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Assessment of Households' Vulnerability and Resilience to Landslide Hazard in Murree Hills of Pakistan

Said Qasim [1]

[1] Professor, Geography and Regional Planning Department, University of Balochistan, Quetta, Pakistan.

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ABSTRACT

Background: During the past few decades, landslide incidents have increased in intensity and frequency.
Objectives: In this paper, we have attempted to empirically assess both the household-level vulnerability and resilience of households in Murree, Pakistan.
Methodology: Variables regarding vulnerability and resilience concerning landslides were collected from the previous studies. The primary data concerning these variables were gathered with the help of a survey from 200 randomly selected households. The views of the experts of the National Disaster Management Authority about the variables were also noted. The subjective method was applied to assign weights to the variables.
Results: Our analysis revealed very high values of vulnerability for the rural fringe (0.96) and urban fringe (0.94) as compared to the inner city (0.85). The overall resilience index of the rural fringe was very low (0.28) as compared to the nearly medium-level resilience index of the urban fringe (0.44) and medium-level resilience index of the inner city (0.51).
Conclusion: The households in Murree were more vulnerable to landslides and had less resilience level.

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1. INTRODUCTION

During the last few decades, an increasing trend of natural disasters and their adverse impacts on humans have been documented worldwide (Coronese et al., 2019; Rahman et al., 2014). Researchers believe that by 2050, the number of people suffering from disasters will be doubled (Ahmad & Afzal, 2019). Climate change caused by global warming has increased the intensity and frequency of landslides (Van der Geest, 2018; Adhikari et al., 2020). Landslides are of serious concern in those mountainous areas which are preferred by people for living (Abraham et al., 2020; Dou et al., 2020). Among natural disasters, landslides are considered to be the most common, most destructive and most recurring disasters (Dikshit et al., 2020) on Earth. Landslides may be small in areal extent but it can cause more damages in terms of financial loss and human lives (Qasim & Qasim, 2020). It's impossible to avoid landslides but their impacts can be minimized through appropriate mitigation plans (Eidsvig et al., 2014). Community-based disaster risk reduction measures are needed to reduce vulnerability and increase resilience of the people to disasters (Rahman et al., 2014). The impacts of landslides in the Murree area on people and their belongings have increased because of unplanned developments and population growth (Rahman et al., 2014; Qasim et al., 2021).

[1] **Corresponding author:** Said Qasim, **Email:** said.geography@um.uob.edu.pk

Vulnerability may be defined as the potential to suffer loss (Nor Diana et al., 2021; Pollock & Wartman, 2020). The physical vulnerability may focus on the intensity and magnitude of the landslides (Eidsvig et al., 2014). The concept of vulnerability came into focus in 1970 (Nor Diana et al., 2021). Vulnerability is an indicator that determines recovery from natural disasters (Nor Diana et al., 2021). High degree of vulnerability of households and society is due to their low level of adaptive capacity to natural hazards (De Andrade & Szlafsztein, 2018; Siders, 2019). Social vulnerability can be assessed using indicators of income, gender, age, infrastructure and lifelines, occupation, family structure, education, health facilities and social dependency (Nor Diana et al., 2021). To reduce the households' vulnerability to landslides, knowledge and identification of its indicators is needed. Adaptive capacity, sensitivity and exposure must be used as components of vulnerability (Prasetyo et al., 2020; Cutter et al., 2010). The use of resilience indicators for disaster assessments has gained attention worldwide. Resilience and vulnerability have an inverse relationship (Rifat & Liu, 2020) because vulnerable societies often show low resilience. Resilience is actually the capability of a system to manage inconveniences (Khan et al., 2011; Qasim et al., 2021). The key parameters for resilience measurements include the physical, social, economic and institutional (Ahmad & Afzal, 2019; Qasim et al., 2016). Social resilience includes variables of educational attainment, age, social capital and disability (Saja et al., 2018; Qasim et al., 2016). Physical resilience to natural hazards consist of variables including house type and its location (Qasim et al., 2021). Economic resilience consists of employment, income, several sources of income and disability (Qasim et al., 2021). Institutional resilience consists of awareness, early warning system (EWS), landslide funds and regulation control. Therefore, resilience here is used as households' ability to deal with serious damages from landslides and is assessed through indicators of physical, social, institutional and economic indicators. In Pakistan, landslides occur more frequently in Murree Hills (Rahman et al., 2014; Qasim et al., 2018; Qasim & Qasim, 2020). Landslides in Murree are also caused by human activities including land use changes, road construction and deforestation (Rahman et al., 2014; Qasim et al., 2021). Policies and legislation for reducing vulnerability and enhancing the resilience of households to landslides will minimize the intensity of damages from landslides. The literature review on landslides identified gaps of research on vulnerability and resilience to landslides in the country. Therefore, the objectives of this research were to 1) assess vulnerability and resilience of the households to landslides using indicators and variables and 2) compare the study sites based on vulnerability and resilience indices in Murree hill station.

