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Cultural Systems in Water Management for Disaster Risk Reduction: The Case of the Ladakh Region

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Abstract There has been an increase in hydrological disasters over the past few decades as a result of climate change. Also, there is a growing recognition of the need to integrate traditional knowledge into Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) policies and practices on a global scale. Traditionally, village folk have used observation-based, traditional methods to avoid high economic costs associated with sustainable management of their resources and livelihood. Due to ongoing climate change impacts and migrations, indigenous knowledge is gradually disappearing, and other modern systems have been unable to effectively replace it to the desirable extent. This paper investigates how the traditional knowledge and cultural systems of local communities living in the high-altitude cold desert region of the Ladakh region in India have contributed to their water management systems. In addition, the article discusses how haphazard changes in the contemporary environment are causing issues related to water scarcity and livelihood leading to the slow onset of disasters. Through non-participant observations during a two-month volunteering engagement and literature review, the present study attempts to track the changing realm and attitude of the Ladakhi community towards water conservation in light of climate change and depleting resources. A comparison was made between the government and non-government initiatives for the conservation and management of water resources. The results of this study suggest that traditional knowledge and cultural systems have a significant role in increasing community participation and awareness of climate change and disaster risk.

Keywords: Cultural System, Disaster Risk Reduction, Climate Change, Ladakh

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1. INTRODUCTION

The Hindukush Himalayas, popularly known as the 'third pole' because of their vast freshwater ice field, are experiencing increasing disasters, including flash flood, landslides, extreme water scarcity, wildfires, glacial lake outburst flow, and so on in recent decades (EM-DAT, 2014) (Sharma E., 2019). Studies have pointed out that natural calamities, including glacial retreat, melting of the ice, extreme rainfall, will aggravate with time due to climate change impacts and anthropogenic reasons (IPCC, 2012) (CRED, 2020). Previous studies warn that the growing number of natural disasters in the region will affect the lives and livelihood of the local communities, such as the risk of human loss, property damage, ecosystem disruption, and interruption of development projects in the coming days. The indirect consequences of these events will be observed as decreasing local resources and self-reliance with increasing external dependency during disasters (Dilshad, *et al*., 2019) (Ives, 1991) (Mishra, 2003). Extreme water scarcity is common in the region today, which is a sign of growing natural disasters in the area. In Ladakh, a part of the Hindukush Himalaya, existing limited water resources are depleting due to climate change, environmental degradation, and rapid socioeconomic changes (Mueller, 2020) (Nüsser, 2019). The conventional technology-driven, engineering-based solutions are found inadequate and ineffective for disaster risk reduction in the region. The Government and non-governmental organizations have introduced innovative disaster mitigation initiatives, yet only a few have meaningful impacts to tackle the increasing disaster risk (Mishra, 2003).

Arguably, these innovative, technology-driven projects failed because they overlooked the cultural aspects and undermined the indigenous knowledge and resources of the region (Dame, 2019). Because for many centuries, the indigenous people of this region have been living a safe and sustainable life by adapting to the extreme environmental and ecological conditions (Hodge, 1991). With experience and understanding of water as a resource, several indigenous mountain communities developed techniques to ensure its conservation and equitable distribution for agricultural consumption and daily activities (Kreutzmann, 2000) (Chettri, 2015). They co-operated among themselves and used indigenous knowledge and local resources to tackle the challenging climate conditions and water constraints (Srichandan, 2021). In different parts of India, we have seen earlier that the indigenous peoples, through their limited natural resources, effectively managed their disaster risks (Pasupuleti, 2013). In India, a few examples of traditional water harvesting in hill regions are the bamboo drip irrigation system of Meghalaya (Ryngnga, 2018), the Zabo system in Nagaland (Singh, 2012), and the Apatani in Arunachal Pradesh. The various water harvesting and distribution systems found in the mountainous region are specific to their regional conditions like climate, topography, and vegetation. However, all follow similar principles to direct, collect, store and conserve the surface run-off water using simple methods, materials, and social cooperation. This effective, sustainable water resource management has become viable because the local people integrated the disaster risk reduction initiatives with the culture (Pasupuleti, 2013) (Samaddar, 2014).

However, there has been limited understanding of how and to what extent the culture has empowered and enabled these local communities to manage and reduce water-related risks in the region effectively. There is also limited understanding of the form and nature of culture effective for disaster risk reduction, including water resource management (Srichandan, 2021) (Pasupuleti, 2013).

This paper focuses on the traditional water management systems of Ladakh that protected the ecological environment and the people from natural hazards and water scarcity despite the harsh geographic conditions. This study investigates how cultural systems and practices have enabled local communities to maintain water conservation systems effectively in Ladakh. For this, the authors have adopted mainly the secondary data collection methods, and the experiences and observations made by one of the authors in 2018 during her two-month internship with an NGO called Ladakh Ecological Development and Environmental Group (LEDeG) in Ladakh.

2. TRADITIONAL WATER MANAGEMENT SYSTEMS IN THE COLD DESERT REGION

2.1 The Humanised landscape of Ladakh and its water traditions

According to the Köppen climate classification, the Indian Mountain ranges fall within the humid subtropical climatic zone. Nevertheless, the region of Ladakh is an exception, geographically classified as the High-Altitude Cold Desert Region. Due to its unique location between the Greater Himalayas and Karakoram range (above 3000 meters), it receives low precipitation between 100 and 250 millimeters and has underdeveloped soil (Crook, 2001). Percolation of water is difficult due to the soil condition. As a result, groundwater in the region is scarce and limited (Labbal, 2000). Additionally, Ladakh experiences huge seasonal variations characterised by short dry summers and extremely cold and windy winters. The region becomes inaccessible during winters (Dame, 2019). The geographic location and climate challenges make this region susceptible to water scarcity and drought.

Humans establish settlements on a site that provides resources (like wood, water, soil, stone) for survival, settlement, and livelihood. In the past, indigenous communities followed several tangible and intangible systems that ensured resource sharing and utilisation without exploitation. Historically, Ladakhis treated water as a precious resource due to its limited availability. The availability and accessibility of water determined the location of settlement, density, building typologies, and building techniques (Labbal, 2000) (Ferrari, 2018) (Nüsser, 2019) (Hodge, 1991). It influenced many aspects of Ladakhi livelihood, lifestyle, and built environment. Water was utilised and managed through various systems and methods. The community's collective effort ensured its equitable distribution and usage. The religious beliefs and norms directed people's attitude to respect and maintain the sanctity of water sources.

