Local Perception of Flood Risk: Evaluating Risk Awareness and Indigenous Knowledge Among Flood-Prone Communities in the Trans-Himalayan Valley, Leh District

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Abstract

The incidence of flash floods has demonstrated a consistent upward trend since the catastrophic events of 1999 in the Leh district. Notably, every settlement in Ladakh occupies floodplains within the river valley, which have been shaped by historical river erosion, deposition activities, and significant flood occurrences. The encroachment of urbanization into flood-prone areas has heightened the vulnerability of local populations to flooding events. Often, susceptibility to floods is exacerbated by a lack of awareness regarding one's natural surroundings. Central to the research is an analysis of risk perception, encompassing individuals' risk awareness, emotional responses, and behavioural patterns towards flood risk. Recognizing risk perception as a key determinant of vulnerability, the study seeks to evaluate local perceptions of flood risk. This involves examining risk awareness and indigenous knowledge, as well as assessing administrative readiness for flood events. Additionally, the research endeavours to provide a retrospective overview of historical flood occurrences in Leh, offering crucial contextual insights into the region's flood risk landscape.

Keywords: *Ladakh, Risk perception, Risk awareness, Indigenous knowledge, Ladakh flood, Vulnerable houses*

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1. Introduction

Ladakh, characterized by its mountainous terrain, is encompassed by three trans-Himalayan Mountain ranges: the Karakoram, Ladakh, and Zanskar. Noted for its diverse geological formations, tectonic structures, minerals, and geological history spanning from the Archean period (approximately 3.5 billion years ago) to the recent past (10,000 years BP) (Mir, Dar, and Ahmad 2023). Leh, the principal urban settlement in the area, typically witnesses an annual precipitation ranging from 80 to 100 mm (Spate et al., 1976), with considerable increases during the summer monsoon months of July and August. Environmental conditions in Ladakh are notably arid, and the area is vulnerable to natural disasters such as floods, avalanches, earthquakes, and landslides. Among these, flood disasters, particularly cloudbursts and flash floods, are prevalent in hilly regions (Sharma et al., 2020) causing significant damage and fatalities in Ladakh. Studies indicate that during the Quaternary period approximately 2.56 million years ago, Ladakh experienced considerable glaciation, as evidenced by (Owen et al., 2006). The unique topography of Ladakh owes much to the pervasive influence of glaciers, which have been dynamically active across various geological epochs, shaping the landscape through erosion and deposition. This geological process has yielded a diverse array of landforms, including valleys, low-slope valleys, aretes, cones, and thang between hills (Mir et al., 2023). However, the escalation of global temperatures has triggered snowmelt, resulting in the formation of U- and V-shaped valleys that have further eroded mountains and given rise to plains. Subsequently, large-scale floods and sporadic glacier melts have occurred, contributing to the creation of floodplains and other landforms. Presently, every settlement in Ladakh is situated on these floodplains within river valleys, which bear testament to past instances of regular flooding.

Notably, in the Nubra Valley, approximately 80% of settlements are situated on alluvial fans, characterized by their triangular sand deposits formed as a consequence of flood occurrences. Thus, whenever instances of natural calamities such as cloudbursts or glacial lake outburst floods (GLOFs) arise, floods inherently follow their course, engulfing settlements in their trajectory. In Ladakh, a yearly flood disaster incident, specifically a cloudburst, happens, bringing devastation to the communities located near the river. The vulnerability to floods in certain areas of Ladakh has been on the rise due to encroachments into flood-prone zones. The process of urbanization in contemporary times has often disregarded environmental indicators of flood risk, such as those delineated in sedimentary records of various streams (Ziegler et al., 2016). Encroachment into flood-prone areas has been identified as a contributing factor to the escalating flood vulnerability globally, particularly as urban areas expand and intensive land use near floodplains proliferates (Chang et al., 2009; Jalis & Abbasi, 2016). Following the year 1974, coinciding with the growth of the economy and tourism, Leh town and surrounding villages witnessed a rapid and unplanned urbanization trend. This trend saw the establishment of hotels, home stays, and residential areas in close proximity to the river, reflecting a departure from environmental determinism towards a perspective rooted in possibilism.

