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Traditional practices of the people of Uttarakhand Himalaya in India and relevance of these in disaster risk reduction in present times

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ABSTRACT

Indepth study of traditional resource management practices of the indigenous people of Uttarakhand Himalaya reveals their appreciably advanced understanding of the causes of various hazards. Through their continued keen observation, experimentation, innovation and recordkeeping these people devised techniques of maximizing resource availability while minimizing the wrath of the hazards. For ensuring universal compliance of the rules so laid down these people relied on social sanctions and religio -magical practices interwoven around little tradition of the people. With weakening social solidarity in the recent times these practices are fast loosing ground and if adequate steps are not taken for documention this rich knowledge of generations could well be lost forever. These practices are highly relevent even today and hold the key to minimizing losses due to natural hazards in a cost effective and sustainable manner and are therefore required to be studied, documented and dovetailed with modern science and technology.

1. Introduction

The Himalayan region is highly vulnerable to earthquakes [2,11] and has been devastated by four Great Earthquakes (Magnitude > 8 on Richter Scale); 1897 Shillong, 1905 Kangara, 1934 Bihar–Nepal and 1950 Assam earthquakes apart from Kumaun and Garhwal earthquakes of 1720 and 1803 respectively [48]. Regions between rupture zones of these earthquakes represent seismic gaps that have accumulated potential slip for generating future Great Earthquakes [2]. Though shaken recently by 1991 Uttarkashi, 1999 Chamoli earthquakes the state of Uttarakhand in India (Fig. 1) falls in seismic gap of 1934 and 1905 Great earthquakes and is identified as a potential site for a future catastrophic earthquake [2,33].

Ever since stabilization of the southwest monsoon owed largely to upliftment of Himalaya [22], the region has been experiencing heavy rainfall, mostly restricted to monsoon period, rainy season over Indian subcontinent. Localized and abnormally heavy precipitation (cloud burst) which is common in the region often results in debris flow, landslide and flash floods. Apart from 1894 and 1970 [34] Uttarakhand has been devastated by floods in 2010, 2012 and 2013 (Table 1). The human deaths in the incidence of 2013 surpassed 4000 and devastated Mandakini and Alaknanda valleys besides Kali, Goriganga, Pinder, Bhagirathi and Saryu valleys [18].

Due to enhanced pore water pressure and reduced frictional forces landslides are common during monsoon period and cumulative toll of these far surpasses that of other hazards. It is estimated that every square kilometer in the Himalaya has at least two landslide scars [1]. In the year 1998 the state witnessed major landslides in Madhyamaheshwar and Kali valleys in which human death toll was more than 350 [29,35,39].

Most agricultural lands in the region are rainfed and therefore failure, weakening or delay of the southwest monsoon or winter rains results in crop failure or depleted productivity. In the recent times the state has faced severe drought conditions in 2006, 2008 and 2009 [13–15]. Moreover, western disturbances often induce squall and hail storms that cause measure loss of horticultural crops. Forest fires are also frequent in the region and besides causing environmental degradation these often enhance the pace of other erosional processes.

Uttarakhand is thus prone to a number of natural hazards and the people living in this terrain would have often experienced wrath of these. Ensuring safety and continuity of the community has been the biggest challenge faced by human beings all through and everywhere. Continuous and unabated human presence in the