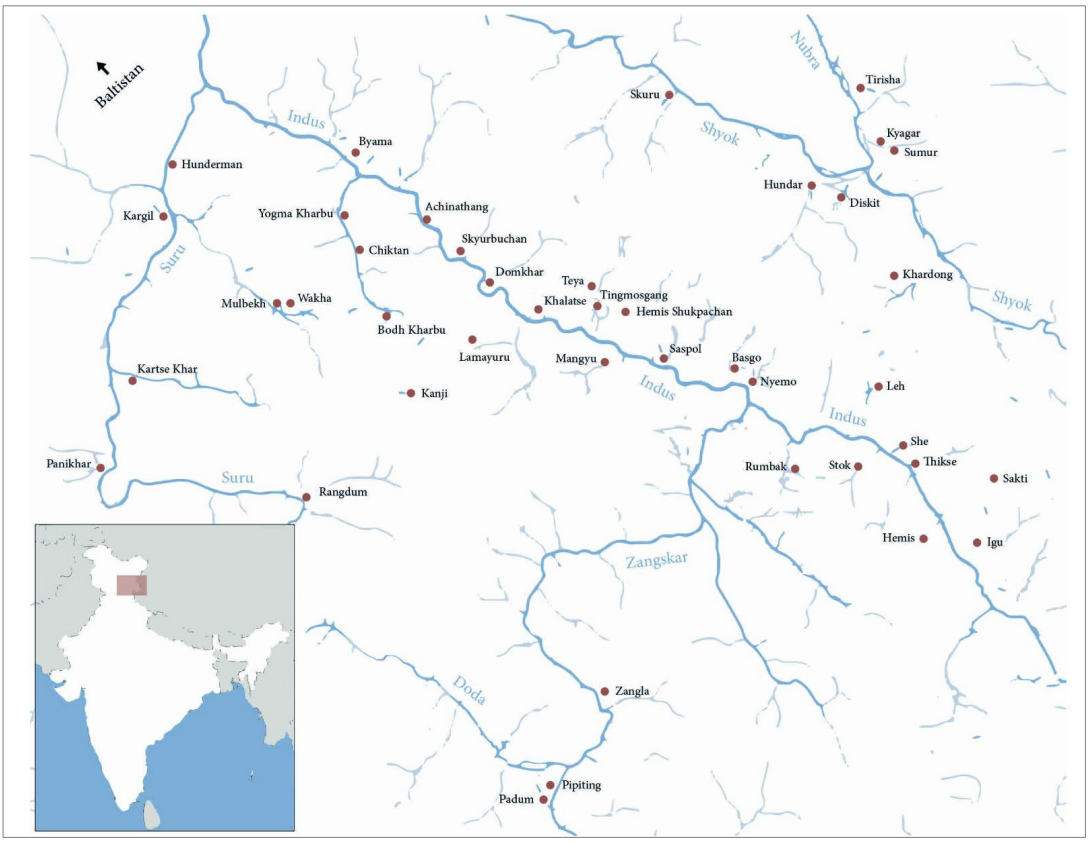

Figure 1. Settlements in Ladakh along the banks of the Indus River and tributaries. Source: (Ferrari, 2018)

Ladakh relies primarily on water from the Indus River and other glaciers that flow through its landscape. Rivers and their tributaries played a crucial role in site selection for settlement and agriculture Fig 1. The village and town settlements, agricultural fields, and willow-poplar trees create an oasis effect in the cold-desert region Fig 2. To sustain and survive within the harsh climate and limited recourses, the locals developed mutual trust and cooperation for water management required for agriculture, animal husbandry, and other purposes. In addition to the settlement location and livelihood, the choice of building materials, building form, and construction techniques helped them for sustainable water conservation and management.

In order to understand the influence and impact of the cultural system for effective water resource management in Ladakh, we developed a conceptual schema as depicted in Fig 3. Based on the framework, it shows that the traditional settlements and their built environments are a result of trial and error processes, based on locally available natural resources. The natural resources available in a region depend on the topography, climate, and vegetation, collectively called natural systems.

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People engage with the natural resources through the cultural system (tangible and intangible systems) that comprises traditional technology, social systems, religious beliefs, and economy; as a whole, interconnected to the other. However, with the rapid changes in the environment, declining available natural resources, and socioeconomic factors, man-made systems no longer rely solely on natural systems. Increasing external assistance has reduced the community's self-reliant capacity. The cultural system that ensured resource management has suffered (Hodge, 1991) (Nüsser, 2016). In recent times, the increasing tourism and outmigration from villages to big cities have negatively impacted traditional water management and availability.

Figure 2. Ladakh as an Oasis.
(Photograph by Sweta Kandari, 2018)

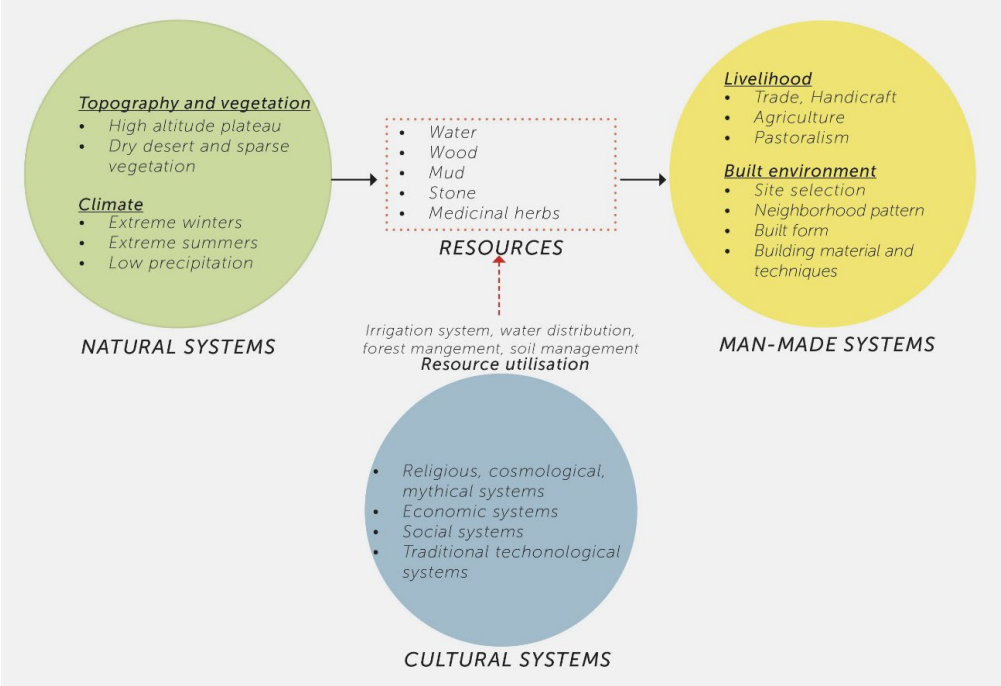

Figure 3. A prototype schema describing the natural, cultural and man-made system of Ladakh.

2.2 Transformation and risks

The region has witnessed tremendous changes rapidly in the past decade that has adversely impacted the water availability and environmental conditions of the region (Bhasin, 1999). This section briefly explains the increasing risks due to regional and global changes.

In the 9th century, the Ladakh dynasty was initially inhabited by nomads. They resided along the banks of the Indus River. Until the 1500s, the region witnessed magnificent construction of palaces and monasteries that were built by a series of kings. At the beginning of the 19th century, Ladakh came under the Dogra rule. In 1846, the region was integrated with the Indian state of Jammu and Kashmir. Finally, in 2019, Ladakh was given the status of Union territory.

The construction of the Leh road in 1966 and the construction of an airport in 1985 marked a turning point in Ladakh's transformation. This accessibility resulted in an increase of tourists from 500 in the 1990s to 205 thousand in 2017 (Kumar, 2019) . There were only 24 hotels in entire Ladakh in the 1980s. In the last four decades, the number of hotels increased to 670, with 60% located in Leh city (Khandekar, 2017) . Along with increasing tourist influx, the introduction of military forces contributed to new construction and expansion of built form in the region. The external influences and increase in the consumption of natural resources have resulted in rapid environmental, cultural, social, and economic changes and depleting natural resources (Bhasin, 1999) (Geneletti, 2009) .

Regional changes combined with the global climate and environmental changes have resulted in the retreat of the glacial belt. Cloud bursts have become frequent in the last decade, resulting in increasing flash floods and untimely rainfall (Ziegler, 2016) . Several studies claim that regional and global climate change may hit the region more frequently, creating more disaster risks in addition to the already existing ones (Nüsser, 2016). Melting of glaciers, increasing frequency of flash floods since 2005 (Masson, 2015), unusual spells of rain (Thayyen, 2013) led to water shortage in Ladakh. Severe water scarcity issues posed problems to the locals impacting their livelihood, lifestyle, and settlement (Keilmann-Gondhalekar, 2015).