2. METHODOLOGY

2.1. Characteristics of Study Site

Murree Tehsil of Rawalpindi Division was chosen as the study location due to frequent incidents of landslide (Khan et al., 2011; Qasim & Qasim, 2020). Murree is in fact located in an adjacent subdivision of the Himalayas. Murree Tehsil is based on fragile rocks and therefore faces frequent landslides. Murree is located in the Himalayan Mountains at 7500 feet elevation (Rahman et al., 2014) and receives the highest precipitation (Rahman et al., 2014; Qasim et al., 2021). Rainfall mainly occurs in monsoon. Temperate type climate prevails in the study area with cold winters and cool summers. Heavy snowfall occurs in January and February months. The thickness of the snow layer during these winter months is about 5 to 6 feet.

Murree has rocks of a very fragile nature (Rahman et al., 2014) and are therefore, vulnerable to landslides (Khan et al., 2011; Qasim et al., 2021). Fragile nature of the rock structure and climatic conditions have disposed this area to landslides. Besides the natural and climatic conditions, road construction, rapid growth of population and unplanned growth of settlements have amplified the probability of landslides. Disrupting roads and interrupted lines of communication are usual difficulties faced by the residents of Murree due to landslides. The landslides cause loss of human lives, livestock, houses and property.

2.2. Data collection

Recent census report of Pakistan shows that Murree had a population of 233,471 (PBS, 2017). We calculated the sample size through the Yamane formula (1967). The formula devised a sample of 200 with a 5% error of acceptance. Murree consists of Urban Fringe (UF), Rural Fringe (RF) and Inner City (IC) based on economic activities, population size and development (Figure 1). The IC is basically the Kashmir point. Majority of the people in IC are involved in tertiary and quaternary-type economic activities. Dhobi Ghat, Chitta Mor, Lower Mall, Kashmiri Mohalla and Bansra Galli are included in the UF. Majority of the people in UF are involved in the retail business and agriculture. Since the UF lies between the IC and RF, it shows mixed activities like farming and some small business activities. Mohra Iswal, Sher Bangla, Ihata Noor Khan and Bari Hatar are included in RF. To compare vulnerability and resilience of IC, UF and RF, we used proportional random sampling. The IC, UF and RF had a proportion of about 78 (39%), 38 (19%) and 84 (42%) of the population respectively (PBS, 2017).

Primary data regarding the components and indicator variables of both resilience and vulnerability were collected from December to March 2021. We prepared two sets of questionnaires. One questionnaire was prepared for households and the other for authorities of disaster management. In the households' questionnaire, we included socio-economic information keeping in view that all information about the variables is contained. The experts-based judgments regarding the ranking of vulnerability and resilience were included in the questionnaire for experts.

Fig 1. Location of the selected area

The household heads were interviewed during the field survey. It took almost half an hour to fill a single questionnaire from the households. SPSS software Version 18 was applied for data analysis. For the computation of indices for vulnerability and resilience, we used Excel. Bar charts were used to compare the resilience and vulnerability indices for the IC, UF and RF.

