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Research article

An assessment of flood vulnerability in Khyber Pukhtunkhwa province of Pakistan

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Abstract: In this research we have attempted to measure vulnerability of the communities living in the flood prone area of Khyber Pukhtunkhwa province of Pakistan. Extensive literature review was conducted to identify the flood vulnerability indicators. Primary data were used to achieve the objective of this study. Questionnaires were used to collect the primary data from the selected households and from the director of Centre for Disaster Preparedness and Management. Subjective assessment technique was used to allocate weights to the selected indicators of vulnerability. A sample size of 280 respondents was taken from three selected locations of Charsadda, Nowshera and Peshawar. Simple random sampling was employed for the selection of respondents. Results revealed that overall vulnerability as well as component vulnerability for the selected locations was very high. The study therefore recommends preparedness, provision of funds for building houses with flood resistant materials and building houses in safer places. There is also a need for enhancing the adaptive capacities of the concerned communities through their socio-economic uplift. Implementation of these policies would lower the vulnerability of the communities to flood disasters.

Keywords: vulnerability; floods; indicators; disaster management; Khyber Pukhtunkhwa

1. Introduction

Vulnerability research is recognized as an important filed due to advancement in natural hazard science & disaster risk management [1]. Vulnerability is generally categorized in to physical, social vulnerability and human vulnerability [2,3]. Vulnerability results from the physical, social, economic and environmental elements that increase the sensitivity of a community to hazards [4,5]. Vulnerability is considered to be a combination of adaptive capacity, sensitivity and exposure [1,4,6-10]. Adaptive capacity is the main element in many definitions of vulnerability [11] and is defined as the ability of a community to accommodate the environmental hazards. Sensitivity is the extent to which a system is affected by worries & exposure is the extent to which a community is faced with the environmental stress [6,12]. Studies of [13,14] revealed that vulnerability is composed of exposure and coping ability whereas coping ability is further subdivided in to resistance & resilience. Flood vulnerability is a multidimensional and complex issue [6,11,15]. Poor people live often nearby the rivers and are more vulnerable to floods [16]. An individual's characteristics such as age, race, health, income, house type and occupation may be used as proxy indicators for vulnerability assessment [17]. Exposure is the possibility that humans and/or physical things will be affected by the floods [4]. Susceptibility refers to the elements exposed in a system that influences the possibilities of being harmed during floods and include people's preparedness and awareness regarding flood risk [8]. The topographical conditions and climate change make Khyber Pukhthunkhwa (KPK) one of high risk area to flooding in Pakistan [18,19]. This is evident through historical records which show that the districts of Charsadda, Noshera and Peshawar have faced floods almost after every three years since 1973 [19,20]. Due to lack of research on flood vulnerability in Pakistan, we in this paper attempted to measure vulnerability of flood prone areas of Peshawar, Charsadda and Nowshera. The results of the study would be useful for policies and plans regarding prioritizing vulnerable communities for funds and enhancing adaptive capacities of the communities. Therefore the study would help to decrease the vulnerability of the communities to floods.

2. Methodology

2.1. Profile of the study area

KPK province is situated to the north west of Pakistan. The province covers an area of about 74,521 km^2. Exact location of the province is 31°15' to 36°57' North latitude and 69°5' to 74°7' East longitude. Due to wide variations in altitudinal characteristics, the climate of the province also shows considerable variations. As a result, the southern part of the province is prevailed with mild winters and hot summers and the northern part is faced with extreme cold climate. The area is drained by Indus, Kabul and Swat rivers. Monsoon often results in river flooding in the area. The three sites of Charsadda, Nowshera and Peshawar have been badly affected by almost every flood due to their proximity to Sardaryab, Jindi, Khyali, Kabul and Indus rivers. Therefore these three sites were selected for this study. The melting of snow on mountains of Himalayas and Hindukush also results in floods due to overflow in the low lying rivers. Recently, the floods of 2010 and 2013 affected the districts of Peshawar, Charsadda, Swabi, Noshera, Mardan and Swat. The 1998 census record shows that KPK had a population of 17.74 million with a growth rate (average annual) of 2.8% and a literacy rate of 37% [18]. Agriculture contributes 38% of gross domestic product of the province and

is thus a major economic activity. Majority of the people in the areas live near river coasts due to fishing activities and water availability. The area is blessed with fertile soils. The two main cropping seasons (i.e., Kharif and Rabi) exist in the area. Livestock are also kept by people due to availability of water and fodder sources in the area.

