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Research Article

Extent and Evaluation of Flash Flood Resilience in Mountainous Communities of Daral and Chail Valleys, District Swat, Pakistan

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Abstract: This study aimed to explore the extent and evaluation of flash flood resilience in mountainous communities of Daral and Chail valleys of Swat. After collecting data from primary and secondary sources, the parameters of Disaster Resilience Capacity (DRC) model was applied for data analysis. The analysis reveals that stream discharge increases during summer mainly because of the rapid melting of snow, ice, glaciers and monsoonal rains, which results in flash floods. The communities living in the mountainous areas of Daral and Chail valleys face problems of multitudes of socio-economic and infrastructural flash flood damages almost every year. However, limited communities have adopted indigenous resilience strategies to bounce back from the recurrent adverse impacts of flash floods. It was found from the analysis that due to indigenous resilience practices by the local communities and the location of most mountainous communities, Daral valley is more resilient to flash floods as compared to Chail valley. Contrary to this, the extent and level of flash flood resilience in Chail valley are low as most of the mountainous communities are more vulnerable to seasonal flash floods. Some wise practices can enhance resilience to flash floods, especially land use planning, community preparedness, afforestation, and improved accessibility and communications.

Keywords: Flash Flood, Mountain community, Flood Resilience,

1. INTRODUCTION

In the world, natural calamities are associated with the possibilities of bringing adversaries to human beings and their environment [17]. The phenomenon that carries the potentials of being a threat to human lives and their properties is called hazard. [1]. Among the hazards, flash flood is a type of flood hazard that happens abruptly suddenly with very little time for early warnings and emergency response. Flash floods occur rapidly and is also characterised with associated hazards including mudflow, landslides and causes death toll, casualties and infrastructural damages [2]. Landslide is a broader term including a wide variety of mass movements associated with slope failure, movement of debris and rocks due to the influence of gravity. [3].

The term resilience is widely used to "to avoid" in the field of disaster risk management. However, the common uses including description of jumping, leaping and rebounding [4]. In the framework of disaster resilience it is defined as the capabilities related to preparedness, response and recovery before, during and after the disaster. Disaster resilience enhances the capacities to mitigate the adverse impacts of natural hazard, it deals with prevention, adaptation and mitigation. The ability of an actor or a system to bear shocks and return to its state of origin is also known as disaster resilience. Resilience is also considered as the capability to handle with the unanticipated dangers and to bounce back in an effective way [5]. Resilience is differently defined in different disciplines, therefore there is a long list of definitions, but one thing is common in all these definitions to focus on the ability to resist and absorb shocks of unforeseen events and to recover [6]. The concept of resilience is being used by researchers both as process and as an outcome [7]. The concept of resilience refers to the capacity of a community to adapt, cope with, and recover through changing impacts and sustaining a suitable

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structure and function during and after a hazard [8]. The indigenous factors related to a specific locality may have positive or negative impacts on level of resilience [1].

The main features of resilience are repelling the impacts of disasters and recovering from and acclimatising with the new settings to manage any unforeseen hazard [18]. Community resilience is explained at various inter-related levels, such as the community's capacity to "bounce back" and use of their own resources to recover. The objectives of resilience are to contribute to protecting human lives, the built environment, and livelihoods and to safeguard administrative and economic stability [9]. Mountainous communities are considered to be at greater risk to natural disasters due to low level of resilience, the factors including, steep slopes, rugged topography, geology, heavy precipitation, and surface lithology. [10]. Though the inhabitants of mountainous communities live there for centuries, they handle the dangers posed by natural calamities, including earthquakes, landslides, extreme temperature, storms, and flash floods [11]. Regardless of all the dangers posed by mountainous areas, a large number of people reside there. Due to sharp population increase and high land value in the plain areas, the settlements are sprawling towards mountains. Due to continuous anthropogenic activities over the fragile slopes and social and economic systems changes, the degree of people's proneness to various hazards has been increasing [12].

The mountains are; naturally active landforms therefore, the mountainous communities are vulnerable to natural calamities. Generally, the rural settlements are associated with mountains, but it is not only rural, according to current estimates, more than 50 % of world population lives in urban areas and there are urban localities within the mountains. In urban areas with nearby mountains the settlements sprawl into the slopes because the poor people are pushed to the mountains for housing due to comparatively low land value. It makes them more vulnerable to natural hazards including flash floods [13].