2.3. Selection of Indicators and Components

2.3.1. Vulnerability

To measure the vulnerability of households to landslides, its' constituents i.e., adaptive capacity, exposure and sensitivity were selected (De Andrade & Szlafsztein, 2018; Nor Diana et al., 2021). We chose the index method for calculating household vulnerability to landslides. For the "exposure component", the variables of past experience with landslides and houses constructed on vulnerable slopes were used. For the "sensitivity component", six variables including low-quality construction materials, people with disability, dependent population (people > 60 and/or <15 years age group), illiteracy, deaths of humans due to landslides and livestock losses due to landslides were used. For adaptive capacity, we considered variables of EWS, access to credit, social networking, education (Education up to class 10), working age group (15-60 years age group), and several sources of income and service.

2.3.2. Resilience

Resilience is an intricate concept. We, therefore, considered variables of institutional, physical, social and economic aspects. Resilience was measured in America in a very simple manner by Cutter et al. (2008). Neither standardized indicators nor absolute measurement methods have been used for resilience assessment. Researchers normally use proxy indicators to measure it. Physical, social, institutional and economic variables are used for resilience measurement (Cutter et al., 2008). We also used the social, physical, institutional and economic components to measure resilience to landslides. Social component of resilience include age, educational attainment, disabled members and social capital. Except for age and disabled members of the family, the other variables have positive association with resilience (Table 1). The economic component of resilience consists of household members with employment, income and households with several sources of income. All the variables of economic resilience suggested above have a positive effect on resilience. We used Ravallion et al. (2009) study as a yardstick to determine the poverty line for our surveyed households. Therefore, households whose monthly income was below U.S. $ 32.74 were considered poor. Institutional resilience consists of variables including early warning system (EWS), provision of landslide funds, regulation control and awareness. The institutional variables have an affirmative relationship with resilience. For the physical resilience, we have considered variables of, the type of house material (house made with breaks and cement or houses made of mud) and location (location on a safe place or vulnerable slope). The variable of type of house material has a positive association with resilience. The variable location of the house was considered to have a negative association with resilience because most of the houses were constructed in landslide-prone locations.

Table 1. List of components indicators and variables for landslide resilience

Constituent indicators	Variables and sources	Unit	Rationalization and association (+ or –) with resilience
Social Resilience	Educational status (Pollock and Wartman, 2020; Eidsvig et al., 2014)	% population with high school education	Access to education increases understanding of preparedness, +
	Age (Cutter et al., 2010; Pollock and Wartman, 2020)	% population (>60 years + <15 years)	Children are more prone to landslides, –
	Social capital (Lin et al., 2008)	% population having memberships of social organizations	Social capital increases cooperation during emergencies, +
Economic resilience	Disability (Eidsvig et al., 2014; Cutter et al., 2010)	% of people with any type of disability	Evacuation becomes difficult in case of physical and mental disabilities, –
	Employment (Eidsvig et al., 2014)	% of households with employment	It enhances the economic capabilities of the households, +
	Income (Eidsvig et al., 2014; Qasim et al., 2021)	% of households above the poverty line	Population above the poverty line may recover soon after a disaster occurs, +
	Several means of income (Eidsvig et al., 2014; Cutter et al., 2010)	% of households who had multiple income sources	Diversified income sources lead to fast recovery and rehabilitation, +
Institutional resilience	Awareness (Eidsvig et al., 2014; Pollock and Wartman, 2020)	% of households who had awareness of landslide risk	It enhances the knowledge and skills of the community against landslides, +
	Regulation control (Eidsvig et al., 2014; Qasim et al., 2021; Lin et al., 2008)	% of households who followed regulation control and laws	Rules and regulations existing for construction and land use planning may enhance resilience, +
	EWS (Eidsvig et al., 2014; Qasim et al., 2021)	% of households who were provided with basic hazard maps and EWS about landslides	EWS helps in evacuation before a disaster can occur, +
	Landslide funds (Eidsvig et al., 2014; Qasim et al., 2021)	% population who have insurance and access to disaster funds	Existence of government sponsored landslide funds helps in recovery after disasters, +
Physical resilience	House structure (Eidsvig et al., 2014; Qasim et al., 2021)	% houses totally made of bricks and concrete	Bricks and concrete used houses are less affected during natural disasters, +
	Location (Eidsvig et al., 2014; Qasim et al., 2021)	% houses located on steep slopes	Location at vulnerable slopes makes it more susceptible to landslides , –