In the major flood incident that occurred in Leh district in 2010, 224 fatalities were reported, and approximately 9,000 individuals were affected by the cloudburst event, the imperative of understanding the risk perception within flood-impacted communities has been underscored. This recognition dates back to the seminal publication of Gilbert White's "Human Adjustment to Flooding" in 1945 (Whyte, 1986), a work that has significantly influenced discourse on flood risk management. Within contemporary flood risk management paradigms, risk perception stands as a crucial facet of subjective risk analysis (Schanze, 2007). A nuanced comprehension of citizens' perceptions of flood risk is essential for informing policy decisions, shaping effective flood mitigation strategies, and facilitating decision-making processes. Indeed, the perception of flood risk among community members not only aids in understanding vulnerability to floods and their potential ramifications but also plays a pivotal role in determining the efficacy of flood impact mitigation efforts (Filatova et al., 2011; Shen X, 2010). Research has highlighted that neglecting public risk perceptions in flood management endeavours, even if technically sound, can result in suboptimal outcomes and may foster maladaptation. Risk perception serves as a critical factor in gauging the vulnerability levels of individuals or social groups to environmental hazards (Neil, 1999). (Mileti, 1980) defines risk perception as the cognitive assessment or belief in the severity of the threat posed by an environmental extreme, coupled with the subjective estimation of the likelihood of encountering such detrimental environmental events. Understanding risk perception is integral to anticipating and comprehending public responses to hazards, setting priorities, efficiently allocating resources, and effectively communicating risk information to both laypersons and experts. Therefore, the objective of this study is to evaluate local perceptions of flood risk through an examination of risk awareness and indigenous knowledge, as well as assessing the preparedness of the administration for flood events. Additionally, the research aims to provide a historical retrospective of flood events in Leh for contextual understanding.

2. Research Objectives

a. To examine how riverfront communities perceive flood risk and to assess their awareness and indigenous knowledge regarding flooding.

b. To evaluate the historical frequency of flood occurrences in the Leh district.

3. Methods

The methodology employed in this study entailed a multistage purposive sampling approach, focusing on riverfront households as the primary units of investigation. Selection criteria were established based on the identification of villages and rivers delineated as high-risk areas in the District Disaster Management Plan Leh (DDMP), with particular emphasis placed on households situated in close proximity to the riverbanks. Leveraging Geographic Information System (GIS) technology, 36 villages adjacent to 29 rivers, identified as risk sites by the DDMP, underwent digitization in the software. Subsequently, 20 village households located along the riverbanks were identified, with 7 villages demonstrating a notable concentration of such riverfront residences. From these targeted areas, a total of 48 households were identified, dispersed across Choklamsar (23), Kharu (2), Nang (3), Tia (3), Tingmosgang (4), Nimoo (5), and Saboo (8).

During September 2023, the second author conducted face-to-face interviews schedule with occupants of 48 riverfront households. These interviews employed both structured and unstructured questionnaires to assess the participants' perceptions of flood risk. Each interview was conducted with a representative of the household, typically the head of the family. The age range of the participants spanned from 35 to 66 years, and the gender distribution included 36% male and 64% female respondents.

The collected data were subsequently analyzed using thematic analysis, facilitated by the use of computer-assisted qualitative data analysis software (CAQDAS), specifically ATLAS.ti. This approach enabled the identification of key themes and patterns in the participants' responses, providing a nuanced understanding of flood risk perceptions among the surveyed households. In addition to interview data, historical information on early flood events in Leh district was collected through news articles and the District Disaster Management Plan (DDMP) of Leh district. This secondary data was also analyzed using ATLAS.ti, further enriching the analysis by providing contextual insights into the region's historical flood events.