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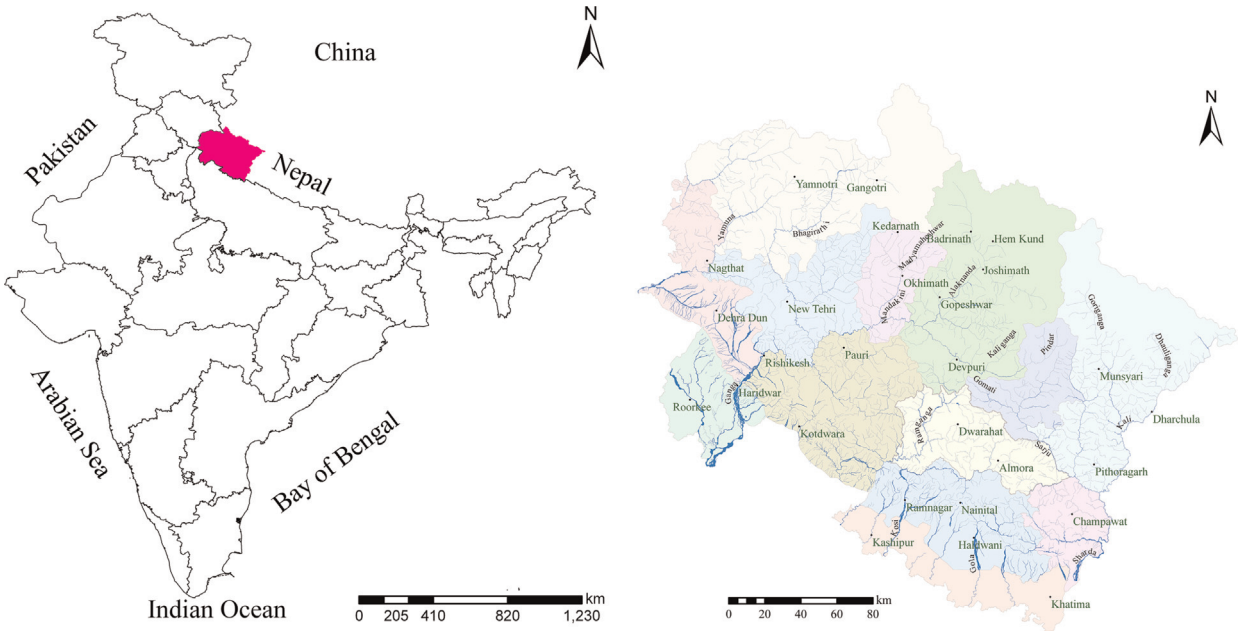

Fig. 1. Location of the study area.

Table 1
Losses incurred due to debris flow and flash floods caused by heavy precipitation in 2010, 2012 and 2013 in Uttarakhand. (Source: [16,17,18]).

Sl. no.	Item	2010	2012	2013
1.	Period of occurrence	August–September 2010	August–September 2010	June 2013
2.	Number of affected districts	13	02	13
3.	Number of villages affected	9162	129	1603
4.	Population affected (in lakh)	29.24	0.84	> 5.0
5.	Permanent loss of land (in ha)	2,35,160	–	11,481.88
6.	Cropped area affected (in ha)	5,02,741	–	10,898.96
7.	Damaged houses	21,045	652	19,309
8.	Human lives lost	214	81	169
9.	Human beings missing	00	06	4024
10.	Persons injured	227	27	236
11.	Animals lost	1771	537	11,091
12.	Damage to public properties (in million US $)	3526.3	133.9	2163.2

region despite persistent and serious threat of a number of hazards suggests that the indigenous people of this region, based upon their acquired knowledge, could satisfactorily mitigate losses from these hazards.

Basic understanding of the processes inducing these hazards is however required for doing so. This could however not be done without keenly observing various natural hazards and probing causes thereof. Understanding of probable causes of these hazards would have led the people to experiment with various likely influencing parameters and devise ways of minimizing losses in subsequent events. It is only with this observation, experimentation and carrying forward of the acquired knowledge that these people could successfully understand the processes inducing these hazards and devise ways of ensuring safety from these.

There exist enough evidence to infer that these people possessed superior understanding of the processes underlying the hazards and devised ways of minimizing losses from these. These are discussed in detail in the sections below. Passage of this knowledge through oral tradition alone could however not transmit observations made during hazards such as earthquake that have long recurrence interval. Evidences pertaining to formal documentation and transmission of knowledge related to these hazards remains a major missing link in disaster management related understanding of the indigenous people of this region and the same warrants dedicated and specialized research.