There are three associated aspects related to natural hazards in mountainous areas. The mountains are hydrologically and geo-physically more active and are also biologically diverse due to multiplicity in altitude, humidity and temperature. The second point is that mountainous regions have different social makeup, including isolated small settlements dependent upon agriculture, livestock, and forest wood to larger diversified urban settlements with complex transportation and communication networks. The urban settlements in the mountainous areas also attract migrants for jobs,

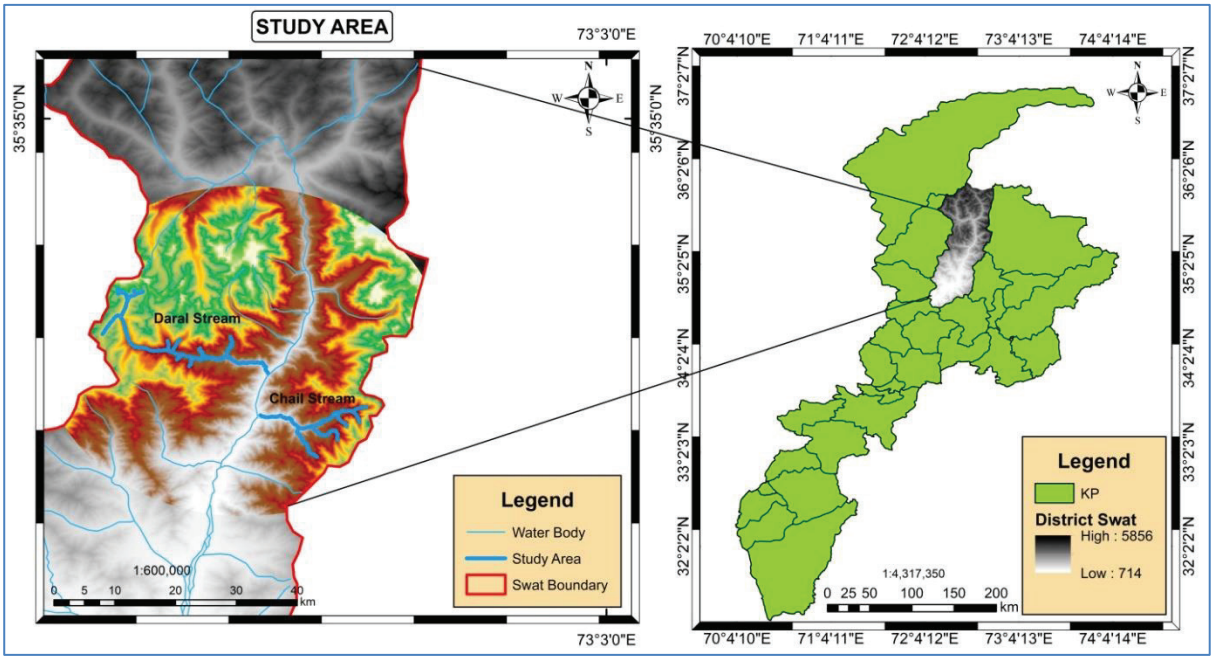


Fig. 1. Location of the study area

tourism and other economic activities. The third point is that the mountains are communicated with other areas through water, air, people, information, economy, goods and services etc. With time, the linkages between highlands and lowlands have sharply increased in number and importance [1].

1.1 The Study Area

Swat valley is situated in the northern part of Pakistan bordering with Chitral and Gilgit Baltistan which are in the northern extremes of the country. Swat valley is mountainous with natural beauty and is a famous tourist destination. In Swat Valley, river flooding dominates downstream Madyan while flash floods dominate in the valley's upper reaches [20]. The research work was conducted in the sub valleys of Daral and Chail. Daral valley is drained by Daral stream as an important tributary of river Swat which join the river at the town of Bahrain, the valley is situated in the north-western part of Swat valley. There are high up mountains in the valley with maximum altitude reaching up to 15,000 feet above mean sea level, while the altitude at lower reaches of the alley is 4600 feet above mean sea level. The valley settlements comprise medium and small villages, hamlets, and scattered settlements. There are ten medium and small villages in the valley and 12 hamlets with isolated settlements. High mountain peaks surround the valley therefore the monsoon influence is considered to be low. The precipitation is mostly received in the form of snow during winter and as rain during spring, the snow fall reaches up to five meter depth during winter [14].