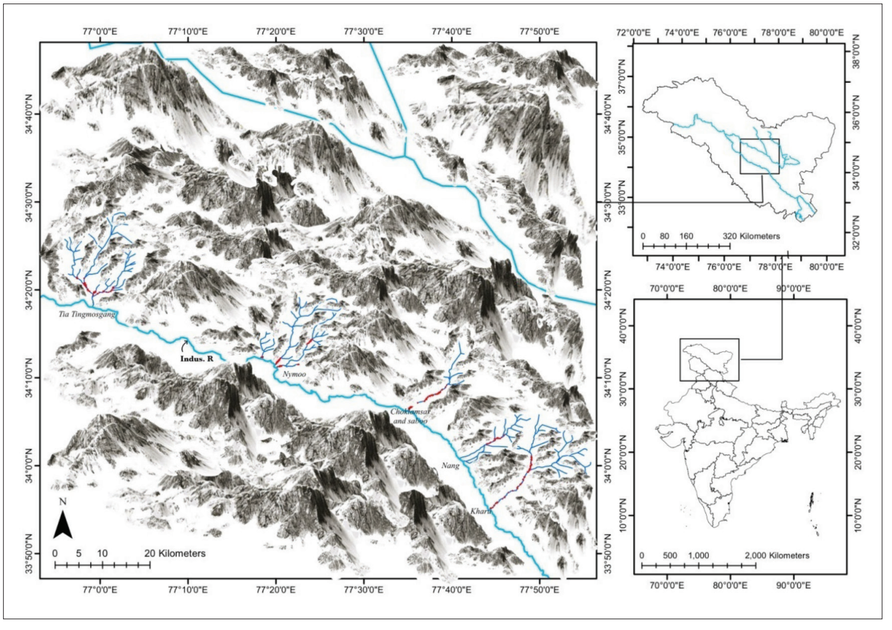

Figure 1 : The map illustrates the study region, highlighting the selected villages and river within it. (PNG has been used for the physiography visualisation)

4. Result and Discussions

4.1 Early settlement and Flood Events in Leh district: Historical Retrospective

During the early settlement period, the town of Leh was strategically situated close to higher elevations adjacent to mountains as a means of flood protection. Notably, each community featured a Buddhist monastery erected atop a hill, with human habitation largely confined to the areas surrounding these monasteries (Suri, 2018a). For instance, it is believed that the earliest permanent villages in present-day Leh city were established around 1400 AD in the marshy offshoot of the Chubi settlement, situated behind Tsemo Hill. Subsequently, in the seventeenth century, the construction of the Leh Palace on the hilltop marked a significant development. Consequently, the entire settlement gradually relocated to the softer south-facing slope of the hill, providing natural protection against floods originating in the Leh Valley, as outlined by (Morup & Chodon, 2018). With the increase in population towards the end of the nineteenth century, Leh experienced significant urban expansion, characterized by an unplanned growth pattern (Jest & Sanday, 1983). This surge in population was attributed to migration from rural areas of Ladakh (Dame et al., 2019), such as the Changthang, Nubra Valley, and Sham regions, with settlers dispersing along the valleys. The opening of Ladakh to tourists in 1974 further accelerated the process of urbanization in Leh.

Figure 2 : A satellite image of the Phyang River reveals evidence of past flooding and erosion scars, (sourced: Google Earth)

Despite the entire Leh valley being populated at present, it remains vulnerable to the threat of flash floods, capable of causing widespread devastation. The Nimoling Valley during the 2010 flood event serves as a poignant illustration of an unorganized or unplanned settlement. The examination of historical catastrophic events offers valuable insights for strengthening flood risk mitigation strategies by cultivating a heightened awareness of risk (Cœur & Lang, 2008). Analysis of flood river marks along various watercourses has uncovered evidence of significant past flood occurrences in numerous villages, including Nymoo, Phyang, Saspol, Ney-Basgo, and others (see Figure 2). The potential recurrence of a flood event of similar magnitude in the future could result in the complete devastation of entire settlements. Moreover, given the dynamic shifts in climate patterns, the likelihood of large-scale and potentially catastrophic floods occurring in this region is significantly heightened.

4.2 Historical Flood Events

In 1833, a glacial flood swept through the Shyok Valley, resulting in the destruction of every settlement from Nubra to Skardo that lay in its path. Similarly, major glacial flooding in 1841 devastated most communities along the Shyok River. A Glacier Lake Outburst Flood (GLOF) in 1907 engulfed the Leh Valley in mud. Local accounts from the 1930s recall the Kumdan Glacier Lake Outburst Flood, originating from the Kumdan glacier in Tibet, which caused widespread devastation, impacting the entire Nubra Valley from Khardong to Turtuk village (Suri, 2018a). In 1971, Nymoo Village experienced extensive destruction due to a GLOF, resulting in 13 to 16 reported fatalities (Ikeda et al., 2016). Subsequently, a flood in 1999 ravaged homes, farms, and claimed numerous lives in the Leh Valley. Flash floods in Ganglas and Gompa caused minimal impact in Leh, although some fields in Sankar were covered in mud, attributed to the rupture of a glacial meltwater lake on Khardung-la. Domkhar Village witnessed a GLOF in 2003 (Narama et al., 2011). Flooding occurred in Phyang and Leh in 2005, followed by flooding in Igu, Phyang, Khalsar, and Tsati Village in 2006, resulting in damage to several homes. Flood events were also recorded in Stok Village in 2008 and Uleytokpo in 2009 (DDMA, 2011).