2. Water management

The people of the region attribute flash flood, landslide and drought to excessive presence and scarcity of water. Overview of the rules framed by these people for managing these hazards lead to the conclusion that these people with their keen observations and quest to understand reasons of these hazards were able to decipher some of the intricacies of hydrological cycle including the relationship between recharge of groundwater in the upper reaches of the hills and discharge of springs and other seepages in the middle and lower slopes.

Round the year availability of drinking water in adequate quantity is an important criteria for selecting site for settlement in the hills. Water of the glacier fed major rivers of the region is however not fit for human consumption during summer and rainy seasons due to excessive suspended and dissolved load due to glacial melt and surface erosion respectively. To survive in this terrain the people had therefore to devise ways of exploiting other sources of water.

2.1. Groundwater exploitation

Himalayan region has highly fractured and jointed rock mass that results in quick dispersal of precipitation beneath the ground and makes groundwater exploitation in the region highly challenging. Moreover, unlike plains there exists no permanent water table in the hills and for exploiting subsurface water one has to be precise enough to locate and hit the perched aquifers.

Initially the indigenous people utilized the water of the local streams that are fed by the water oozing out of the hill slopes but soon they developed the art of tapping this oozing out water at

Fig. 2. View of traditional shallow dug well, *naula in local parlance*.

suitable locations and the same provided the people the clue regarding the presence of water below the surface but mastering the art of harvesting the same would not have been that easy.

The people first developed naturally occurring seepages. For this a stone lined chamber is generally created for collecting the water of the seepage and stone with a through hole is utilized for regulated and continuous discharge of this stored water. This stone is often sculptured in the shape of some animal head that allows the water to flow out of the mouth of the animal in an esthetically pleasing manner. Stone slabs are laid down at the place where the flowing out water hits the ground. Besides preventing erosion of the ground beneath, this ensures cleanliness in the surrounding area. These structures are called *dhara* in local parlance.

With the passage of time these people devised technique of exploiting groundwater by way of shallow dug wells that are called *naula* (Fig. 2) in local parlance. These are generally 5–6 feet deep and square in shape. Flight of stone lined stairs descend from all the four sides to the floor of these structures and water seeping in from around gets collected in the depression (Fig. 3). This invariably has a stone lined roof for protecting the water from getting contaminated. Inside the structure, little above the level of water there is provision for placing sacred lamp and figurine of some local deity is also often placed there. Outside this structure a stone lined outward sloping platform is created for diverse purposes and special care is taken to ensure that the used water does not enter the depression holding fresh water. The stones used for the construction of these structures are often ornately sculptured and figurines of local deities along with floral and other motifs are carved on these (Fig. 4).

Presence of moisture and seepage along with differential vegetation distribution would have helped these people in finalizing the sites of these shallow dug wells. Despite this people could not

Fig. 3. View of stone lined stepped architecture of shallow dug well, *naula in local parlance.*

Fig. 4. View of stone stone carvings on the walls of the shallow dug well, *naula in local parlance*.

afford to dig every place showing signs of moisture and some breakthrough in knowledge was required for narrowing down their search. This becomes particularly necessary, as the quest of these people for exploiting subsurface water was not restricted to shallow aquifers alone.

These people could exploit deeper aquifers and the existence of baked brick lined deep dug wells on the ridges at Almora and Nagthat (in Dehradun district) is testimony to this (Fig. 5). Construction of deep dug wells in the hills is not possible without assessing water yielding potential of the perched aquifers with high degree of accuracy. This leads to the conclusion that the people of this region had developed and mastered the art of ground water prospecting. With no available record pertaining to the technique used one can only guess if they were using something similar to Y-sticks or forked sticks used for water dowsing in many areas across the globe [2,27,49]. Exploitation of groundwater is the most important discovery of the people of this region and it freed them from the compulsion of settling down in close proximity of streams. Without this settlement in the higher reaches of the hills would not have been possible and many townships that include Almora, Pithoragarh, Gopeshwar, Joshimath and Pauri would not have come into existence.