2.2. Sample size and data collection

Charsadda, Nowshera and Peshawar are the three flood prone districts of KPK. Therefore we selected these three districts as sample sites for this study. The population of district Charsadda, Nowshera and Peshawar were 1,022,000; 874,373 and 2,026,851 respectively according to the census of 1998. No census has been conducted after the 1998 census. Therefore we used the 1998 census data for computation of sample size. The cumulative population of the three selected locations is about 3,923,224. We employed the [21] formula that gave us a sample size of 278 with 6% of d value (error acceptance). However, for ease of analysis we took a sample size of 280. We also computed the proportional samples for all the three selected sample sites to show their equal representation in the survey. To compute the proportional samples, the populations of the selected locations and their corresponding proportional sample sizes were rounded off in order to achieve the resultant values in whole numbers. The resultant proportional samples for Peshawar, Charsadda and Nowshera were 143, 72 and 65, correspondingly. Due to recurrent floods in these locations, the rural population is often affected as they are deprived of their standing crops, livestock and houses that are made of mud. We therefore, targeted the rural population from the three selected sites. The director of Centre for Disaster Preparedness and Management (CDPM) of University of Peshawar was also consulted for ranking the variables used for vulnerability in this study.

To achieve the objectives of this study, we used primary data. The literature review enabled us to identify the components of vulnerability to floods. Further in-depth review enabled us to come up with the variables for the components of vulnerability. Two sets of questionnaires were used to collect the primary data in this study. A detailed full length questionnaire was constructed to complete the household survey. A second short questionnaire was constructed for the director of CDPM, University of Peshawar to rank all the selected variables on a percentage scale ranging from 0 to 1. Questionnaire for household survey included socio-economic and demographic characteristics, adaptive capacities, sensitivity and exposure of the respondents related to flood vulnerability. Five students of M.Sc. geography were trained for collection of data from households. However, only the first author of this paper collected data from the director of CDPM. The household heads were generally interviewed in the household survey. However, the elder family member was interviewed in case of unavailability of the household head. About 40 minutes on average were spent on completion of a single questionnaire. The collected primary data was analyzed using SPSS version 16 and Excel programs. Descriptive statistics were used to calculate percentages for socio-economic and demographic characteristics. Excel was used for data entry and analysis about adaptive capacity, sensitivity and exposure. Radar diagrams were constructed to compare vulnerabilities of the communities in the flood prone districts of Peshawar, Charsadda and Nowshera.

2.3. Indicators for vulnerability to floods

An index is a quantitative score [18] obtained through combination of variables according to certain rules [22]. Indices have been used widely in disaster studies and they simplify the intricate data in a single value [18,23]. They serve as important tools in making decisions and policies. Vulnerability can be measured both through quantitative and qualitative ways [24]. Absolute measurement of vulnerability is not an easy task [25,26]. Vulnerability can be measured by using proxy indicators [27-29]. We therefore used proxy indicators to measure vulnerability. Values of the variables were recorded in percentages to overcome complications with dissimilar measurement units. Table 1 shows the selected vulnerability indicators used in this study.