Throughout history, the people of Ladakh had a complex relationship with water due to its scarcity. Local communities of Ladakh developed several social, technological, and religious systems for their management and conservation (Hodge, 1991). The next section describes how Ladakhis traditionally managed and conserved water through a network of tangible and intangible systems (Cultural Systems) (Fig 3) that helped them maintain a sustainable livelihood.

2.3 Traditional Technology and Methods

The traditional technological systems in this paper refer to the tangible aspects that the people of Ladakh incorporated for livelihood and settlement purposes. Agriculture was one of

the major occupations of Ladakh in 1971. To manage water for irrigation and agricultural purpose, the community channeled the water from the mainstream to the fields or settlement through canals made from boulders, branches, shrubs, stones, gravel, and naturally grown weeds. This traditional system of water distribution and irrigation is called Chorus or Churres. In this system, as shown in Fig 4, the first step is to divert the water from the mainstream by building a rough dam called Tokpo. The Mayur or the main channel (usually the first channel) from the Tokpo is directed towards the first water reservoir or pond called Zing. The water is further channeled to different fields through intermediate channels called the Yura and Nangyu or Nangyura and then into side channels and contour band channels called Yihu and Yang.

To implement the Churres system, water availability and its management played a significant role in the siting of settlements and agricultural fields (Clouse, 2017). The site chosen for settlement and agriculture was such that water could be diverted and directed from the stream through gravity without any complex mechanical equipment. Hence, the villages in Ladakh were always situated in the river valleys, as shown in (Fig 1). Houses were arranged in close clusters to provide more land for cultivation and easy water distribution (Ferrari, 2018). The buildings were positioned and oriented according to the natural slope that facilitated water drainage (Borah, 2015). Houses were built on a slightly higher ground than the agricultural fields for easy irrigation and to monitor the farms.

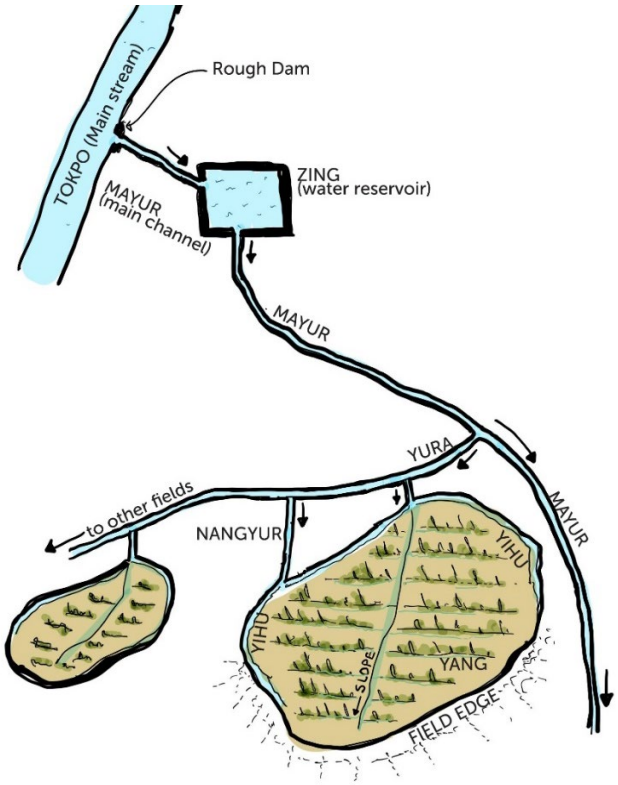

Figure 4. Chorus or Churres – Traditional water distribution and irrigation system in Ladakh. Adapted and modified from (Ives & Messerli, 1991)

From site selection for settlement to irrigation techniques, the people of Ladakh took extreme care to conserve water using simple methods and materials. In the built form, to conserve water, people in the region used dry toilets or composting latrines, locally called Dechot or Sanghot, as shown in Fig 5. Traditional houses had a composting toilet typically built inside the house. The dry toilet was typically built on the first floor with a hole in the slab. After using the toilet, a mixture of ash and mud was shoveled into the hole. The room below acted as a collection or decomposition room. It did not have any openings, and access to this room was from the exterior of the house. The absence of ventilation aided the decomposition of human excreta. The collection room was cleaned once or twice a year with the help of the community, and the human manure thus obtained was used as compost in agriculture fields (Mishra, 2018) (Hodge, 1991).

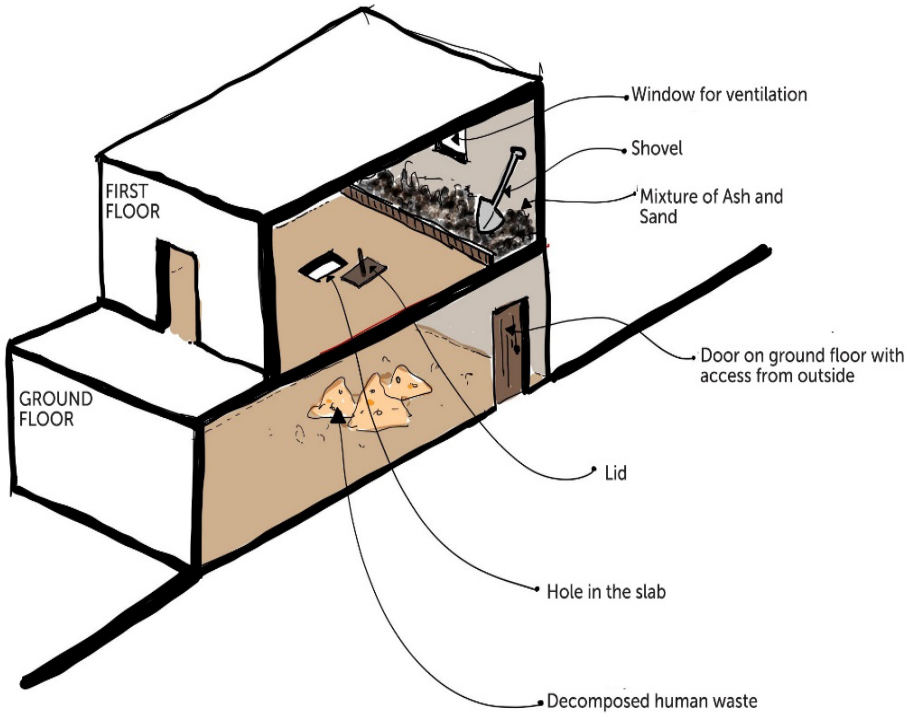

Figure 5. Dechot or Sanghot - Typical Section of Dry toilet.

Tourism has quickly replaced farming to provide sustenance, impacting the agricultural practices, traditional water management system, and water availability. There is a drastic shift in the occupation after the arrival of non-natives (the tourists and military personnel) in the region (Geneletti, 2009) (LAHDC, 2012). Also, the traditional house form is transforming in terms of built spaces and building materials.

Farmers have adopted modern crop production techniques like chemical fertilizers to meet the growing needs and changes while abandoning their traditional organic farming system. Water distribution and conservation methods have been altered to address the changes in the farming system. The Government constructed canals and reservoirs to address the water

shortage using non-local materials (like concrete) and techniques. Due to unfamiliarity with the construction material and technique of the new canals, the locals have started to depend on external help for repair and maintenance. Outsourcing the masons and materials has made the community dependent on external resources (Mankelow, 2003).