With tap water supply becoming increasingly common and loosening of social bonds that ensured their maintenance and upkeep, these water harvesting structures are fast loosing relevance and large numbers of these have already seized to exist. There is thus an emerging need to conserve these structures and undertake detailed study of *naula* architecture and art of citing these.

Fig. 5. View of brick lined deep dugwell at Almora.

2.2. Religio-social relevance of water sources

All the rituals so very necessary in Hindu way of life, from birth to death, are intricately interwoven around sources of water that are accorded sacred status. Presence of water ensures luxurious tree growth in the proximity of these water sources and amongst these *peepal* (*Ficus religiosa*) is particularly nurtured as it serves various religio-magical purposes. Stone figurines of local deities are often placed at its base, together with sacred lamp.

Cleanliness and upkeep of the sources of water is accorded high importance. Rules are at the same time put in place for the same and defecation on the uphill side of these is prohibited. Religio-magical and social sanctions are instituted to ensure voluntary universal compliance of these rules by the community.

Water for household purposes is generally fetched by the females and the ones in the surrounding area visit these together. There are separate timings for females and males to visit the water sources that cater to information exchange and recreational requirements of the people and ensure harmony in the community.

2.3. Recharge–discharge relationship

Even though receiving appreciable rains during monsoon period the region often experiences long dry spells when discharge of streams, springs and other water sources gets depleted and many of these even dry out. This would have forced the people to pay particular attention towards ways of augmenting discharge of water sources in their vicinity.

In the most populated belt of the mountainous region of the Uttarakhand that lies in the altitudinal range of 1000–20 m, oak (*Quercus spp.*) and pine (*Pinus roxburghii*) constitute most of the forest cover [45]. High water yield of the springs around slopes with oak forest and investigation of reasons thereof would have drawn attention of these people towards high vegetation density, thick undergrowth and presence of appreciable quantity of decomposing litter. The same is often correlated with high water yield of the springs around oak forests.

People of the region believe that oak forests retain water for a longer period, resulting in a sustained water yield [44]. Though not proved experimentally, soil and water conservation is considered to be the most important services generated by the oak forest [28]. Similar deductions would have led the indigenous people to deduce that the discharge of the springs located in the middle and lower portions of the hill slope is dependent upon water joining the underground water reserves in the higher reaches of the watershed. Drawing clues from the oak forest the indigenous people thus started to take different measures for maximizing recharge of groundwater.

2.4. Forest conservation

Having understood the relationship between healthy forest cover in the upper reaches and the water availability people of the region devised ways of ensuring vegetal cover on the upper reaches of the hills. For this the forest in the upper reaches of the hills is often dedicated to local deities and the exploitation of the same is customarily regulated or restricted. In some places the exploitation of this forest is totally banned while in others the same is restricted through a set of rules. At many places extraction of resources from these forests is resorted to after a predefined time interval. Fulfillment of certain rites and rituals together with oblations is often made a precondition for doing so. Moreover in many instances use of tools and implements for collecting wood or fodder is banned. All these practices ensure extraction of only limited and required forest produce from these areas.

Relationship between lopping and forest health is now well understood. It is well established that annual, heavy and indiscriminate lopping precludes flowering and seed production for regeneration. Loss of photosynthetic surface as a consequence of repeated lopping is held responsible for early senescence and impaired ability to coppice [45]. A comparative study has shown that trees lopped every year and at an interval of two years do not produce seeds, while trees lopped at the interval of three years or more do produce seeds [43].

Fig. 6. View of traditional recharge pits, *chal* and *khal*.

2.5. Artificial recharge

For augmenting groundwater recharge the people of this region take recourse to construction of recharge pits in the mid slopes of the hills. These are called *chal* or *khal* in local parlance and are generally ditches dug out in the middle slopes of the hill at places with relatively low gradient where rainwater from the upper slopes naturally runs down (Fig. 6). Settlement of clay layer at the bottom ensures these pits to retain water for appreciable duration after the rains. Besides augmenting recharge of groundwater these cater to the needs of the household grazing animals.