Chail a sub valley is situated in the northeast of Swat valley, extended towards east at the town of Madyan. There are high up mountains with perennial streams, the valley is also rich in natural resources with diversified flora and fauna. The valley lies at 35° 3' 40" to 35°11' 40" north latitude and 72°32' 1" to 72°43' 3" east longitude (Figure 1). The valley is also prone to natural calamities, including flash floods, landsliding, snow avalanches, etc. In Chail valley, most of the settlements are situated along the main stream and its tributaries, making them more prone to flash floods [15]. The settlements in Chail valley are distributed in medium and small villages and hamlets with isolated houses. According to census 2017 the people are inhibited in 20 medium and small villages grouped around three major localities, including Bashigram, Shanko and Chail. According to Census 2017 the total population of the valley is 20,091 consist of 2820 households [19].

2. MATERIAL AND METHODS

All possible efforts were being made during the research work to collect consummate information by applying different tools and models. Data collection was started initially by a pilot survey in which the valley was visited. The tools were made based on the compatibility with the local area and theme of research. The tools consist of structured interviews through questionnaires, semi structured interviews, focused group discussions and direct observations.The diversified tools were used for different respondents including households, civil society, key informants, government line departments and commercial points.There are medium and small size villages in the target valleys, including 20 in Chail valley and ten in Daral valley with surrounding hamlets and scattered isolated houses. During data collection ten localities were selected on the basis of proneness to the flash floods including five in Chail valley and five in Daral valley. During data collection the tools including household questionnaire, semi structured interviews with the key informants, focussed group discussion, and direct observations were used in these localities. In each of the ten selected localities 20 household questionnaires, at least one FGD and three semi structured interviews were conducted. During data collection the information was also triangulated by using different types of tools for same type of information.

The information was properly analysed after data collection by applying different latest software, including MS Excel, MS Access, and SPSS. The maps and related data was presented by using Arc GIS software. The Disaster Resilience Capacity (DRC) model was applied during data collection and analysis. In the DRC model there five levels, the first one describes the DRC of communities. As shown in (Figure 2) in the second level the DRC is divided into two including community preparedness (CPD) and community environmental conditions (CEC)

In the third level, the CPD criteria is further

divided and focussing on the disaster preparedness, early warning system, capabilities of emergency response and reporting system, the CEC at the third level further focus on assessment of hazards of landslide and flash floods. Then in the fourth and fifth levels the parameters of third level are further subdivided for having detailed information. According to the scale developed by Satty in 1980 from one to nine was used for measurement of every element, 1 is used for less significance while 9 is used for more significance [16].

(Figure 2) is showing the details of five hierarchies the multiple criteria decision-making technique was used. The system of hierarchies simplify complicated issues related to the research. There is a hierarchic scheme of five levels for evaluating Disaster Resilience Capacity (DRC).

3. RESULTS AND DISCUSSION

3.1 Vulnerability to Flash Floods

3.1.1 Vulnerabilities to Flash Floods in Chail Valley

The seasonal flash floods are prominent in Chail valley; 2010 flood was extremely disastrous for the valley, in the five surveyed localities a total of 255 houses were washed away. The flood also destroyed agriculture lands along the streams, water mills, forest trees, and fish hatcheries. The detail