Table 1 : Showing the Historical Flood Events in Leh District

Year of flood	Area of Flood
1833	Glacial flood down the Shyok valley. Destroyed every village in its path, from Nubra to Skardo
1841	Major glacial flood. Hit most of the villages along the Shyok
1907	Flood in Leh valley (GLOF)
1929	Great flood, Shyok river (Famine induced by flood)
1930	(GLOF) Hunder Valley
1932	Major flood, Shyok
1933	Major flood, Shyok
1971	Houses and fields at Neymo were destroyed by a cloudburst
1999	Flash floods, in Gompa and Ganglas. Not much impact in Leh, though some of the fields of Sankar were covered with a thick layer of mud. This was caused by the bursting of a dam impounding a lake of glacial meltwater on Khardung-la
2003	GLOF in Domkhar
2005	Flood in Leh and Phyang
2006	Flood in Leh, Igoo, Khardong(Rongju) and Phyang, Khalsar, Tsati
2008	Flood in Uleytokpo
2009	Flood in Stok
2010	Flash flood in Nimoo, cloudburst around Leh, GLOF in Nidder
2014	Flood in Gya and Markha valley
2015	Flood in Wakha river, GLOF in Phugtal and Nubra valley
2017	Flood in Achinathang
2018	Flood in Saboo, Shey(Stakmo) and Tirisha
2019	4 houses damaged in Nubra valley and 5 houses from Durbuk block
2020	8 houses damaged in Nubra valley and two house from Leh tehsil

2021	11 from Kharu village, 92 from Nubra valley, 2 from Khaltse and 2 from Durbuk block
2022	10 from Nyoma block, 2 from Leh tehsil, 8 from Khaltse block and 1 from Nubra valley
2023	37 from Khaltse block, 3 from Likir, 3 from Kharu, 14 from Nubra, 8 from Durbuk, 2 from Nyoma, 74 from Leh tehsil

In the aftermath of the 2010 cloudburst in Ladakh, the term "cloudburst" likely entered the lexicon of local inhabitants for the first time (Suri, 2018a). According to the administration of the Union Territory of Ladakh, the disaster resulted in the loss of

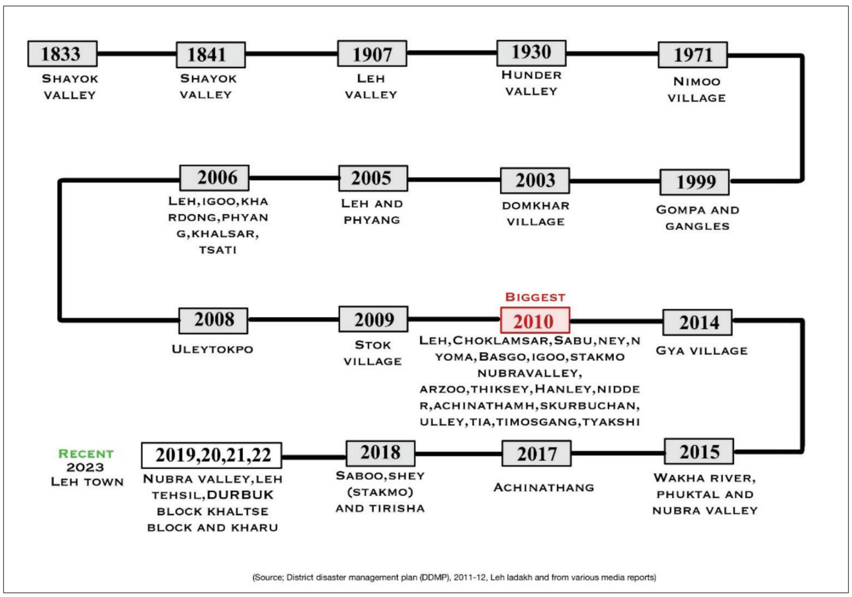

Figure 3 : The figure depicts a chronological timeline detailing flood occurrence within the Leh district.