2.4. Selection of Indicators and Components

Indicators have been applied for the assessment of resilience and vulnerability to natural disasters. The intricate data are being condensed into a single value through the use of indicators (Qasim et al., 2021). Indices provide important information for making policies. To safeguard ourselves from issues of normalization of data, we selected percent values for the variables for both vulnerability and resilience. In index calculation, it is necessary to allocate weights to each selected variable. The literature review suggested the use of a subjective approach for such data because the objective approach for this situation is not appropriate. Therefore, we also followed the subjective approach as used by Eidsvig et al. (2014) and Ahmad and Afzal (2019).

To assign weights to the variables of resilience and vulnerability, simple questions were asked on a percent scale of 0-1 in the questionnaires for the director of the National Disaster Management Authority (NDMA). On the scale, 1 represented high resilience and vulnerability and 0 represented low resilience and vulnerability. The variable vulnerability indices (VVIs) for each variable of exposure and sensitivity were computed by dividing percent values suggested by the director NDMA by the actual values obtained in the household survey. For the component of adaptive capacity, the calculation process was inversely used because the more the adaptive capacity, the less the vulnerability. Then the component indices i.e., exposure (EVI), adaptive capacity (AVI) and sensitivity (SVI) were computed. From values of EVI, SVI and AVI, we calculated the overall vulnerability index (OVI) by using the formula used by Ahmad and Afzal. (2019) for calculating vulnerability, equation (1) is given below.

$$\text{Landslide Vulnerability Index (LVI)} = \frac{\text{Exposure} * \text{Sensitivity}}{\text{Adaptive Capacity}} \quad \text{(Eq.1)}$$

Since vulnerability and resilience are like two opposite sides of a coin, consequently, for calculating variable resilience indices (VRIs), the percentage values of the variables received from the household survey were divided by percentage values assigned for each variable by the director NDMA. VRIs with low values show low resilience to landslides and vice versa. If, however, a variable whose high values indicate less resilience, we then reversely used the scale for director NDMA. The scale was used inversely for these variables because these variables have contrasting effects on resilience. The component indicators of resilience were achieved using their average values. Overall resilience indices (ORIs) were also designed in a similar method as shown in equation (2).

$$\text{Landslide Resilience Index (LRI)} = \frac{\text{PRI+SRI+IRI+ERI}}{4} \quad \text{(Eq. 2)}$$

3. RESULTS AND DISCUSSION

3.1. HH Socio-economic information

The majority of surveyed households from IC (68%) followed by UF (58%) and RF (51%) had expressed past experience with landslides (Table 2). Almost the same pattern was followed for the location of houses on vulnerable slopes for the IC (65%) followed by UF (50%) and RF (36%). This shows that the IC was more vulnerable than the UF and RF. In the IC, majority of the dwelling places and houses were constructed on vulnerable slopes. Majority of the houses were either too old or were constructed with low-quality materials. The percentages of dilapidated buildings were more in IC (35%) than in the UF (30%) and RF (25%). The dependent population was more in the RF (81%) than the UF (72%) and the IC (30%). The illiteracy was more in RF (49) and IC (24) than the UF (18). Members with disability were the least in all the 3 sites. Human losses were more in RF (11%) than in the UF (7%) and IC (8%). The livestock losses were also higher in the RF (19%) than in the UF (10%) and IC (5%). More people from the IC (55%) had access to credit than the UF (45%) and RF (25%). People with social networking systems were also more in the IC (66%) than the UF (13%) and RF (6%). People with several means of income were more in the IC than in the other two places. People with employment were more in the IC (42%) than the UF (32%) and RF (15%).