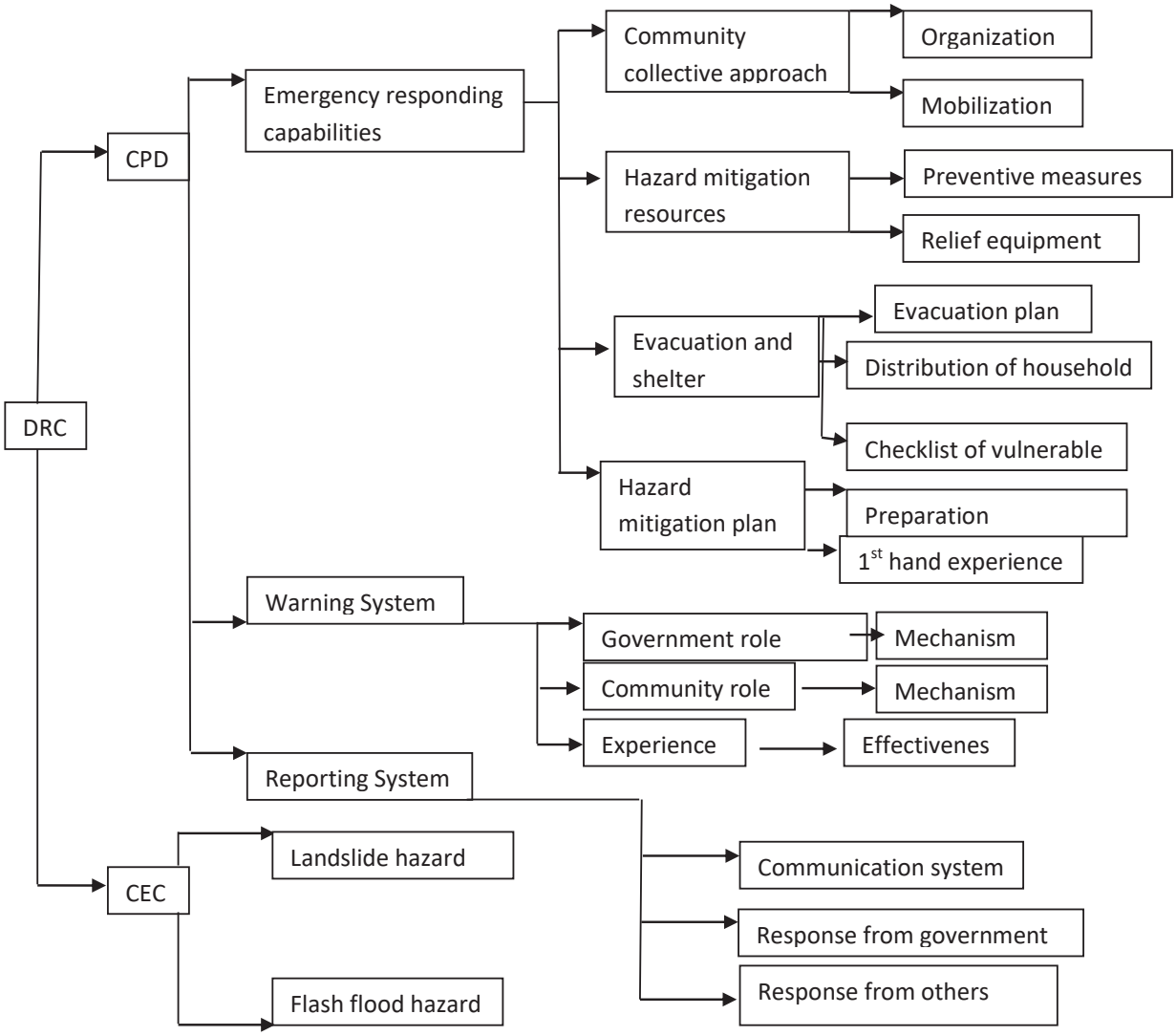


Fig. 2. Research process

of vulnerabilities is shown in (Table 1). In Chail valley, according to household survey in the five selected localities, 49 % of the respondents told that roads and bridges are most vulnerable, while 46 % responded that houses are most vulnerable, besides, 5 % told that agriculture lands are more vulnerable. (Table 1) shows that the most vulnerable to flash floods are roads/bridges, houses and water supply system and the least vulnerable are hotels/shops and irrigation channels.

In Chail valley, to cross the stream the people fixed wooden bridges at different points. In the bigger localities like Bashigram, Shanko and Chail the settlements are situated along both the sides. While some of the people live at one side of the stream while their agriculture lands are lying towards the other side. Therefore, for local people's routine mobility to cross the stream, the wooden bridges are very important.