As agricultural activities have reduced due to increasing tourism-related activities, the need for a traditional water management system declined from 2005 onwards (Spindle, 2019) (Mishra, 2003). Water is no longer treated as a shared commodity. Today, water is extracted from the groundwater sources through borewells or mechanical pumps to meet the growing requirement of the locals and tourists. Water is also drawn from the Indus River using pumps and supplied through private water tankers (Mueller, 2020). Combined with climate change, this will only aggravate the existing pressure on the limited water availability. It will further impact the ecosystem of the mountain region and its community, making them vulnerable.

Table 1. Changes in the social systems and their impact on the livelihood and built environment.

	Traditional Methods since 16th century		Changes since 1966	
	Livelihood	Built environment	Livelihood	Built environment
Traditional Technological Systems	Organic agricultural practice through equitable water distribution system called *Churres* or *Chorus*	The site selection; building orientation, typology; construction material, techniques; construction of dry toilets responded to the water scarcity of the region	Introduction of alternative farming technique; abandonment of *Churres* in some towns; use of private borewell and mechanical pumping from Indus River	Introduction of flush toilets instead of dry toilets, bathroom; non-local materials used for construction; Change in building form and typology

Due to outward migration and the introduction of new construction technology, the local communities have refrained from adhering to the traditional knowledge and customs for site selection and building construction. Existing traditional residences are modified or rebuilt as homestays to keep up with the changing livelihood and economic opportunities. The building form and space allocation are modified to accommodate tourist demands and growing aspirations (Fig 6 and 7). Newly constructed residences have flush toilets instead of traditional dry toilets. In some cases, dry toilets are built as independent structures (Mueller, 2020). As per a Ladakh Ecological Development and Environmental Group (LEDeG) survey in 2019, an

average tourist consumes 75 liters of water a day compared to 21 liters of water used by locals. This change in traditional dry toilet systems adds water requirement pressure on the cold-desert region with scarce water. The lack of proper sewage has degraded the environment and water quality (Keilmann-Gondhalekar, 2015). In addition to this, the extremely low winter temperature freezes the water in pipes making the conventional toilets non-operational in winters.

The traditional technological water management system influenced the livelihood pattern and built environment (Table 1). As a part of the larger network of the cultural system, the traditional technological systems addressed the region's water scarcity and its extreme climatic condition. Abandonment of traditional technological systems and rapid transformations has led to an alarming water shortage in Ladakh.

2.4 Social systems

The functioning of the traditional irrigation system called Chorus or Churres depended heavily on the social system within the community and vice-versa. The objective of this system was to ensure the equitable distribution of water. The farms in the village were divided into groups or clusters, depending on the topography, area of land, soil type, and plantation. Each group was known as Bandabas or Bandobasti. The group or clusters of the villages came under one revenue officer jurisdiction, called Patwari. The revenue officer was in charge of resolving intra-group water conflicts and ensuring equal and fair water distribution across the village. However, before taking any water issue to the Patwari, the matter was resolved within the community (Angchok, 2006).

The responsibility of water distribution within the village was on the Chhurpon, derived from local words Chhu meaning water and Pon meaning Lord - translated as the 'Lord of Water'. The Chhurpon was elected annually by the community in every village. He was an experienced man with knowledge and expertise in the construction and functioning of the Chhures. On his selection, the Chhurpon and the community members signed a document called Kamgya. This agreement stated the obligations and duties of the Lord of the water. He was responsible for water management and its equitable distribution. He estimated the water requirements of the field by knowing the farm area and the type of crop cultivated. However, he did not do all of this alone. The community members assisted in the entire process of diverting, preserving water, and maintaining the system. The water channels and water tanks leading to the fields were built using natural materials with the help of villagers. After seasonal rains or winters, the community worked together to clear the debris and repair the canals. While supplying water to the fields, the collective system of Bandabas would enable the community members (along with the Chhurpon) to keep an eye on others and their water consumption to get a fair quantity of water for their fields. As a token of gratitude and in return for his services to the village, the villagers gave the Chhurpon a one-person load of the crop (ration required by one person). The

system of Chorus was successful only due to the community's collective efforts. They helped the Churrpon with the operation, maintenance, and monitoring of the entire system.

Some social systems also helped with the water distribution beyond the village boundaries. A mutual agreement was made between two villages for water storage and distribution if they were located along the same stream (upstream and downstream). The agreement helped maintain unity within the community and with the neighboring villages. The objective is to ensure equitable water distribution to both villages relying on the same water source. The neighbouring villages of Phey and Phyang are one such example. Another document made in the early 20th century called Riwaz-i-Abpasha, meaning 'the custom of irrigation,' outlined the water distribution rules between villages and the customs for sharing water(Dollfus, 2008).

Traditionally, due to the social nature of the Chhures system, any built form expansion or agricultural expansion required consent from the entire community. But, due to tourism-driven outward migration, the villages are becoming less occupied. As per the locals, the abandonment of consent from the community members for expansion or new construction and newly constructed canals under the government schemes has resulted in unregulated expansion. Tourism has led to the economic up-gradation of the people, enabling them to hire non-native (Bihari or Nepali) for agriculture and construction of new structures. The migrant workers are employed for comparatively cheaper rates and faster construction techniques as compared to the traditional masons (Schreiber, 2016) (Mishra, 2018). The hired laborers are unaware of the local customs, knowledge, and traditional techniques. The shift in the construction preferences has led the local masons and artisans to adapt to other livelihood opportunities causing a decline in traditional construction and material knowledge. People now depend on external assistance to repair or maintain the buildings, with a high risk of losing their identity.

Ever since the tourism and other service sectors became the main livelihood of the people instead of agriculture, the practice of Chhurpon and Chhures system began to disappear from Ladakh gradually. Today, the management and distribution of water are more private than communal Spindle (2019) points out from the notions of the community that the traditional systems such as Chhurpon have gradually begun to disappear in the region, indicating directly or indirectly the loss of mutual trust between the individuals and communities. When trust no longer sustains, traditions tend to dissapear. This then results in the beginning of institutionalization. Communities became dependent on the bore well systems, guided and further institutionalized by the local authority frameworks.

Table 2 demonstrates that transitioning into a singular family system from a non-multigenerational system, non-dependence among community members, and dependence on external sources for agriculture and construction have transformed the community. With these changes, the community has transformed from sustainable and self-dependent to dependent. The people of Ladakh are now majorly reliant on external assistance for their livelihood and construction of built form, further adding to their vulnerability (Dame, 2008) .

Table 2. Changes in the social systems and their impact on the livelihood and built environment

	Traditional Methods since 16th century		Changes since 1966	
	Livelihood	Built environment	Livelihood	Built environment
Social Systems	The Churres system brought the social concept of *Chhurpon- Lord of Water;* The tradition of maintaining the *Bandabas or Bandobasti for water management - a list that contains the groups of farmers residing in a particular village; Another social tradition of signing the Kamgya- a work contract between Chhurpon and community*	*Riwaz-i-abpasha;* Polyandry; communal house construction	Decreasing communal help and reliance on the community due to rural-urban migration; more individualistic approach, hiring non-native workers for agriculture	more reliance on external help (both material and labour) for house construction

2.5 Religious and belief systems

To understand sustainable water resources management, one has to look into another aspect of the complex cultural system, including religious, cosmological, and mythical beliefs. Water was acknowledged and given importance in the local folklore. Chuu- is the Ladakhi name for water. One such folklore described below emphasises the equitable distribution of water (Angchok, *et al*., 2008).