224 lives and affected 9000 individuals. Public properties suffered extensive damage, estimated at 133 Cores, impacting 71 villages. Among the worst-affected areas were Leh town, along with Taru, Nymoo, Basgoo, Stakna, Shey, Arzoo, Thiksey, Kungyam,

Anlay, Nidder, Achinathang-Lungba, Skurbuchan, Rezong, Ulley, Tia, Tingmosgang, and Tyakshi in the Turtuk area (DDMA, 2011). In Choglamsar, a particularly hard-hit locality, debris flow resulting from the cloudburst swept away 40 houses, expanding up to 2 km after traveling approximately 10 km from the epicentre near Saboo (Khattri, 2012). Within the Shaksaling stream's catchments, debris flow travelled approximately 3 kilometres from an elevation of 3800 meters to 3410 meters. The Sonam Norboo Memorial Hospital, radio station, Nimoling settlements, Bus Stand, and BSNL mobile communications centre were among the devastated infrastructure. The disaster resulted in 424 injuries, 224 fatalities, and 79 individuals still unaccounted for (DDMA, 2011). In 2014, the community of Gya experienced flooding due to a Glacial Lake Outburst Flood (GLOF), while Nubra Valley faced flooding in 2015. Achinathang village witnessed a flood on August 4, 2017, resulting in the deaths of four individuals, including three non-local labourers and one native resident. Subsequent floods occurred in August 2018 in Saboo, Shey, Stakmo, and Tirisha (Suri, 2018b) following that Minor flooding incidents were observed in Ladakh during the years 2019, 2020, 2021, and 2022. In July 2023, a cloudburst triggered a flash flood during the night in the Chok-hang, Chubi, Khalshal, Katpa, and Lamdon areas of Leh town. This event led to the rush of debris into market areas, resulting in damage to several houses, vehicles, and shops. Since the flood event of 1999, there has been a noticeable increase in the frequency of flooding incidents. Consequently, the months of July and August have become periods of heightened flood risk, prompting concerns among both the public and administrative authorities. Particularly, residents living near the river express heightened apprehension regarding potential flood hazards.

4.3 Local Perceptions of Flood Risk: Examining Risk Awareness and Indigenous Knowledge within Community Contexts

The ability to perceive and mitigate adverse environmental conditions is essential for the survival of all organisms. Furthermore, the capacity to encode and learn from past experiences contributes significantly to survival. Human beings possess an additional capability to both adapt their environment and respond to it, thereby introducing both potential hazards and opportunities for risk mitigation (Slovic, 1987). Various academic fields, including geography, sociology, political science, anthropology, and psychology, have made significant contributions to our current understanding of risk perception. Originally, geographic research focused on comprehending human behaviour in natural hazard contexts, but it has since broadened to encompass technological hazards as well (Beckinsale, 1979). Sociological and anthropological investigations (Douglas & Wildavsky, 1982) have emphasized the role of social and cultural factors in shaping risk perception and acceptance. An essential step in defining the risk management process is identifying the factors that expose individuals to flood risks. Frequently, susceptibility to flooding is associated with a lack of awareness about one's natural surroundings (Mondino et al., 2020a). The examination of risk perception entails delving into individuals' awareness, emotional responses, and behavioural tendencies toward hazards. Originating from the nuclear discourse of the 1960s (Sowby, 1965; Starr, 1969), this field of study has expanded into various domains, including flood risk management (Messner & Meyer, n.d.). Understanding the factors contributing to individuals' vulnerability to flooding is essential for informing effective risk management strategies, with flood vulnerability often linked to a lack of awareness regarding one's natural surroundings (Mondino et al., 2020b). In the literature on natural hazards, risk awareness and risk perception are frequently used interchangeably across diverse disciplines such as psychology, geography, medicine, sociology, anthropology, and political science (Bera & Dank, 2018). However, while closely related, these terms possess subtle distinctions. Risk awareness pertains to the acknowledgment of a risk's existence, whereas risk perception encompasses a broader concept of "intuitive risk judgment" (Slovic, 1987). Consequently, while interconnected, the level of awareness and the perception of a hazard are not interchangeable. Risk perception emerges as a crucial factor in determining individual or societal vulnerability to environmental hazards (Neil, 1999).