3.2. HH vulnerability indices

Exposure in the context of a landslide is defined as a set of elements at risk in the landslide-susceptible zone (Pellicani et al., 2014). Past experience of landslides and location of houses on vulnerable slopes were the two variables used for exposure component of vulnerability to landslides in this study (Table 2). Results showed that the IC had a higher (0.90) exposure level as compared to the UF (0.75) and RF (0.57). More damage has occurred because the houses were constructed on vulnerable slopes. The results of our study are confirmed by studies of Rahman et al. (2014), Lin et al. (2008) and Eidsvig et al. (2014).

Table 2. Indices of landslide vulnerability

Vulnerability indicators	IC		UF		RF	
	% value	VVI	% value	VVI	% value	VVI
Exposure						
Past landslides know-how	68	0.88	57	0.70	51	0.59
House location	65	0.92	50	0.80	36	0.56
EVI		0.90		0.75		0.57
Sensitivity						
Dilapidated buildings	35	0.14	30	0.50	25	0.92
Dependents	30	0.50	72	0.56	81	0.69
Illiterate	24	0.83	18	0.83	49	0.82
Disable members	02	1.0	01	1.0	02	0.1
Human Losses	08	0.63	07	0.71	11	0.91
Livestock losses	05	01	10	0.80	19	0.79
SVI		0.68		0.73		0.86
Adaptive Capacity						
Awareness	41	0.68	32	0.64	25	0.83
Access to credit	55	0.92	45	0.90	25	0.71
EWS	08	0.18	03	0.08	03	0.12
Social networking	66	0.94	13	0.37	06	0.20
Multiple Income Sources	72	0.9	71	0.95	45	0.82
Employment	42	0.7	32	0.80	15	0.38
AVI		0.72		0.58		0.51
OVI		0.85		0.94		0.96

Any external or internal disturbance which brings disorder is a system called sensitivity (Ahmad & Afzal, 2019). The sensitivity values show that RF has more sensitivity (0.86) than the UF (0.73) and IC (0.68). This is because of the underlying variables. The variable "illiteracy" shows that the RF has a more illiterate population as compared to the UF and IC. Similarly, the variable "dependents" shows that the RF has more dependent family members than the UF and IC. The livestock losses were also higher in RF as compared to the UF and IC. Results of several other studies have also found that illiteracy, dependent family members and livestock losses lead to higher sensitivity (Khan et al., 2011; Eidsvig et al., 2014).

An individual or a household or a community's ability to take adaptation measures to deal with the unforeseen events of a disaster is called adaptive capacity (Cutter et al., 2008). Results of the adaptive capacity index showed that the IC (0.72) had more adaptive capacity as compared to UF (0.58) and RF (0.51). This shows that the IC had more adaptive capacity and is, therefore, less vulnerable to landslides than the UF and RF. The contributing factors to adaptive capacity are higher awareness level, higher access to credit, sources of EWS, more social networking system and sources of employment and several sources of income. Households that faced reduced landslide hazard were those that had higher awareness level of environmental condition, had reacted to EWS, had strong social linkages with members of the society and had multiple income sources. Multiple income sources enable households to buy house in a safer area at higher land price as compared to limited-income households (Ahmad & Afzal, 2019; Eidsvig et al., 2014). Employment gives the household members an option to invest in costly adaptation measures and thus reduces household's vulnerability to hazards. Similarly, in all the three sites, those households that had higher awareness level and had more access to credits were able to adapt measures for reducing landslides. Our study results confirm the previous study of Eidsvig et al. (2014) and Qasim et al. (2021).

3.3. HH resilience indices

Results for the component and overall landslide resilience were interpreted based on the average values of the index range. Index range of 0, 0.5 and 1 were considered as low, medium and high categories of resilience, respectively. Results for the overall resilience indices of UF (0.44) and RF (0.28) were below medium levels. Only the IC (0.51) had an overall resilience level of medium category (Table 3).

