveness of crises management framework	2.46
Frequency of natural hazards	3.20	Land-use in natural terms	2.33
Income	3.13	Land-use in natural terms	2.33
Intensity/severity of natural hazard	3.06	Budget and subsidy	2.00
Food Security & Environmental policy	3.06	Sanitation & solid waste disposal	1.80
Effectiveness of institutions in response to a disaster	2.93	Employment	1.60
		Finance & saving	1.46

Table 8. Strengths of Muzaffarabad City against flood disaster

Variable	***Average Rating***
Legal access to electricity from electric supply company	5
Legal access to water supply from Maakri Water Treatment Plant (MWTP)	4.75
The access of city population to toilets including hygienic latrine, pit latrine, water sealed latrine or sanitary latrine	5
The percentage of houses with ownership as opposed to rented	5
The extent of affected people evacuate voluntarily after a disaster	5
The institutional collaboration of city with national government during and after a disaster	5

Table 9. Weaknesses of Muzaffarabad City against flood disaster

Variable	Average Rating
The alternate external provision of electricity to the city	1.00
The alternate water supply provision to the city	1.00
The percentage of city population with hygienic access to sanitation e.g. connection to a public sewer, connection to a septic tank.	1.00
The percentage of solid waste treated before dumping	1.00
The percentage of solid waste recycled both by formal and informal means of municipal solid waste management and the waste recycling activities of scavengers and waste pickers	1.00
The percentage of population under 14 years old	1.00
How does the city authority organize public awareness programs/disaster drills?	1.00
Extent of city's population participate in a club or social activity group	1.25
Percentage of labour employed in informal sector	1.00
Access and availability of credit facility in the city's financial institutions to prevent disasters	1.00
Effectiveness of credit facility after a disaster for urban poor or low-income groups	1.00
Percentage of city's household's properties under any sort of insurance scheme	1.00
Existence of or access to a catastrophe risk financing framework/instrument	1.25
Availability of subsidies/incentives for residents/institutions to rebuild houses after a disaster	1.75
Availability of subsidies/incentives for residents/institutions to receive/provide alternative emergency livelihood during a disaster	1.25
Incorporation of disaster risk reduction and climate change adaptation in city's school education curriculum	1.00
Availability and efficiency of trained emergency workers during and after a disaster	1.75
Availability and frequency of regular disaster training programs for emergency workers	1.75
Existence and frequency to run drills for disaster scenarios led by city government	1.00
Frequency of natural hazards: Flash floods	1.50
Intensity of land -use---urban morphology (level of urbanization; extent of urbanized areas)	1.75

5. Conclusion

In the light of Climate Disaster Resilience framework, the extent and evaluation of flood disaster resilience of Muzaffarabad city has been analysed. The analysis has revealed that the resilience level of the study area is low. As wards 8, 9, 11 and 18 with their respective overall CDRI scores of 2.71, 2.49, 2.15 and 2.37. Which exposes the fact of low potential and capability of Muzaffarabad city against flood disaster. These measures such as Alternative capacity or external provision of Electricity and Water, Provision of treatment plants, Public sewerage system and septic tanks, treatment and recycling procedures for solid waste need improvement. Similarly, there is lack of public awareness programs and disaster drills, which should be enhanced. Access and availability of credit facility, availability of catastrophic risk financing framework/instrument and insurance, subsidies schemes and proper Compensation also require improvement. Induction and proper training of emergency workers should be initiated. Engineering measures such as embankments and protection walls need to be constructed. Land use and building byelaws and need base assessment and implementation to avoid political interference also require proper implementation. Flood Early Warning and forecasting System need to be improved. Coordination between multiple line agencies and general public need to be strengthened. However, all these will not be fruitful until the preparation and proper implementation of a Comprehensive Master plan. The findings of the study are helpful in contributing disaster risk reduction and building resilience of the study area against flood.

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This manuscript is part of the Ph.D Dissertation of the Principal author.

Author's Contribution

Muhammad Ayub, proposed the main concept and involved in write up. Atta-ur-rahman, did technical review before submission and proof read of the manuscript. Samiullah was involved in assistance in preparation of illustration, plates and figures. Attaullah khan helped in data gathering and writing of the manuscript.

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