3.1.2 Vulnerability to Flash Floods in Daral Valley

According to the household survey in Daral valley, 47 % of the respondents were of the opinion that roads and bridges are more vulnerable, after roads the agriculture lands were considered more vulnerable, 31 % responded about agriculture lands are more vulnerable, Furthermore houses were considered to be most vulnerable and 18% of the respondents responded about it, while 2 % told that hotels and shops are more vulnerable. (Table 2) is showing that the most vulnerable to flash floods are roads/bridges, houses and water supply and the least vulnerable are hotels/shops and irrigation channels. (Table 2) also shows that houses are considered the second most vulnerable to flash floods.

In Daral valley as shown in (Table 2) mobility of local people to cross stream is highly vulnerable to seasonal flash floods due to washing away of wooden bridges. These wooden bridges are also very important for evacuation, the people also face problems in evacuation. In Daral valley, roads and pathways are also found along both sides of the stream and damaged during flash floods. The patches of agriculture land along both the sides of stream are also being affected by the overflow of the stream during flash floods. In the valley however most of the settlements are situated a bit far from the stream but still some of the settlements

Table 1. Chail valley, Vulnerability to flash floods (Responses are in %age)

Vulnerability rank	Houses	Agriculture land	Roads/B ridges	Water Supply	Irrigation Channel	Shops/Hotel
Most vulnerable	46	5	49	_	_	_
2nd most vulnerable	41	10	37	12	_	_
3rd most vulnerable	5	41	14	38	2	_
4th most vulnerable	8	19	_	33	27	13
5th most vulnerable	_	15	_	12	57	7
6th most vulnerable	_	9	_		12	33
Not vulnerable	_	1	_	5	2	47
Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field Survey, 2018

Table 2. Daral valley, Vulnerability to Flash floods (Responses are in %age)

Vulnerability ranking	Houses	Agriculture land	Roads/B ridges	Water Supply	Irrigation Channel	Shops/ hotel
Most vulnerable	18	31	47	2	_	2
2nd most vulnerable	57	18	15	6	_	4
3rd most vulnerable	21	11	38	26	_	4
4th most vulnerable	4	_	_	32	_	27
5th most vulnerable	_	1	_	34	35	1
6th most vulnerable	_	10	_	_	50	10
Not vulnerable	_	29	_	_	15	52
Total	100	100	100	100	100	100

Source: Field Survey, 2018

are situated close to stream on vulnerable points and are vulnerable to flash floods.

3.2 Causes of Flash Floods

During data collection different causes of flash floods were explored after having inputs from key informants, existing literature and direct observations. Based on that the causes of flash floods were listed and the respondents were asked to rank causes according to their significance to cause flash flood.

3.2.1 Causes of Flash Floods in Chail Valley

Chail valley, due to the location of settlements and other resources, is considered more prone to flash floods than Daral valley. After the 2010 flood due to lateral erosion, the stream flows in a wide channel. The tributaries of Chail stream transport the weathered rock material in the shape of boulder or gravel and deposit it in the down valley areas.

During field survey the respondents recorded (Table 3) torrential rainfall as the most significant cause stated by 49% respondents, while 22% reported it as second most significant, 21% as 3rd most significant and 8% as fourth most significant cause. The second most significant cause of flash floods was reported as cloud bursts followed by high snow melt, deforestation and overgrazing.

3.2.2 Causes of Flash Floods in Daral Valley

As compared to Chail valley, Daral valley is narrow and the slopes are steeper with hard rock materials. In the lower part of the valley towards Bahrain town the settlements including Jheel and Niam are more prone to flash floods, while in the middle and upper reaches of the valley the settlements are situated a bit far from the main Daral stream therefore the roads and bridges are prone to flash floods while the settlements are prone to flash floods of the tributaries and gullies of Daral stream running along the settlements.

As mentioned in (Table 4) most of the respondents stated that torrential rainfall is the major cause of flash floods followed by high snow melt, clouds burst, deforestation and overgrazing. During summer the heavy rainfall in the catchment area causes overflow in the tributaries and gullies and exceed the flow of Daral stream, during summer due to increase in diurnal temperature also contribute to high snow melt and increase in stream flow.