2.4. Vulnerability components and their accompanying variables

The three components of vulnerability (i.e., adaptive capacity, sensitivity and exposure) were chosen to cover vulnerability. For the first component of adaptive capacity we selected six variables including working age group, social networks, education, income, employment and multiple livelihood sources. The working age group variable, in this study includes the percentage of population below 60 years plus the percentage of population above 15 years. The population in this age group is active and may decrease vulnerability to floods. Social capital can also increase linkages and are considered to help people during disasters. The presence of social networks therefore makes the communities less vulnerable to floods. Education is an important variable because the educated people are supposed to be less vulnerable to disasters [30,31]. Income of the family also affects vulnerability to floods. This is because due to more income the people can have their houses in safer areas and they may also use flood resistant materials in house construction. Therefore, the more the income of the people, the less will be their vulnerability to floods. In the research of [32], he used USD 32.74 per month as a standard for poverty measurement. Therefore, we used this definition and people with an amount of less than USD 32.74 per month were considered as poor in this study. Employment is also supposed to affect people's vulnerability to floods. The more the percentage of people employed on a community, the more they will be able to invest in flood protection measures. Similarly, multiple livelihood sources in a community make them less vulnerable to floods. In case one livelihood source is affected, the community might have the other income sources to bear the loss. For the second component of exposure we identified two variables (i.e., past experience with floods and houses built near river coasts). The variable past experience with floods, was selected because the study area is one of the badly affected flood prone areas and majority of the households were expected to have experienced flood events in the past. The variable, location here refer to the percentage of people living in flood prone coastal areas. For the third component of sensitivity, we identified four variables including building material, disability, dependent population and illiteracy. The building material variable is about percentage of people with mud houses. This is due to the reason that bulk of the respondents from the area had houses that were made of mud and were vulnerable to floods. A large majority of these types of houses makes them more susceptible to floods. Presence of a large number of disabled and dependents in a community makes it more susceptible to flood hazards. Therefore, we also included disability and dependent population for susceptibility measurement. The poverty and illiteracy are also variables that make the communities more vulnerable to flood hazards. Therefore, we also included these variables in measuring sensitivity to floods.

Table 1. Indicators and their concerned variables for vulnerability assessment.

Indicator	Variable & sources	CDPM director suggested weights	Explanation	Justification & positive or negative impact on vulnerability
Adaptive capacity	Working age group ([1,3,4,11,36-40]	25	Percentage of population <60 years plus percentage of Population >15 years	Presence of a large number of working age people makes the community less vulnerable to floods , −
	Social networks ([1,3,4,13,15,36,41]	05	Percentage of population that have membership in any organization	The more the social capital of the population, the less the vulnerability, −
	Education [1,3,5,8,36-38,40,42]	02	Percentage of population that have high school education	The more the educated people in a community, the less the vulnerability, −
	Income [1,3,8,13,32,36]	05	Percentage of households above poverty line	People above poverty line are less vulnerable to flood hazards, −
	Employment [3,36,43]	15	Percentage of population employed	People with employment are less vulnerable to floods, −
	Multiple income sources [18,20]	04	Percentage of population with multiple income sources	People with multiple income sources are less vulnerable to flood events, −
Exposure	Past experience with flood events [37,39,40,42,44,45]	100	Percentage of people who were affected by flood events in the past	The more the exposure to floods in the past the more the vulnerability, +
	Houses built near river coasts [3,15,18,25,26,36,37,39]	94	Percentage of housing units built near flood prone rivers	People living very close to flood prone rivers and coastal areas may be more exposed to floods, +
Susceptibility/ Sensitivity	Building material [12]	96	Percentage of housing units made of mud	Houses made of mud will be more vulnerable to floods, +
	Disabled people [3,13,26]	92	Percentage of population with physical or mental disability	Physical and mental disability creates hindrances in mobility and evacuation and increases vulnerability, +
	Dependents [1,3,4,11,36-40]	88	Percentage of dependent population >60 years plus percentage of Population <15 years	Presence of a large number of dependent population makes the community more vulnerable to floods , +
	Illiteracy [18,20]	98	Percentage of illiterate population	The more the illiteracy, the more the vulnerability, +