"chhuk-po nor-ri mi-gang, gya-tso chhu-yi mi-gang"
(Wealth does not satisfy a rich person; water does not satisfy the sea)

"chhu-zyig be-na gyal, mi-zyig dum-na gyal"
(Diverted water is safe, (and) people living together are safe)

"phu-a kang-ri chags-na, do-a gyam-tso khi"
(When glacier forms in phu (high altitude areas), the ocean is formed in the lower parts)

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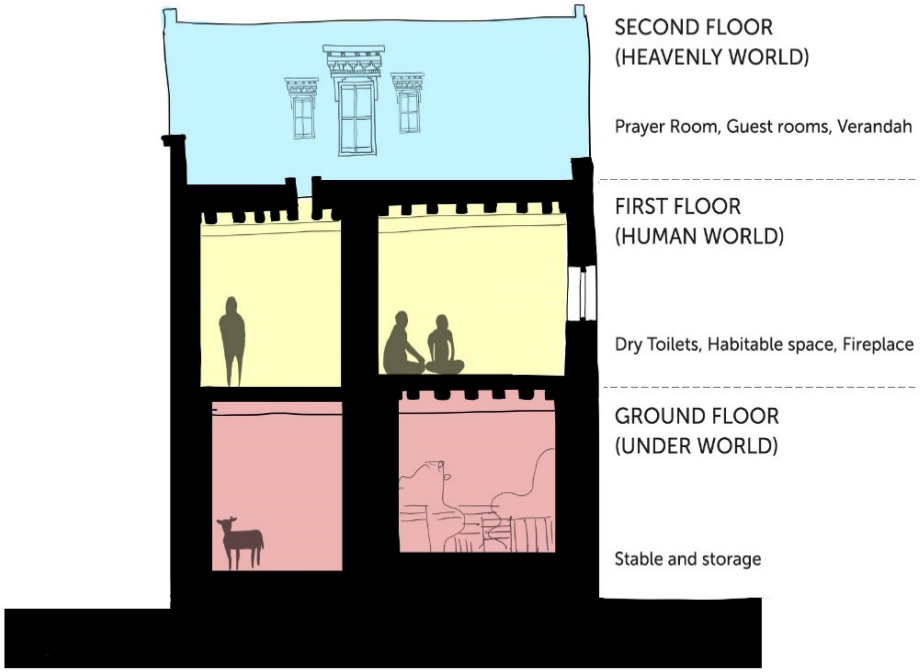

Figure 6. Typical Ladakhi house section showing the floor distribution as per cosmological and religious beliefs.

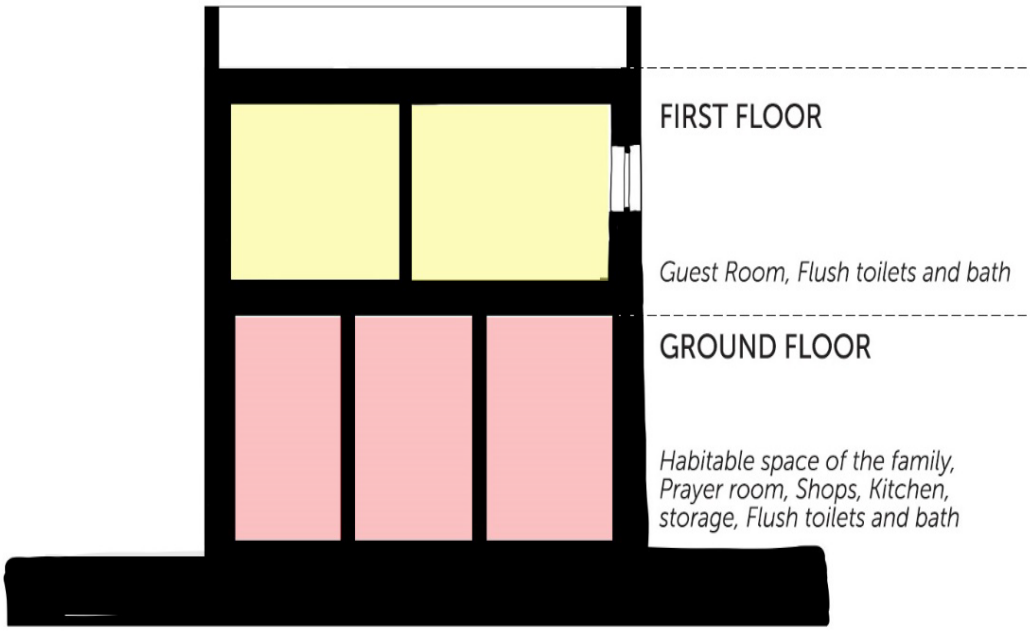

Figure 7. A changed typology of houses.

In his study, Angchok explains that the above folklore stresses the importance of social harmony and diversion of water through water channels like Mayur, Yura, Nagyur, etc. It ends

by indicating the importance of balance between climate and the natural process of the water cycle. When translated, the last line of the folklore is that water will be available for usage in lower altitudes only when the glaciers are timely formed in the high-altitude regions. With changing climate, one can observe the adverse effects of the receding glacial belt and untimely melting of glaciers in the region.

Traditional Buddhist communities strongly believed in the co-relation and co-existence of humans, spirits, and nature. They believed that humans' objectionable or disrespectful acts against nature or spirits resulted in unfavourable events. In one such belief, Lhu- a female deity associated with earth and water resides near water bodies like rivers, lakes, and natural springs beneath the earth's surface. In other beliefs, Lhu is also identified as the Nagasin, the Hindu Pantheon (Kaplanian, 2014). It is a popular belief that the spirit of Lhu provides good fortune to the villagers, along with the healthy production of crops and animals. To mark its presence, Lhu-bang is erected near water springs. It is a small rectangular structure with a base and conical or spherical top. The community members take special care to please the spirit by maintaining the sanctity and hygiene around Lhu-bang. It is believed that polluting the environment, chopping trees, polluting streams and water points offends her and can lead to misfortune (Angchok D. S., 2006). The religious, mythological, and spiritual beliefs directed the people to respect water as a resource and use it judiciously (Kaplanian, 2014) (Mann, 2002).

Table 3. Changes in the religious, cosmological, and other belief systems for water management in Ladakh and its effects on the livelihood and built environment.

	Traditional Methods since 16th century		Changes since 1966	
	Livelihood	Built environment	Livelihood	Built environment
Religious, cosmological, and mythical systems and belief systems	*Lhu*-bangs-religious structure, consultation to *Onpo* or *Lamas* for irrigation, sowing, harvest; festivals to celebrate sowing and harvest. These practices ensured that water was used as a common resource.	Site location, space allocation in the house based on belief in realms; folklore	Reduced consultations to *Onpo* or *Lamas*, comparatively less participation in the festivals	Less consideration of mythological realms or religious beliefs for new expansions and building typology

With growing water scarcity, change in economic pattern, outward migration, and the success of farming seasons with fertilisers, many traditional rituals and beliefs are abandoned

(Crook, 2001) (Dollfus, 2008) (Gagne, 2016). With the decreasing beliefs and increasing economic generation, locals try to meet the needs of the tourist while compensating for their rituals, practices, cosmological beliefs, and customs. This change in attitude is also reflected in the construction techniques and spaces in the built environment. Today, the spaces in the houses are designed solely on tourist requirements overlooking the region's water scarcity and geographic limitations. The construction of dry toilets to conserve water overlapped with the mythological belief in different realms (Fig 6). With changing requirements and aspirations, the building typology is altering rapidly (Fig 7). These changes overlook the traditional technological system of constructing dry toilets and the mythological belief of different realms within the house that supported water conservation (Table 3).