Social resilience is the ability of individuals, communities and organizations to handle natural hazards (Saja et al., 2018). The component resilience category i.e., social resilience also showed similar results as the overall resilience levels for the study sites. IC had a medium level of resilience (0.51) as compared to the low resilience levels of UF (0.39) and RF (0.22). The IC had more of its households with educational achievements (percent) and also the majority of the households that were surveyed had high social capital which has contributed towards its high social resilience. Low values of the indices of social resilience for UF and RF may be due to the factors of a high percentage of dependent family members and a low percentage of households with social capital. Our study findings are confirmed by Cutter et al. (2008), Pollock and Wartman (2020) and Eidsvig et al. (2014).

Economic resilience refers to the well-organized resource distribution in reaction to the risk of a disaster (Ahmad & Afzal, 2019). Except for the RF (0.38) which had low resilience, the IC (0.71) and UF (0.61) both had high resilience levels. The high resilience values of the IC and UF may be because of factors such as more households having employment, households (5) having high income and more number of households having several means of income. The low level of resilience in rural fringe may be attributed to fewer chances of employment opportunities and fewer chances to access the diversification of income sources and hand-to-mouth income sources. Low economic resilience leads to more vulnerability of households to natural disasters. Similar findings were shared by studies of Eidsvig et al. (2014), Pollock and Wartman (2020) and Qasim et al. (2021).

Table 2. Indices of landslide resilience

Indicators and their relevant variables	**IC**		**UF**		**RF**	
	% value	VRI	% value	VRI	% value	VRI
Social Resilience						
Literacy level	76	0.89	82	0.96	51	0.60
Age (Dependents)	38	0.01	72	0.00	81	0.00
Social capital	66	0.94	13	0.19	06	0.19
Disability	02	0.02	01	0.04	02	0.02
SRI		0.51		0.39		0.22
Economic Resilience						
Employment	42	0.57	32	0.44	15	0.20
Income	74	0.81	76	0.83	44	0.48
Multiple livelihood sources	72	0.74	71	0.73	45	0.47
ERI		0.71		0.67		0.38
Institutional Resilience						
Awareness	41	0.42	32	0.33	25	0.25
Regulations control	44	0.46	45	0.47	42	0.43
EWS	08	0.08	03	0.03	03	0.03
Landslide funds	17	0.28	06	0.10	09	0.15
IRI		0.31		0.27		0.24
Physical Resilience						
House type	94	0.97	79	0.82	54	0.56
Location	33	0.02	63	0.01	70	0.01
PRI		0.50		0.41		0.28
ORI		0.51		0.44		0.28

Institutional resilience is concerned with the policies, rules and regulations implemented for the mitigation of natural hazards (Cutter et al., 2008). In this study, the institutional resilience level was very low in all the sites. Low values of the institutional resilience may be attributed to low awareness levels of the households, low number of households with facilities of EWS, low number of households with landslide funds and most importantly the low number of households who followed rules and regulations and building codes. Our findings for institutional resilience are confirmed by the findings of Lin et al. (2008), Cutter et al. (2008), Pellicani et al. (2014) and Ahmad and Afzal (2019).

The ability of households to protect and recover from disasters by using better infrastructure is called physical resilience (Ahmad & Afzal, 2019). The IC had medium physical resilience (0.51) and the other two locations had low resilience values. The medium level of physical resilience of the IC may be attributed to factors such as a higher percentage of the population with concrete and cement houses and a smaller number of households with houses located on vulnerable slopes. The low resilience of UF and RF indicate that majority of the households had their houses made of low construction materials and were placed on vulnerable locations due to their low-income levels (Lin et al., 2008).

3.4. Comparison of HH vulnerability and Resilience

Vulnerability and resilience to landslides in study sites are shown in Figures 2 and 3, respectively. The results for both indices of vulnerability and resilience were divided into 3 classes of low resilience and vulnerability as 0, medium resilience and vulnerability as 0.5 and high resilience and vulnerability as 1, respectively. Figure 2 for vulnerability to landslides indicates that the RF has higher vulnerability indices than the other two sites. Due to these high vulnerability results for the study sites, it is essential for the disaster management authorities to raise awareness levels of the local people to adopt preventive and mitigation measures. The overall vulnerability indices for all three sites were high. Results show that the overall vulnerability indices values for the RF (0.96) and UF (0.94) were higher than the IC (0.85) (Figure 2). To reduce the vulnerability of these landslide-prone sites and make them more resilient to landslides, more effective policymaking is needed by the disaster management authorities at local and regional levels.