4.4 Risk Perception and Risk Awareness

The perception of risk holds significant sway over residents directly affected by flooding (Rahimizadeh et al., 2024), influencing their awareness, knowledge, and understanding of the associated hazards (Lara et al., 2017). The majority of respondents (78%) living near rivers have experienced flooding firsthand, yet none anticipated a flood of the magnitude witnessed in 2010, which caused extensive damage to both lives and properties. Notably, individuals' perception of their personal exposure to flooding assumes a pivotal role in shaping overall risk perception (Bosschaart et al., 2013). Interestingly, when asked to explain cloudburst phenomena, all riverfront residents described clouds as akin to water-filled balloons that burst upon collision with mountains or sudden lightning strikes, releasing their contents. This perception highlights the local use of "cloudburst" and "cloud blast" interchangeably. And Regarding flood risk awareness, 62% of respondents acknowledged the vulnerability of their residences to flooding and the potential for functional damages, while 38% believed their properties to be immune to such consequences. Residing in close proximity to rivers, respondents displayed varied perceptions concerning the potential damage inflicted by flooding upon their residences. Specifically, 48% of respondents perceived flooding as a significant threat to their homes if it were to recur, whereas 38% regarded it as non-threatening. Additionally, 42% expressed uncertainty regarding the extent of potential damage. This divergence in viewpoints can be attributed to the spatial distribution of residences in relation to the river, with those situated closer to the riverbank exhibiting heightened concern compared to those positioned farther away. Analogously, respondents' overall sense of safety residing near rivers reflected a similar pattern. Notably, 46% of respondents conveyed feeling entirely unsafe, 42% expressed uncertainty, and only 12% reported feeling secure in their residential proximity to rivers. Moreover, residents within the village exhibited a cognizance regarding the elevated flood risk associated with residing near a river, along with an understanding that homes situated along the river's edge were particularly susceptible to flooding. This understanding was substantiated by the response of 88 percent of respondents who expressed a belief that a flood could significantly imperil the residences situated in close proximity to the village river. However, despite possessing pertinent knowledge or experiences conducive to heightened awareness, certain respondents disclosed a lack of personal concern regarding their own exposure to flood hazards. For instance, some participants acknowledged being well-versed in the flood risks prevalent in their vicinity, citing instances of familial or communal properties being repeatedly inundated. Nevertheless, they appeared to selectively discount this knowledge when assessing their individual vulnerability to flood risks (Burningham et al., 2008). As posited by (Thaler & Levin-Keitel, 2016) the absence of recent flood occurrences within a given region can potentially impede the cultivation of community participation in flood management initiatives. This hindrance may stem from a decline in individuals' awareness of flood threats and their corresponding interest in engaging with flood management efforts. Furthermore, flood risk awareness is intricately linked with the collective human memory of past flood events. Consequently, the temporal gap since the last significant flood event may contribute to a decline in individuals' recollection of flood-related hazards. Consequently, this lapse in flood memory may inadvertently lead to the resettlement of individuals in flood-prone areas. Such resettlement actions, particularly evident in locales like the Choklamsar area, could precipitate substantial damage in the event of future flood occurrences.

4.5 Rural vs Urban Risk Perception, Awareness and Indigenous Knowledge

Differences in the inclination towards resettlement in flood-prone regions are observable between rural villages and urban centres within the Leh district (see Figure 4). In villages, inhabitants exhibit a heightened awareness of historical flood occurrences, often inheriting this knowledge through intergenerational transmission or discerning it from visible indicators such as flood marks, which dissuade them from establishing residences near rivers susceptible to inundation. In the Nubra Valley, villages are predominantly situated on alluvial fans, exposing residents to the frequent occurrence of flash floods. Take, for example, Hunder, the village with the largest catchment area in the Leh district spanning 527.3 square kilometres. Due to the considerable catchment

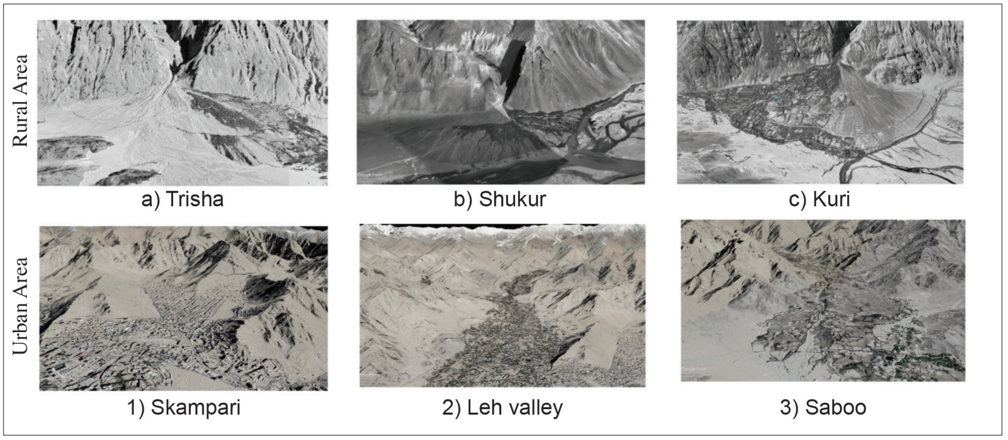

Figure 4 : Illustrating the spatial distribution of settlements influenced by environmental determinism and possibilism within rural and urban regions of Ladakh (source: google earth)