The people realize that in the absence of regular upkeep and maintenance the discharge of the water bodies might get depleted. Various social sanctions as also religio-magical rites are therefore instituted around water bodies, their recharge zone and structures created there for recharge augmentation.

3. Landslide mitigation

Besides maximizing water availability traditional water management practices of the region ensure safe disposal of surface run off during periods of prolonged and concentrated rainfall. There exist enough evidences to deduce that these people had fairly good understanding of the relationship between excessive rains, ensuing saturation of soil mass and occurrence of landslides. Thus with their experience and accumulated knowledge these people could deduce that the occurrence of landslides can be minimized by avoiding presence of excess water on the hill slopes or by quickly draining off the same.

Landslides often take place repeatedly at a certain place and in many cases with keen observation of the slope conditions it is possible to comment on the susceptibility of slope failure. Evidences suggest that these people could identify vulnerable slopes.

3.1. Jungle gool

In order to restrict the build up of pore water pressure, particularly in the identified vulnerable locations these people resorted to disposal of rainwater into the main drainage channel located in close proximity through a network of stone lines canals that are called *jungle gool* in local parlance. These were constructed and maintained for this very purpose in the upper reaches of the

identified vulnerable locations. These helped in maintaining pore water pressure in the identified vulnerable slopes within the threshold limits and thus minimized possibility of slope failure.

Remnants of these structures are observed around Ransi and other places in Madhyamaheshwar and Kali Ganga valleys (tributaries of Mandakini river) in Rudraprayag district. When functional, construction, repair and upkeep of these structures is reported to be the responsibility of the community with special care to ensure their efficient functioning before the onset of monsoon period.

3.2. Terrace farming

Though done primarily for augmenting area under agriculture and perhaps with scant regard to landslide mitigation, terracing has improved the stability of the hill slopes. Terracing is widely recognized as one of the oldest means of soil and water conservation and is still used throughout the world ([4,5,9,12,19,23–26,30–32,41,46,47] AAFC, 1999). Terraces are created to intercept surface runoff, encourage it to infiltrate, evaporate or be diverted towards a predetermined and protected safe outlet at a controlled velocity to avoid soil erosion ([10,50] USDA Soil Conservation Service, 1992) and it is no surprise that terracing is still promoted as the best management practice for effective soil and water conservation in some cases [51]. Even today terracing is the most widely used technique for stabilising landslide prone slopes and one can only argue if the same is not motivated by this tradition of the hilly regions.

With high rates of migration from the region and two of the 13 districts of the state, Almora and Pauri Garhwal, showing negative decadal population growth (Census of India, 2011) large tracts of hitherto cultivated lands are presently lying barren. Little attention is thus presently being paid towards routine maintenance of the agricultural terraces. Ensuing wear and tear together with lack of routine upkeep are observed to be responsible for initiation of landslides at many places where breach of the terraces in the upper reaches results in debris flow that takes devastating proportion as the flowing mass travels downslope and gathers mass and momentum. Slope instability related devastation around Devpuri in 2007 and Okhimath in 2012 is attributed to this [7,8].

3.3. Unbunded far flung fields

Washing off of top soil of the agricultural terraces is a common feature in the hills during rainy reason and this depletes productivity of the fields exposed to prolonged erosion. Such fields are easily recognised by preponderance of cobbles and pebbles that are left behind. For conserving the top soil people of the area traditionally resort to construction of earthen bunds along the outer edges of the terraces and plant these with vegetation.

Despite this the people do understand that prolonged stagnation of water in the terraces due to the bunds could destabilize these. Provision of draining out water from the terraces during spells of prolonged and heavy rains is therefore resorted to and in the fields where it is not practical to resort to these measures bunds are not provided traditionally.