2.6 Economic systems

According to the conceptual framework (Fig 3) used to study the cultural system for water management in Ladakh, the last aspect has taken the most rapid transformation and seems to be the driving factor that now influences the cultural systems the most. This section explains how it has gone from being the least dominant to the most dominant factor influencing water resource management in the region.

Before the 1900s, the city of Leh in Ladakh acted as a nodal point due to its strategic location for trading in the Trans-Himalayan commercial route (Bureau, 2015). The earlier lifestyle of the Ladakhis was strongly influenced by Buddhist ideologies with negligible or no emphasis on financial aspects of life. They strongly believed in synergy between human spirits and nature. The community was founded on communal cooperation, ecological sustainability, and spiritual harmony (Hodge, 1991). In the past, the occupation of the Ladakhi population was agriculture, animal husbandry, and trading.

However, since Leh opened to tourism in the 1980s, there has been a drastic shift in the occupation. Many Ladakhis have abandoned agricultural practices and migrated towards the city for better opportunities in the tourism sector or government jobs (Clouse, 2017) (Patel, 2008) As a result of migration towards cities, villages in Leh lack a workforce during the sowing, farming, and harvesting period, coinciding with the tourist influx. The locals hire migrants and non-natives to meet manual labor needs for agricultural production. During summers, about one hundred thousand seasonal migrant workers reside in Leh (Spindle, 2019).

Today, receding glaciers (due to climate change) and their untimely melting overlaps with high tourist influx. Combined with the increase in water demand, Ladakh- a cold desert region, experiences extreme water shortage (Fig 8). The region experiences drought-like situations, making water unavailable during the sowing period. As the sustenance of the region was mainly on agriculture, water shortage affected the production of crops, making the community dependent on external resources. To meet the water scarcity for daily use and agricultural production, the Government introduced the Watershed Development Program and the Public

Distribution System, respectively. Rice and other non-native pulses-vegetables were introduced in this region under the Public distribution system (Mishra, 2003). Subsidies and handouts have significantly reduced and eroded the characteristics of self-sustenance and sustainability of these mountain communities (Dawa, 1999).

The chase towards economic upliftment opportunities has resulted in adverse effects, causing environmental degradation and impacting the soil, water, wildlife, vegetation, and people. (Borsdorf, 2015) . The self-sustaining cohesive cultural system of the community for water management has now become isolated, driven solely by the economy, and extremely reliant on external resources (Table 4).

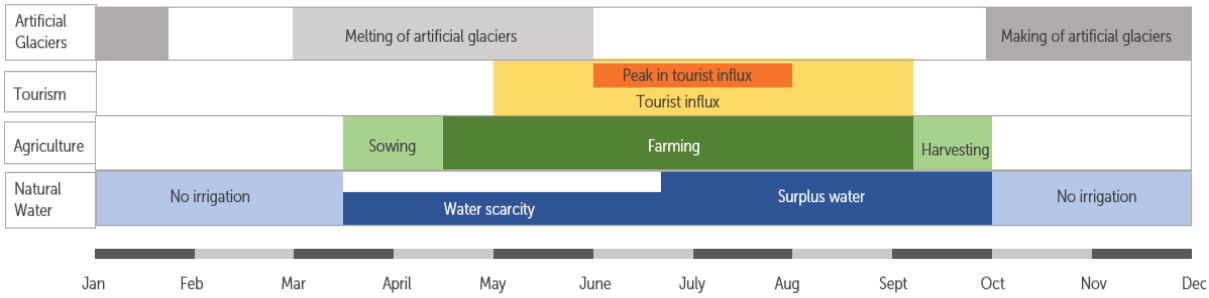

Figure 8. Yearly timeline showing the natural water available from the glacier for farming and its overlap with tourists visiting the region. Together, the increased water requirement results in water scarcity in the region.

Table 4. Understanding the Change in the economic systems for water management in Ladakh and its effects on the livelihood and built environment.

	Traditional Methods since 16th century		Changes since 1966	
	Livelihood	Built environment	Livelihood	Built environment
Economic systems	Agriculture; animal husbandry; trade- not driven by money but by social systems	Not money driven	Heavily influenced by tourism and military personnel	Heavily driven through monetary gains

2.7 Development Initiatives and Interventions

A decline of the traditional techniques and practices for water conservation and increased consumption has led to water shortages in the region. The Government and Non-Governmental Organizations (NGOs) took several initiatives to address the water shortage in the area and local requirements. While some of these initiatives consider the existing cultural systems, others overlook them. Initiatives that ignore the cultural systems are modified, discontinued,

or abandoned by the community. To address the rapid changes in the region, it is critical to understand and incorporate the existing cultural system for sustainable water resource management and project implementation.

The Indian Government has launched several state-driven centralised infrastructure development schemes in the region. In 2001, the Watershed Development Program funded by the state and central Government aimed to improve economic conditions by enhancing ownership and re-empowering the communities to be self-sustainable. However, Gutschow & Mankelow (2001) study provides several examples of unused and non-functional canals built under this project. They observed that extreme weather conditions cause rupturing of the cement lining and create racks in the concrete channels. In Zangla village, the community, unfamiliar with the new material and construction technique, attempted to repair the ruptured concrete using sods of the earth (Mankelow, 2003).

In 2013, the Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) was launched under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) mission for water distribution and sewage treatment. The UIDSSMT project planning documents describes the traditional water management system (Churres) as "provincial and contradictory to modernity" (Mueller, 2020). Though the program aimed at providing water to the locals, it was not very successful. It overlooked the local communities, their context, and characteristics, such as hydrology and geomorphology, socio-cultural or religious aspects. The project received a lack of public participation and caused spatial inequalities, leading to changes in the traditional land use pattern and haphazard expansion of the settlements (Dame, 2008) (Mueller, 2020).

NGOs play a significant role in the development of Ladakh. Since the 1970s, they have successfully channeled a substantial flow of international funds into the region (Dame, 2008). They have a long history of representing Ladakhi people, their practices, and traditions (Hodge, 1991). The NGOs play a pivotal role in organising and coordinating meetings with the community and the government agencies. They also raise funds, organise awareness campaigns, workshops and expeditions (Mueller, 2020), to put forth aspirations, ideas, concerns, issues, and initiatives of the Ladakhis.

To address the growing concern of water shortage and melting of receding glacial belts, two local engineers with the help of NGOs have taken the initiative to store water for agriculture and daily needs in the form of artificial glaciers and ice stupas. These initiatives became more successful than the top-down government initiatives because they integrated local resources and knowledge in the project and local communities in the decision-making process (Mueller, 2020).

Table 5. Analysis of Government and local initiatives for water management and conservation.