3.3 Chail valley: Communities' Resilience against Flash floods

In Chail valley before flood 2010 the stream was flowing in a narrow deep channel, there were trees in large number towards both the sides of the stream and the seasonal floods were not disastrous

Table 3. Chail valley, Causes of flash floods (Responses are in %age)

Ranking of causes	Torrential rainfall	High snow melt	Clouds burst	Loose rocks	Deforestation	Over grazing
Most significant	49	12	12	_	18	9
2nd most significant	22	43	8	_	9	18
3rd most significant	21	18	60	_	_	1
4th most significant	8	8	12	12	58	2
5th most significant	_	19	8	1	12	57
6th most significant	_	_	_	78	_	9
Insignificant	_	_	_	9	3	4
Total	100	100	100	100	100	100

Source: Field Survey, 2018

during peak seasons, except lateral erosion at few points. There were also trout fish hatcheries along the stream. During the massive flood 2010 the trees and grassy point bars were washed away, the houses close to the stream were destroyed, the width of stream channel was increased by few times. After 2010 every year, the valley faces flash floods in June, July and August, it results in blockage of road access to some of the villages and sub valleys. Every year during flood season the small bridges are being washed away and the houses are more prone to seasonal flash floods.

3.4 Chail Valley: Communities' Preparedness against flash floods

In Chail valley the resilience was evaluated according to the elements mentioned in (Table 5), each of the elements was scored according to its significance in the sample localities, the average of sample localities for Chail valley is mentioned against each element. Score 9 is for maximum significance and 1 for least significance.

In Chail valley the communities are more proactive to help each other in emergency situation, therefore however without any formal body the communities are organized and mobilized to help each other and to cope with flash floods. The people also care about vulnerable people, however they are not having formal lists but they care about disable, elderly women and children during flash floods. The community got a good experience to respond to floods during and after flood 2010. The people are also proactive in warning each other on time while the government's warning system is very poor. In the valley, most of the villages are lacking evacuation plan and some of the villages and sub valleys lack access to main roads. In some of the elements including relief equipment, preventive measures, distribution of households and preparation for flash floods the target villages got intermediate figures. The community is responding to rehabilitate their infrastructure after flash floods, the re keeping some of the equipment and after flood 2010 some of the organizations also provided them with basic skills and equipment.

3.5 Chail Valley: Communities' environmental conditions and flash floods

Some of the components of community environmental conditions differ before and after flood 2010. In Chail valley the slope gradient is comparatively gentle and the rocks are in loose form. Chail valley was experiencing flash floods each year during the months of June, July and August. During floods, the area was experiencing flash floods, which resulted in lateral erosion at few points. The settlements were safe from flash floods because open spaces were covered with big trees between stream and settlements.

In 2010 the area was hit by a devastating flood that brought huge damages and changed local environmental conditions. The stream channel was increased in size, the open spaces were washed away and the settlements along the stream are now

Table 4. Daral valley, Causes of flash flood (Responses are in %age)

Ranking of Causes	Torrential rainfall	High snow melt	Clouds burst	Loose rocks	Deforestation	Over grazing
Most significant	46	32	12	_	9	1
2nd most significant	34	36	18	_	3	9
3rd most significant	16	22	51	_	9	2
4th most significant	3	8	10	22	46	2
5th most significant	1	2	9	5	18	51
6th most significant	–	–	–	43	1	10
Not significant	_	_	_	30	14	25
Total	100	100	100	100	100	100

Source: Field Survey, 2018

Table 5. Chail valley, Communities' resilience score according to the model (1-9)

Elements	Average Score	Remarks
Community mobilization/organization	6.17	Collective approach of local people
Preventive measures	4.31	Site selection, alternate routes
Relief equipment	3.68	Some communities are having relief equipment
Evacuation plan	4.03	No access to hospital and markets during flash floods for most communities
Distribution of household	4.67	The big villages situated close Chail stream
Checklist of vulnerable	5.22	Having knowledge and value for vulnerable
Preparation	3.45	Collective approach towards emergencies
1st hand experience	6.59	Experience in flood 2010, and seasonal floods every year
Warning systems government	3.58	Less effective government warning system
Warning system community	6.35	Communities are proactive to communicate with each other
Response from government	4.15	Less effective response from government
Response from others	4.4	Response only for recovery after flood 2010

Source: Field Survey, 2018

Table 6. Chail valley, Houses destroyed in the sample villages during flash floods 2010

Village Name	No. of houses destroyed
Badalai	55
Depo	15
Kuz Chail	25
Shinko	65
Bashigram	95
Total	255

Fig. 3. Settlements in Chail valley exposed to flash floods and access of a sub valley to main road, they loss this access during flash floods

adjacent to the stream channel. In the selected five localities a total of 255 houses, adjacent agriculture lands and 04 fish hatcheries were washed away.