area and the heightened risk of flash floods in this region, inhabitants have strategically chosen to maintain a significant distance from the river. This settlement pattern reflects a broader phenomenon observed across all villages in the Nubra Valley, such as Tirith, Sumur, Tiricha, Kuri, Shukur, Taksha, Hundri, Skuru and Udmaru etc, illustrating the influence of environmental determinism on settlement practices. Conversely, urban areas witness a predominant demographic influx from rural locales, with settlers primarily driven by the pursuit of economical land acquisition, often disregarding the inherent risks of flooding. This pattern of settlement typifies the development of new urban sectors across Leh.

The entirety of the Skampari area, the vicinity surrounding the Nimoling bus station, the Army Hospital in Skara, and the CSD depot area near the airport have been densely populated within the expansive catchment area of the valley. Following the severe devastation caused by the 2010 cloudburst in the Nimoling bus station area, the Leh administration allocated land behind the existing housing colony for the relocation of affected individuals. Despite being designated as a high-risk zone by the administration, resettlement efforts led to the re-establishment of residences in this area. A similar scenario unfolds in Choklamsar, where dwellings are once again erected in close proximity to riverbanks. Moreover, the diminished level of risk awareness prevalent in urban settings is multifactorial, encompassing factors such as lower educational attainment, limited exposure to flood events, fading collective memory of past floods due to temporal distancing, insufficient engagement in risk awareness initiatives, unplanned urbanization, and the absence of comprehensive disaster risk mapping.

Additionally, the respondents advocate for proactive measures aimed at mitigating potential flood-related damages. These measures include: a) the clearance of riverbeds to enhance hydraulic conveyance, b) the construction and maintenance of robust riverbank defences to mitigate flood impacts, c) the implementation of effective warning and communication systems to alert residents to impending flood hazards, d) the enforcement of regulations prohibiting development within flood-prone zones or adjacent to river basins, and e) the implementation of surveys to monitor and regulate residential development within vulnerable areas. These initiatives are perceived as essential preparatory measures to minimize the adverse consequences of flood events within the region. As articulated by (Newell & Wasson, 2002), there is a notable concern regarding the current flood mitigation practices in certain parts of Ladakh, particularly evident in the construction of small protective retention walls alongside streams such as Choglamsar's Sabu Stream. These measures, implemented in anticipation of future cloudbursts, may inadvertently instil a false sense of security among residents. This concern is corroborated by (Thayyen et al., 2013), who note the inadequacy of these diminutive protective walls in effectively mitigating flood risks. They highlight that during the 2010 flood event, which experienced depths of 2-3 meters in certain areas, the protective walls currently being constructed were significantly lower in height. Such findings underscore the urgent need for reassessment and enhancement of flood mitigation strategies in Ladakh to better align with the region's susceptibility to extreme flood events. The residents of Choklamsar in Ladakh have reported experiencing heightened apprehension during the summer months of July and August, characterized by a notable rise in water levels accompanied by ominous sounds, instilling fear of potential flooding throughout the night. Some individuals have reportedly evacuated their homes on such occasions, seeking refuge elsewhere as a precautionary measure. Furthermore, in the aftermath of the cloudburst event that occurred in Leh on August 6th, 2010, inhabitants of the Leh valley responded swiftly by relocating to the nearest elevated terrain, primarily the surrounding hills. These hillsides quickly became populated with makeshift tents, as residents opted to reside there for approximately a week to ensure their safety. Notable locations included the hills adjacent to Housing Colony, Shanti Stupa Hill, and Tsemo Hill. The decision to seek refuge on higher ground was influenced by indigenous knowledge passed down through generations, which led residents to perceive elevated areas as safer havens during periods of flood risk. Such adaptive measures underscore the Ladakhi people's ingrained indigenous knowledge of safety precautions, particularly evident in their practice of relocating to higher ground during flood-prone periods. This tradition reflects a longstanding cultural adaptation strategy tailored to the unique environmental challenges of Ladakh, where extreme weather events such as cloudbursts pose significant risks to local communities.