	Government Initiatives	Artificial glacier by Chewang Norphel	Ice stupa by Sonam Wangchuk
Implemented Since	2001 onwards; 2001- Watershed Development Program (WDP); 2013- UIDSSMT under JNNURM; 2019- Jal Jeevan Mission (JJM)	late 1980s onwards	2014 onwards
Construction Cost	Under the WDP-around four thousand $ per project; JJM mission-3.62 billion $	The construction cost is 4 thousand-1 million $ as compared to 2.5 million $ cement reservoirs; About 3.6 million $ is allotted per project fund through the WDP; however, only 860 thousand $ has been released in the last six years.	The pilot project costed 3 million $, but Wangchuk claims that the cost can be brought down to 500 thousand-1 million $; for 39.625 thousand gallons of water, the capital cost is 0.00032 $ per liter.
Technological system	UIDSSMT- State-driven centralised infrastructure scheme for formalised water distribution network and sewage system- theoretically aimed at re-empowering the community's irrigation system	Ten high-altitude artificial glaciers were built till 2009. Each provides about 6 million gallons of water; no machinery is required for its construction and operates entirely on gravitational force	Can be built anywhere as required, works based on gravitational force and properties of water, plastic hose pipes are required
Social system	not incorporated	Initially, the community took active participation, but over the years, it has reduced	community participation is through competitions, the locals are taught to build, repair and maintain on their own ice stupas
Religious, cosmological, and mythical systems and beliefs systems	not incorporated	not incorporated	The shape resembles Buddhist stupa in the region; tying of prayer flags due to association and religious belief
Economic systems	not incorporated	not incorporated	ice-café, and prospects of 'ice hotels' and 'ice climbing winter sports.'

Artificial glaciers were built at high altitudes, between 2400-3600m, in the late 1980s by a local engineer named Chewang Norphel (Vince, 2009). The large-continuous ice sheet about 300 m long is built by blocking, collecting, and freezing the water. To construct an artificial glacier, water is diverted from the mainstream and distributed along a gradually cascading

horizontal ground with the help of gravity. This method reduces sun exposure and prevents untimely melting of Ice. The artificial glaciers are built without using any machines and work on the principles of gravitational force. The frozen glacier starts melting in spring (April) during the sowing season. The water lasts for about 45 days until the high-altitude natural glaciers start melting (Norphel, 2017). The diversion of water from the mainstream, the use of simple technology without machines, and the active involvement of the community to divert, block and regulate water are the reason for the effectiveness of this initiative (Dar, 2017) (Vince, 2009). These characteristics relate to the traditional cultural (Churres) system for water management followed in the region.

Another conventional example for water conservation and distribution is ice cones, popularly known as Ice Stupas, built by Sonam Wangchuk. Unlike the glacier built by Chewang Norphel that requires a large horizontal space and high altitude, the ice stupas by Wangchuk can be built next to the village. The size of the stupa can be as per the requirement of the village. In this system, water is directed from a height with the help of gravity and released vertically upwards with pressure. This process is done at night to facilitate fast freezing (Maheshwary S, 2019). While maximising the volume of Ice, the stupas' conical shape helps the ice shadow itself and minimizes the exposed surface area to sunlight. As assessed in 2016, the water holding capacity of all Ice Stupas in the valley was about 27 million gallons per year.

The word 'stupa' comes from Buddhist shrines prevalent and predominant in the Buddhist region of Ladakh. Due to its visual resemblance to the stone and earth stupas in the region, people have a strong religious, spiritual, cultural association, and significance (Geneletti, 2009) (Killing Ladakh, 2018). Ice stupas aim to recharge the region's groundwater and provide water for agriculture and other purposes (Clouse, 2017) .

The construction of ice-stupas is solely by the local people and non-governmental participants. The NGO's play a significant part by providing either personal funding or sponsorships. So far, the Government's involvement is limited only to consenting the area the construction of ice stupas (Kumar, 2019). Over the last few years, the ice stupas have scaled up in the region. An annual ice stupa-making competition is being organized across Leh to spread this knowledge and encourage local participation. The villagers are first taught to build ice stupas and then encouraged to participate in a competition that challenges them to build the biggest stupa in the region within a stipulated time. During the winter of 2019-20, 26 ice stupas were constructed across the valley (Pandit, 2020). In addition to their contribution to the technological, social, religious, and spiritual system. The ice stupas can also contribute to the economic system of the locals (Nayar, 2019) (Safi, 2017) by creating hospitality opportunities like 'ice restaurants or café', 'ice hotels' or for adventure sport like 'ice climbing' (ET, 2019) (Kumar, 2019). Ice stupas have demonstrated the importance of religious and cultural association with sustainable and inclusive water resource governance.

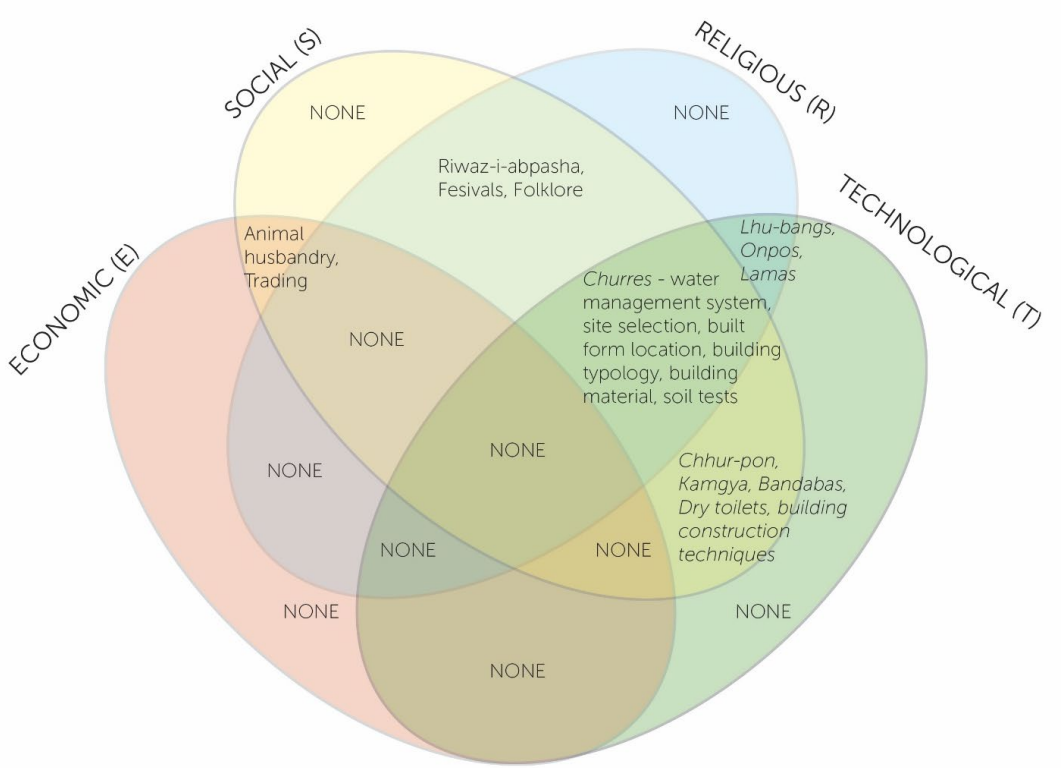

Figure 9. The overlaps between the economic, social, religious, and technological aspects that collectively shaped the traditional system for water management in Ladakh region.

3. DISCUSSION

Water plays a fundamental role in the daily life of Ladakhis and is embedded in their culture and identity (Mueller, 2020) . In the past, it was considered sacred, and the community guarded it against exploitation and pollution (Schreiber, 2016). A well-maintained irrigation system was viewed as a symbol of the self-reliance of the village and its households (Mankelow, 2003) (Crook, 1994). Through social participation and monitoring, regulation of common resources gave a sense of association, ownership, and responsibility that collectively formed the village solidarity. The traditional cultural systems ensured optimum and equitable water utilisation by everyone in the community and neighbouring village. According to Hodge, the Ladhaki community was established on the principles of communal cooperation, ecological sustainability, and spiritual harmony. The rituals and ceremonies were not limited to religious and social practices but informed the nature-human interaction, aiding harmonious co-existence (Hodge, 1991).