The resilience indices values are shown in Figure 3. Results showed except for the IC with medium resilience, RF and UF had low levels of resilience. Results indicated that the RF was highly vulnerable and had low resilience levels due to low social (0.22), economic (0.38), institutional (0.24) and physical (0.28) resilience indices. The overall resilience index of RF (0.28) was very low as compared to nearly medium-level resilience levels of UF (0.44) and medium-level resilience levels of IC (0.51) (Figure 3).

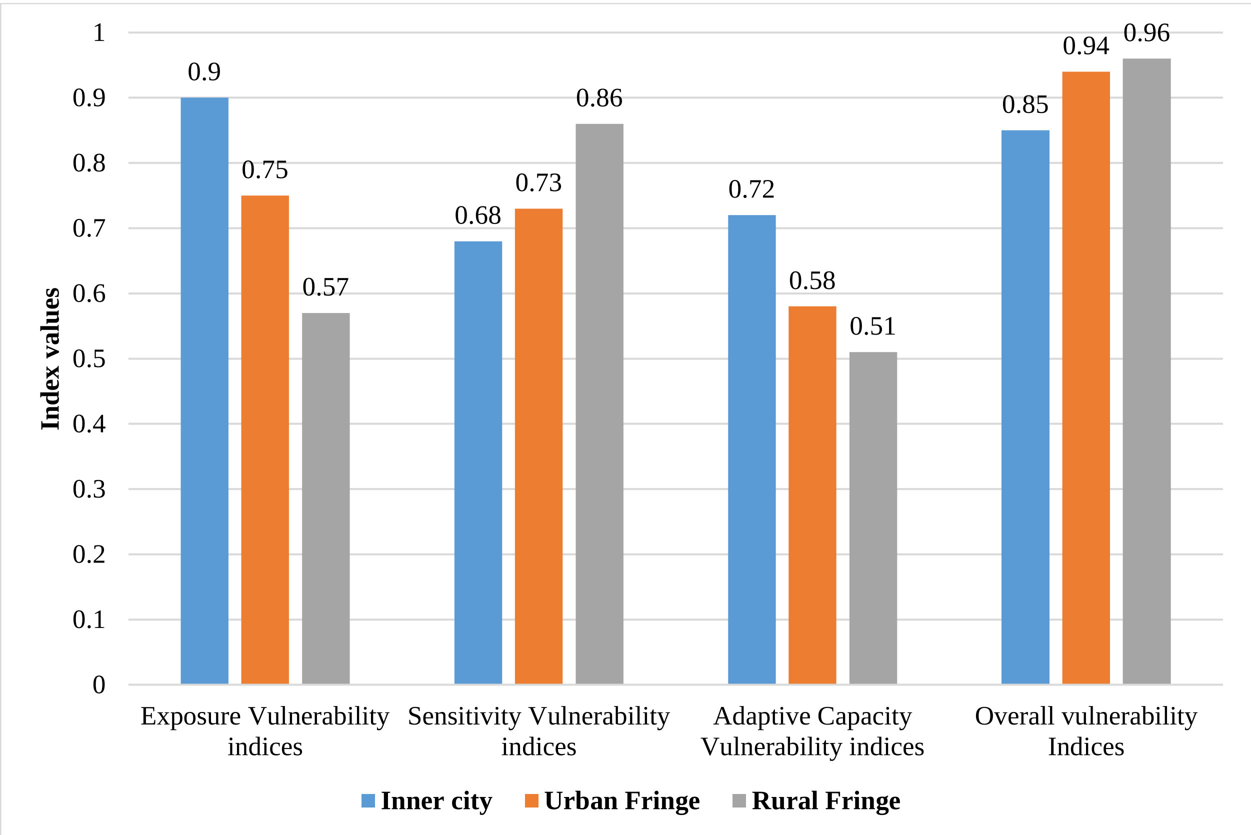

Fig 2. Household vulnerability indices for the study sites

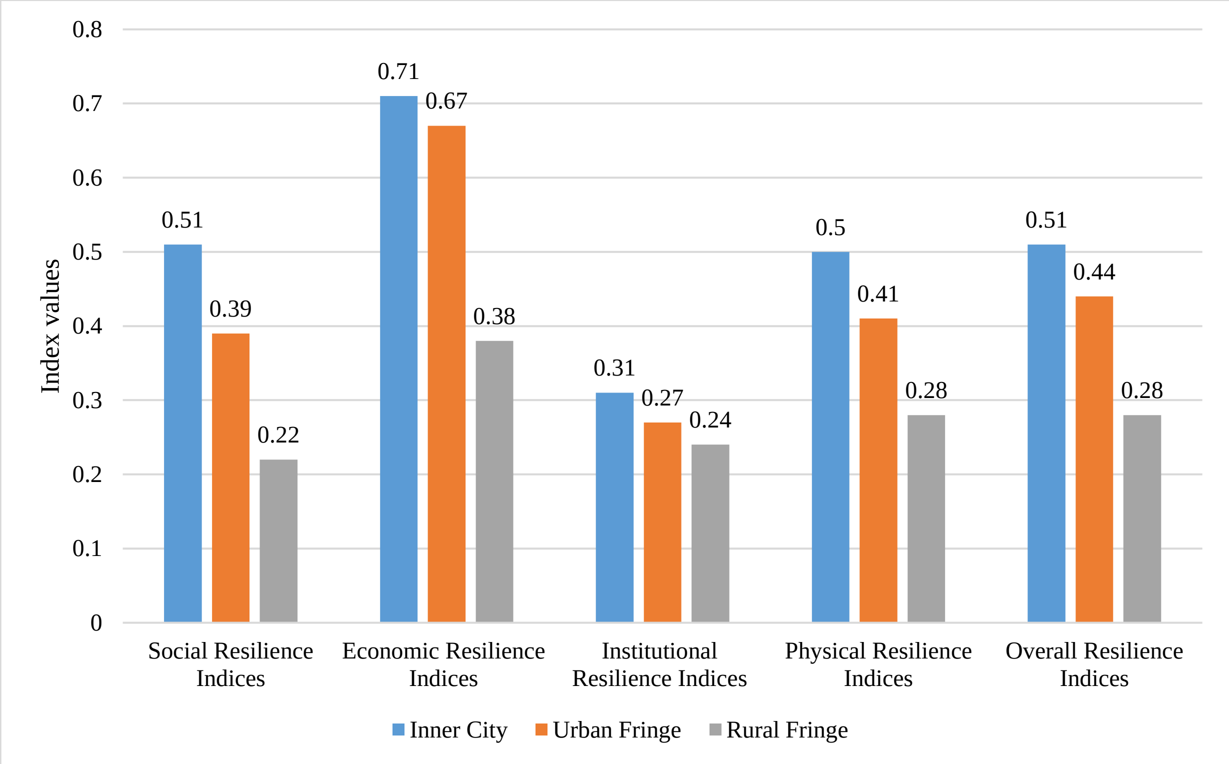

Fig 3. Household resilience indices for the study sites

4. CONCLUSION

This study carried out household level assessment of vulnerability, resilience and their comparison for the IC, UF and RF of Murree. Results for all the sites showed high vulnerability and low to medium level of resilience to landslide hazards. The composite indices showed that UF and RF have low-level resilience. The RF showed low resiliency and high vulnerability. This research will provide guidelines for the government authorities related to disaster management and NGOs for enhancing resilience and reducing the vulnerability of households in Murree Hills of Pakistan. To enhance the economic resilience of the households in the sites, they should be provided with easy access to credit facilities and employment opportunities. Besides providing employment opportunities, efforts should also be focused on rural communities to increase their means of income. Efforts should be made by disaster management institutions to enhance awareness of the communities to natural hazards and implementation of policies for the construction of buildings and houses. If these rules and regulations are properly implemented, it will decrease the adverse landslide impacts on the local population.

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