2.5. Allocating weights to selected variables

The three components of adaptive capacity, sensitivity and exposure were used to compute the overall vulnerability of the three sites (i.e., Peshawar, Charsadda & Nowshera). The two component indicators (i.e., adaptive capacity and susceptibility) consist of different variables except for exposure which is based on a single variable. The values of all the variables were collected in percentages to overcome the normalization process. In the research of [33], they had discussed that weights can be allocated to the variables based on their importance. Weight allocation can be done either through empirical or subjective methods [26,34]. Due to data limitations, we used subjective method for allocating weights to variables. Subjective method and weight allocation has been employed by [35] and cutter et al., 2010 in their studies. The director of CDPM was asked to give scores to the variables given in Table 1 on a percentage scale ranging from 0 to 1. The values obtained from the director CDPM, were divided by the actual values of the variables obtained from the household survey (in percentages) which gave the vulnerability index for each variable i.e., Variable Vulnerability Index (VVI). The low values show less vulnerability and high values show high vulnerability for that variable. For variables whose high values leads to high vulnerability, the scale for such variables in the questionnaire for the director CDPM as well as the calculation process for such variable was inversed. For example, the more the exposure, the more the vulnerability. For variables that increases vulnerability, the scale was inversed in such a way that the director CDPM was asked to rank the variable on a percentage scale from 1 to 0 in a manner so that the values close to 1 on the percentage scale will show less vulnerability and vice versa. The vulnerability for the components (Component vulnerability) was then computed through calculation of the averages of their concerned VVIs. Theses component vulnerability indices for adaptive capacity vulnerability index, exposure vulnerability index and susceptibility vulnerability index were represented by AVI, EVI and SVI respectively. The composite vulnerability indices (CVI) for the three sites were then computed by using the formula used by [3]. According to her, vulnerability index can be calculated as $FVI = E * S/R$, where FVI = Flood vulnerability Index, E = Exposure, S = Susceptibility/Sensitivity & R = Resilience/adaptive capacity.

3. Results & discussions

3.1. Demographic & socio-economic information of the respondents

The survey showed that Peshawar, Charsadda and Nowshera had 1,401,776 and 516 household members, respectively (Table 2). Results of the survey showed that Peshawar, Charsadda and Nowshera about 75%, 76% and 68% uneducated population, respectively. Peshawar had comparatively less percentage of dependent people (53%) as compared to Nowshera (75%) and Charsadda (70%). The percentage of population below poverty line was about 78%, 92% and 95% for Peshawar, charsadda and Nowshera, respectively. All the three sites had about 1 percent disabled population. A large majority of the population (i.e., 62%, 61% and 62% from Peshawar, charsadda and Nowshera) were found settled near flood prone areas. The percentage of population that had mud houses were about 82%, 83% and 78% from Peshawar, charsadda and Nowshera. A large majority of the population (i.e., 86%, 82% and 79% from Peshawar, charsadda and Nowshera) had experienced floods in the past. The survey showed that 23%, 19% and 28% from Peshawar, Charsadda and Nowshera had employment, respectively. The percentage of population from Peshawar, charsadda and

Nowshera that had income levels above poverty line were 22%, 8% and 5%, respectively. Only 6%, 5% and 6% people from Peshawar, charsadda and Nowshera had multiple livelihood sources respectively. The percentage of population that belonged to working age groups from Peshawar, charsadda and Nowshera were about 47%, 30% and 25%, respectively. The percentage of population that had membership in social organizations was about 5% for Peshawar and 8% for both Charsadda and Nowshera.

Table 2. Demographic and socio-economic information of the respondents.

Variable	Peshawar (N = 143)	% value	Charsadda (N = 72)	% value	Nowshera (N = 65)	% value
Educational status	353	25%	184	24%	164	32%
Illiterate	1048	75%	592	76%	352	68%
Household members	1401		776		516	
Age (Dependents)	744	53%	546	70%	386	75%
Working age members	657	47%	230	30%	130	25%
Social capital	66	5%	59	8%	42	8%
Disabled population	20	1%	8	1%	4	1%
Employment	321	23%	147	19%	145	28%
Income above poverty line	9855	22%	4869	8%	4166	5%
Multiple livelihood sources	84	6%	38	5%	30	6%
Mud Build houses	1149	82%	644	83%	403	78%
Location	869	62%	473	61%	320	62%

3.2. Results of the vulnerability indices

The mean values of the index range were used to interpret results of vulnerability indices. So, 0 was considered as low vulnerability, 0.5 as medium and 1 as high vulnerability. All the three sites also have high values of component vulnerability indices. The composite vulnerability indices were also high for all the three sites. The composite indices for Peshawar, Charsadda and Nowshera were 0.81, 0.72 and 0.66, respectively (Table 3). The component resilience indices for the sample sites are discussed below.