It is for this reason that the people often leave the far flung and hard to manage agricultural fields without bunds [21]. This is part of a planned strategy of the people of this region to rule out possibility of stagnation of water and to avoid chances of landslides.

3.4. Habitation on higher ground

Site selection is the most important aspect of the safety of any habitation. It is the first step towards disaster preparedness in mountain regions and the people have to locate their houses at safe places, away from debris flows, flash floods, and snow avalanches [6]. The people of the region traditionally settle down over firm ground in the upper and middle slopes, appreciably away from streams and rivers, even though both the sources of water and agricultural lands are mostly located on middle and lower slopes of the valley. The people thus willingly accepted the challenge of traversing long distances on daily basis for various agricultural pursuits, as also for fetching water. This clearly shows that they accorded priority to safety over comfort and convenience. This however would not have been possible without mastering the art of groundwater exploitation, that was a major breakthrough in growth of habitations in this rugged terrain.

The people of the region settled down at higher locations that were safe from both landslides and flash floods. These locations at the same time provided strategic advantage. During times when internal strife would have been high one could keep track of the movement of the adversaries from these higher locations and ensure safety of the community.

3.5. Avoiding terraces and old slide zones for settlement

Besides the terraces developed by the people over stabilised old landslides mostly on the middle and upper slopes of the hills most agricultural operations in the region are undertaken on the alluvial terraces along major perennial rivers that include Yamuna, Bhagirathi, Mandakini, Alaknanda, Pinder, Ramganga, Gomti, Saryu and Kali. The alluvial terraces are highly productive and account for most agricultural production of the region. Despite this the people do not traditionally have habitations over terraces and invariably settled down at a respectable distance from the streams over hard rock on the uphill side.

There is a popular saying that ‘water never forgets its path’and the people believe that rivers and streams can always reclaim the terraces. The traditional settlement pattern ensured that loss of human lives is avoided even when there is erosion of the alluvial terraces during high floods. Similarly, based on the presence of exotic boulders on the surface as also buried in the ground people traditionally recognize old landslide zones and avoid these for settlement.

Pattern of devastation in the region due to floods in the previous years (2010, 2012 and 2013) suggests that ignorance of traditional settlement practice is largely responsible for most of the losses. It is observed that lately people have started to settle down over the terraces in close proximity of the rivers. Alignment of roads along the course of the rivers has promoted this trend and people are also lured by savings in construction cost due to reduced cost of site development and transportation.

3.6. Seasonal migration

People in many areas of the region have two habitations and they practice migration to higher ground during the monsoon period together with their animals. This ensures safety of the people during the monsoon period from both flash floods and landslides.

4. Earthquake safety

Communities residing in areas often affected by earthquakes were quick to understand the fundamental premise of earthquake safety that indicates possibility of avoiding loss of human lives in a seismogenic event by ensuring safety of the structures. This led to the evolution of innovative practices for minimizing human losses emanating from structural collapse.

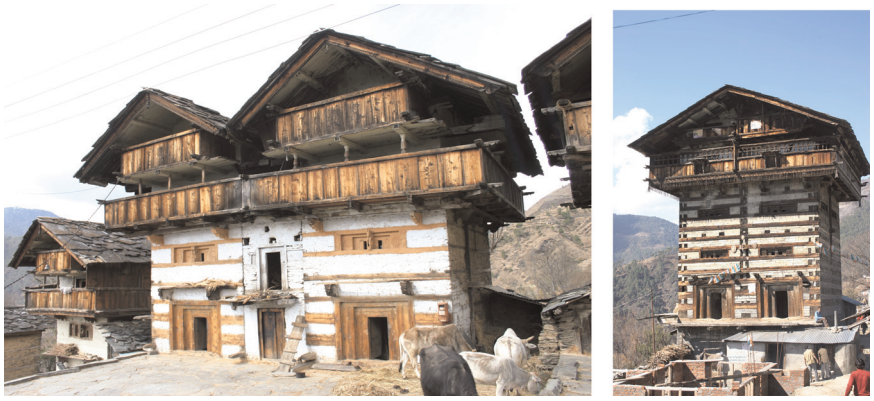

Fig. 7. View of traditional multistoreyed houses from Yamuna valley in Uttarkashi district.