During flood 2010 the width of Chail valley was increased and now some of the sub valleys and villages are accessed through a road across stream channel and small bridges. After 2010 flood the flash floods became more disastrous in the valley. Every year the road across the stream channel and small bridges are washed and some of the sub valleys and villages are disconnected with the main road. These communities are not having access to main road in case of any emergency or food shortage, especially during evacuation. Some of the villages are now accessed by chair lefts and it will be difficult for a crowd to evacuate in case of unanticipated situation. There is also very weak response from government to rehabilitate bridges and access roads. Therefore after flood 2010 the communities in Chail valley are more vulnerable to flash floods.

3.6 Daral valley: Communities' Preparedness to flash floods

In Daral valley the resilience was evaluated according to the elements mentioned in Table 7, each of the elements was scored according to its significance in the sample localities, the average of sample localities for Daral valley is mentioned against each element.

In Daral valley, the communities are also more proactive to help each other in emergency situations; therefore, without any formal body, the communities are organized and mobilized to help each other and cope with the flash floods. They also work together to rehabilitate bridges or any side wall damaged during flash floods. The people also care about vulnerable people including disable, elderly, women and children during flash floods. Like Chail valley, the communities got a good experience responding to flash floods during and after flood 2010. The people are also proactive in warning each other on time while the government's warning system is very poor. In the valley most of the villages are situated on steep slopes and lacking evacuation plan and they are also not accessed by road. Mostly the communities are not keeping any relief equipment for any emergency situation. The community is responding on their own to rehabilitate their infrastructure after flash floods.

3.7 Daral Valley: Communities' Environmental Conditions and flash floods

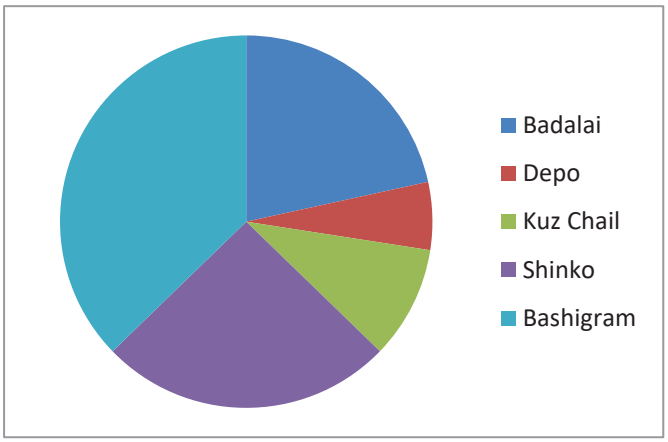
In Daral valley the slope is steep and the valley composed of hard rocks. Due to the local environmental conditions, most communities are a bit safe from direct damages, including washing away houses by flash floods. Before flood 2010 the peak flow was observed during the months of June, July and August. Daral stream was flowing in a very narrow channel almost a gorge with steep slopes towards both sides. During peak flow the stream was cutting its sides due to lateral erosion at few points especially in the down valley areas near Bahrain town.

During flood 2010 a very devastating flood hit the area, due to some local environmental conditions the damages were not that much as compared to the stream flow. Mostly the damages occurred in the down valley communities; it washed away hotels, bridges, roads and houses. In Daral valley the communities situated on upside are more resilient to the direct damages of flash floods. (Table 8) showing damages to houses in the five sample localities during flood 2010.

After flood 2010 flash floods are occurring in the months of June, July and August. Mostly it results into washing away temporary bridges, adjacent agriculture lands and side walls. In Daral valley the environmental conditions were not so much changed during the floods except few points and down valley areas, apart from that the stream is still flowing in a narrow channel with steep slopes towards both sides.