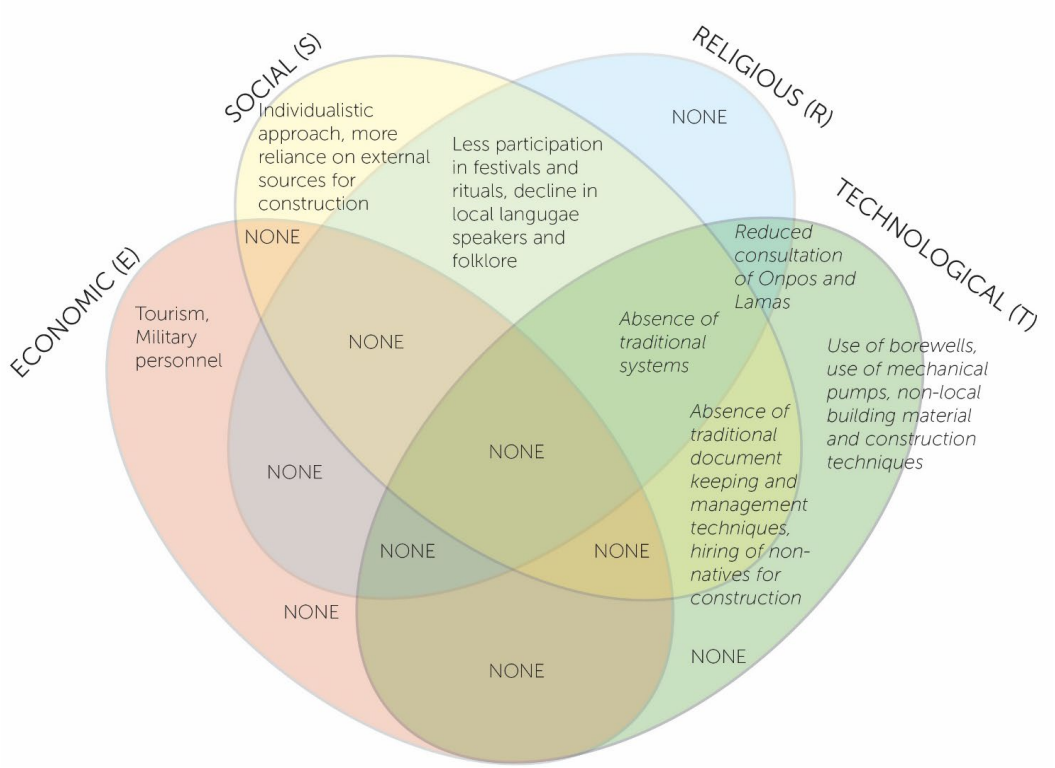

Figure 10. Changes in the traditional systems of the region that impact the water management and conservation.

We conceptualized the cultural system as the integration of technological (T), social (S), religious (R), and economic (E) sub-systems in order to systematically analyze the importance of culture for effective and sustainable water resource management in the Ladakh region. The Venn diagram in Fig 9 demonstrates the cultural system in the Ladakhi traditional water management method. The traditional cultural system was not solely driven by the economy (E). The only aspect that the economy influenced was the occupation of animal husbandry and trading. The systems for water conservation and management were dependent on the relationship between various social (S)-religious (R) and technological (T) sub-systems. The figure helps us understand that the systems are not isolated but interlinked.

The Venn diagram in Fig 10 explains regional changes induced by tourism have adversely impacted the cultural systems that ensured water conservation. In contrast to the traditional system that did not give much importance to the economy, today's cultural system is primarily driven by the economy. Due to outward migration, there is a decline in the social system of the villages. The systems of Churres, Chhurpon, Bandabas, cleaning of dry toilets have collapsed in villages. The recent changes mainly focus on economic upgradation and do not address the network within the cultural system. New constructions, agricultural practices, and development programs often overlook the existing cultural systems. Due to their correlation, as explained in Fig 11, any change in one system creates an unavoidable impact on the other.

In addition to the global changes, the regional changes have added pressure to the existing water scarcity of the region. The changing social relations and economy have resulted in a draught-like situation, low food production, water scarcity for agriculture, and daily needs.

The government initiatives are unsuccessful as they focus mainly on the technological and engineering aspects. John Crook expresses his concern on the implementation of 'so-called development programs' in Ladakh, stating that it "would weaken and the old system of local linkages through inter-familial goodwill would break apart" (Crook, 1994). Another study claims that the governmental approach of formal construction of water management increases the dependency of self-reliant communities on the Government (Dame, 2019). Implementing unfamiliar technology makes the communities dependent on external support and help. In many instances, the initiatives are abandoned, dilapidated, or unused (Gutschow, 2001) . After its completion, such projects do not empower the people to maintain and operate them. The government-initiated Watershed Development Program demonstrated the failure of an authority-driven centralised structure for formalized water distribution solely focused on technological and economic aspects (Mankelow, 2003) (Mueller, 2020). Studies in other parts of the world also reported that government-driven water resource management programs are often unsustainable as these projects ignore the local communities' meaningful engagement and self-reliance (Samaddar S, 2019) (Samaddar S., 2021). On the contrary, ice stupas are more successful as they solve water shortages and involve the community in its construction. The ice stupas incorporate a strategy of construction and management by the community members (Kumar, 2019). In addition to its contribution to the technological, social, religious, and spiritual system, the ice stupas also contribute to the economic system (Nayar, 2019) (Safi, 2017).

This study helps to analyze the relationship between the cultural system, changes, and development interventions. It demonstrates that adaptation of cultural systems (that focuses interlinking the traditional technological-ecological knowledge, social and religious systems) with modern technology can revive and enhance the community's resilience while addressing the depleting resources, natural hazards, risks, and social vulnerability.

4. CONCLUSIONS

This study deals with the increasing water-related risks in the ecologically fragile Ladakh region of India, and the significance of culturally viable alternatives. Unlike conventional studies focusing solely on the technical and engineering aspects of water resource management, this study intended to explore the role of cultural systems and practices to enable these risk preventive interventions to be sustainable and effective. With experience and knowledge, the mountain communities have developed several tangible and intangible methods that defines their cultural systems. These traditional systems respond to the geographic and climatic constrais of particular region.

The study findings show that though several governmental and non-governmental initiatives have been introduced recently to deal with scarcity issues, the projects that received success are the ones that effectively integrated socio-cultural values, beliefs, and practices in the risk management process. The study of artificial glaciers and ice stupas exemplifies that a development initiative has higher chances of success when it identifies, acknowledges, and includes traditional systems and the community. The inclusion of a cultural system makes the community resilient while boosting its economy and livelihood.

The traditional water resource management practices also demonstrated that financial gains and opportunities did not solely drive such initiatives. The traditional system paid adequate attention to the cultural well-being of the community while dealing with water-related risks. The systems for water conservation and management were dependent on the inter-relationship and interconnection between various social (S)-religious (R) and technological (T) sub-systems of the system. However, in contrast to the traditional system that did not give much importance to the economy, today's cultural system is primarily driven by the economy. Due to outward migration, there is a decline in the social system of the villages. The social systems of Churres, Chhurpon, Bandabas, cleaning of dry toilets have collapsed in villages. The recent changes mainly focus on economic up-gradation and do not address the network within the cultural system. New constructions, agricultural practices, and development programs often overlook the existing cultural systems. Due to their correlation, any change in one system creates an unavoidable impact on the other. The regional changes induced by tourism have adversely impacted the cultural systems which were responsible for sustainable water conservation.

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