Figure 5 : The image displays a low flood protection wall along the Choklamsar River (captured by Tsering Dorjay in Sept, 2023)

4.6 Administration Preparedness

The consideration of public perception is paramount within the top-down communication framework between authorities and the lay population concerning the management of risks associated with natural hazards (Pagneux et al., 2011). The success of public participation in flood risk management is contingent upon the understanding, competence, and confidence of local stakeholders, as well as the transparency of governmental processes (Thaler & Levin-Keitel, 2016). (Pearce, 2003) emphasizes the importance of involving local communities in risk management endeavours, as their engagement can significantly influence decision-making at the local governmental level, thus enhancing the likelihood of successful outcomes. All respondents expressed a willingness to actively participate in community-based programs aimed at reducing flood damage and recognized the significance of local public involvement in governmental flood risk management. For instance, governments in South and Southeast Asia have advocated for the establishment of flood management committees with clearly defined compositions, responsibilities, and tasks both pre- and post-disaster (Prasad, 2005). Urban communities in the Philippines have played an integral role in identifying and categorizing post-disaster aid, facilitating its distribution to affected areas (Carcellar et al., 2011). Similarly, in Cuttack, India, collaborative efforts between the community and government have been pivotal in conducting comprehensive risk assessments (Lara et al., 2017). Hence, community preparedness becomes imperative to furnish an efficient response to flooding, thereby attenuating its adverse consequences (Syarif et al., 2022).

According to Sub-section (2) of Section 30 of the Disaster Management Act of 2005, it is mandated that a Disaster Management Plan (DMP) be established for each district (DDMA, 2011). In the aftermath of the significant cloud-burst event of 2010 in the Leh district, which resulted in extensive property damage and loss of life, the Leh administration promptly issued its inaugural district disaster management plan (DDMP) in 2011. The DDMP (2011) outlined a commitment to annual updates; however, no subsequent disaster management plans have been observed since 2011. On October 31, 2019, Ladakh transitioned to a union territory status. Subsequently, the administration initiated the development of new disaster plans for the periods of 2019-20 and 2022-23. These plans remained in draft form according to administrative records. The 2023-24 plan is reported to be nearing completion in its final stages, as asserted by the administration. Oversight of Disaster Management, Relief, Rehabilitation, and Reconstruction (DMRRR), along with the union territory disaster rescue force (UTDRF), is led by the Deputy Commissioner of Leh, who heads the UT District Disaster Management Authority (UTDDMA). The DDMP adopts an integrated strategy that ensures the active participation of local communities, governmental agencies, the military, and various other relevant organizations.

5. Conclusion

This study examines local perceptions of flood risk, risk awareness, and the indigenous knowledge of communities residing in the valleys of the Trans - Himalayan Mountain range in the Leh district. It highlights historical flood events and their implications for settlements, underscoring the importance of these findings for the District Disaster Management Authority (DDMA) of Leh and the local planning department.

The findings indicate that individuals residing in close proximity to rivers are cognizant of their exposure to flood risk and acknowledge the potential for significant functional damage. Despite this awareness, they express feelings of insecurity about residing in these areas. Conversely, those residing farther away from rivers perceive lower levels of risk and feel safer, yet recognize the vulnerability of homes situated on the riverbank. The indigenous practice of seeking refuge on higher ground during floods is observed to be highly effective, particularly in mountainous regions of Leh, where villages are situated in the floodplain of river valleys.

Rural villages demonstrate a stronger awareness of historical flood risks, leading to more cautious settlement patterns, such as avoiding flood-prone areas near rivers. In contrast, urban centers, driven by economic factors, see increasing resettlement in high-risk zones despite the dangers. This contrast underscores the importance of integrating indigenous knowledge into urban planning to mitigate flood risks effectively. Addressing the growing urban vulnerability requires improved risk awareness and land-use management. The months of July and August pose heightened flood threats to communities residing near rivers, a pattern evident across various villages such as Choklamsar, Saboo, Timosgang, Nymoo, Ney, Sakti, Igoo, Shara, Domkhar, and Tykshi, where settlements lie within 20 meters of the riverbanks.

Given the increased frequency of floods since the significant event in 1999, which has been linked to climate change, there is an urgent need for the administration to conduct targeted flood risk awareness campaigns directed at vulnerable communities (Bogdan et al., 2024). Furthermore, it is recommended that the planning department establish a policy prohibiting new settlements within a 20-meter buffer zone along riverbanks. Such measures are essential for reducing potential flood damage and avoiding unnecessary expenditures in the aftermath of flood events. Additionally, strengthening collaborative efforts between the planning department and the DDMA is crucial for minimizing disaster-related damage and loss of life, ultimately enhancing the resilience of communities facing climate-induced flooding.

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