Following is the comparative analysis of Chail and Daral valleys

i. In Chail valley the settlements are comparatively more vulnerable to flash floods than Daral valley due to the location of settlements close to the stream.
ii. In Chail valley, some sub valleys, especially Kwandai remain cut off from the main road every year due to seasonal floods, making it less resilient to flash floods.
iii. The slope is much steeper in Daral than



Source: Field Survey 2018

Fig. 4. Houses destroyed in the surveyed villages of Chail valley during flash floods 2010

Table 7. Daral Valley, Communities' Resilience score according to the model (1-9)

Elements	Average score	Remarks
Community mobilization/organization	7	Collective approach during natural hazards
Preventive measures	4	Most settlements on safe sites
Relief equipment	3	Not having special relief equipment
Evacuation plan	5	Having tough alternate routes to access Bahrain
Distribution of household	6	Houses on mountain slopes away from stream
Checklist of vulnerable	7	Knowledge of disable and vulnerable
Preparation	3	No collective approach for preparation
1st hand experience	5	The communities experiencing flash floods after and during 2010.
Warning systems government	2	Less effective early warning system by the government
Warning system community	5	The communities are proactive to inform each other
Response from government	2	The response is slow and very limited
Response from others	1	Different organizations worked only after 2010

Source: Field Survey 2018

Table 8. Houses destroyed in the surveyed villages of Chail valley during flash floods 2010

Village Name	No. of destroyed houses
Jheel	80
Niam	8
Lagan	11
Lagankar	4
Shaledar	2
Total	**105**

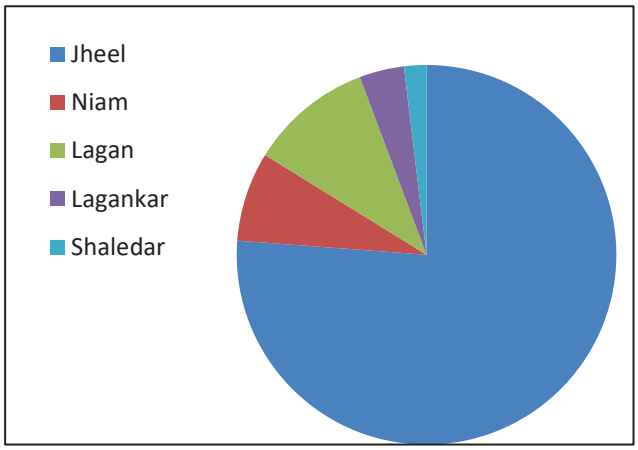


Fig. 5. Chail valley, Houses destroyed in the sample villages during flash floods 2010

Fig. 6. Daral valley is narrow and the settlements are situated on hillslopes above the stream.

Chail valley, but in Chail the rocks are in unconsolidated form while in Daral the rocks are in compact form so the flash floods in Chail valley also results into associated hazards especially land sliding and debris flow.

4. CONCLUSION

The resilience level differs due to differences in community preparedness and local environmental conditions in both the valleys. The Chail valley is resilient due to anthropogenic factors. The people are aware of flash floods. They keep some equipment for emergencies and quickly recover their access to main road and bridges after flash floods. Due to a comparatively wider valley, evacuation during unforeseen conditions will be comparatively easy. While Daral valley is resilient due to natural factors, however the valley is narrow and hardly accessible but the rocks are mostly tough and the settlements are mostly situated on safe sites on mountain slopes. Due to the narrow valley and location of settlements on steep slopes, evacuation and access to basic health services during emergency situations are more challenging. The resilience level is considered low in both the valleys mainly due to evacuation and accessibility to emergency health services and safe places in case of flash floods. There is no any effective early warning system but the local people are proactive to inform each other in case of any unanticipated situation. In case of emergency related to flash floods, including casualties and damage to houses, rescue activities will be almost impossible to most of the communities in both the valleys due to hard access and rugged topography. The associated

hazards with flash floods further aggravate the situation especially to the far flung isolated settlements on the mountain slopes.

Due to diversity in local environmental conditions and community preparedness the resilience level differs from place to place within the target valleys. Generally it can be concluded that however some of the natural and anthropogenic factors contribute to the resilience level but in the target valleys due to rugged topography, lack of planning, lack of proper evacuation plan and emergency response, poor infrastructure, and unpaved houses on fragile slopes the resilience level to flash floods is considered low.

5. ACKNOWLEDGEMENTS

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6. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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