a. Adaptive capacity Index

The results of the adaptive capacity indices show that all the three sites have high adaptive capacities. The adaptive capacity indices for Peshawar, Charsadda and Nowshera were 0.53, 0.63 and 0.65, respectively. The reason for this may be because communities in all the three sites had moderate to high values of social capital, educational status, income and employment. The percentage of population that belonged to working age groups was more (47%) in Peshawar as compared to Charsadda and Nowshera. The low percentage of population with multiple livelihood sources in the three sites may also be attributed to the moderate to high values of adaptive capacity indices for the sites.

b. Exposure Index

The exposure index is the result of two selected variable (i.e., percentage of population who had faced flood events in the past and houses built near river coast). The exposure indices for

Peshawar, Charsadda and Nowshera were 0.76, 0.73 and 0.72, respectively. The exposure index is high for all the three sites because preponderance of the population was found settled in the river coasts and had been seriously affected by the flood events. Majority of the population from the three selected sites had also experienced flood events in the past. That's why the exposure indices were high among the component indices for all the three selected sites.

c. Sensitivity Index

The sensitivity index is the result of variables such as building material, disability, dependent population and illiteracy. All these variables make a community susceptible to floods. The exposure indices for Peshawar, Charsadda and Nowshera were 0.56, 0.61 and 0.59, respectively. The results showed that all the three sites have high sensitivity indices. This is due to the fact that majority of the houses in these rural communities in the three sites had mud houses that could be easily affected by floods. Similarly a large percentage of populations in the three localities (more than 60%) were living in the flood prone locations. Poverty and illiteracy were also common in the three sites. A large proportion of the population was dependent because there was more population in the 0–14 age groups but fortunately very low percentage of population in the three sites had some sort of disability.

Table 3. Vulnerability indices for sample sites.

Indicator and their variables	Peshawar		Charsadda		Nowshera	
	% value	VVI	% value	VVI	% value	VVI
Adaptive capacity						
Working age groups	47	0.53	30	0.83	25	1.0
Social networks	05	01	08	0.63	08	0.63
Education	25	0.08	24	0.08	32	0.06
Income	22	0.23	08	0.63	05	01
Employment	23	0.65	19	0.79	28	0.54
Multiple income sources	06	0.67	05	0.80	06	0.67
AVI		0.53		0.63		0.65
Exposure						
Pat experience with flood events	86	0.86	82	0.82	79	0.79
Houses built near river coasts	62	0.66	61	0.65	62	0.66
EVI		0.76		0.73		0.72
Sensitivity/Susceptibility						
Building material	82	0.85	83	0.86	78	0.81
Disability	01	0.01	01	0.01	01	0.01
Dependents	53	0.60	70	0.80	75	0.85
Illiteracy	75	0.77	76	0.78	68	0.69
SVI		0.56		0.61		0.59
Composite VI		0.81		0.72		0.66

4. Conclusions

In this research paper, we calculated and also compared the components of vulnerability and the overall vulnerability of the three selected sites. Results revealed that all the three locations were vulnerable to floods. The composite vulnerability indices show the overall picture of vulnerability of the community in the three sites. The component vulnerability indices help us to compare the selected sites for the individual indicators of adaptive capacity, exposure and sensitivity. The composite vulnerability indices show that all the three localities have high vulnerability to floods. However, Peshawar has a high vulnerability as compared to Charsadda and Nowshera. The government should give proper attention to all the three sites to raise the adaptive capacities of the communities and thus reduce vulnerability to floods. The component indices of adaptive capacity, sensitivity and exposure show high values for adaptive capacity, exposure and sensitivity. The government should arrange programs to provide education, employments and alternate income sources for the rural people to raise their resilience to floods. Sensitivity of the community to floods in the three sites can be lowered through providing opportunities to build their houses in safer places and eradicating poverty and illiteracy. The government and non-governmental organization should provide assistance to change their housing structures (from mud to concrete) that may reduce sensitivity to floods. These activities will reduce vulnerability of the communities to floods in these areas.

Conflict of interest

The authors declare there is no conflict of interest.

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