The decision to settle down over stable and firm ground at a higher location minimized ground acceleration and thus losses during an earthquake besides saving the people from the wrath of landslide and flood but this was no guarantee of complete safety, particularly during high intensity ground shaking.

Despite often experiencing earthquakes (*chalak* in local parlance) multistoried houses are common in Uttarakhand (Fig. 7) and apart from the cattle sheds (*chani* in local parlance) one can hardly locate a single storied traditional house in the region. Moreover both the dialects of the region, Kumauni and Garhwali, have distinct words for four different floors of the house. These are *ghot*, *chak*, *pan* and *chaj* in Kumauni and *koti*, *manjua*, *baund* and *baurar* in Garhwali. Unless often required a unique term is not introduced in any language and presence of these words in local dialects indicates common occurrence of multistoried houses in the region. In Yamuna and Bhagirathi valleys four to five storied traditional structures can still be observed (identified as *chaukhat*; four storied or *panchapura*; five storied). In the absence of the elements of earthquake safety these would have long been razed to ground.

The zeal to protect the community, by utilizing accumulated knowledge and experimenting with locally available building material, the people of the region evolved a unique architectural style that exhibits structural evolution trends whereby dry stone masonry, as also stone – lime/mud/clay mortar masonry was judiciously used with abundantly available wood to provide appropriate strength and flexibility to the structures.

4.1. Site selection

Site selection is the most important aspect of the structural safety of any building. Even today before initiating structural works suitability of the place for siting the proposed building is assured through geo-technical investigations that include assessment of bearing capacity of the ground.

The inhabitants of this region also do the same and based upon their experience and accumulated knowledge of generations some persons amongst them have mastered the art of commenting on the suitability of the site selected for construction based on physical inspection of the soil of the proposed construction site. Interaction with these people indicates that soil texture, composition, smell and presence of humus and moisture in the soil being examined is taken note of before pronouncing the final verdict. It seems that these people have developed an objective algorthim and their final comments are accordingly decided upon by correlation of various observed variables. These people are highly respected by the community and their advise is taken seriously. This practice is still observed to be common, particularly in the remote areas.

With changed ground realities people do not have many options to choose from for constructing their house. Moreover considerations related to convenience, ease of access, commercial opportunities and the like are increasingly being given preference while finalising the site. The traditional practice resorted to for site selection is therefore slowly losing ground.

4.2. Foundation

After site selection foundation is the most important component for structural safety of any construction. Foundation bears entire load of the structure and weak or inappropriate foundation can jeopardize safety of the structure in a seismic event.

Rules were put in place by the people of the region for the foundation of the structures. Foundation trench was generally dug until firm ground or in situ rocks were reached. There was also tradition of leaving the foundation trench open for some rainy seasons. This ensured ground settlement and kept the structures free of settlement cracks that are becoming increasingly common in present day constructions.

Special care was taken by the people of the region in the construction of specifically tall buildings that were constructed on raised and elaborate stone filled solid platforms that were continuation of filled in foundation trench above the ground (Fig. 7). At places where in situ rocks were exposed the platform was raised directly over it. The height of such platforms constructed using dry stone masonry is observed to vary between 6 and 12 feet above the ground.

Massive solid platform at the base of the structure ensured that center of gravity and center of mass are in close proximity and close to the ground. This minimized overturning effect of the particularly tall structure during seismic loading [36].

4.3. Simple design

Simplicity of structure is often indicated as being an essential attribute of safe construction [20]. The structures in this region were traditionally constructed on a simple rectangular or square plan with length and width varying between 4 and 8 m. The ratio of the two sides of the structures is observed to vary between 1.1 and 1.4. The height of the structures above the platform is also observed to be restricted to double the length of the shorter side (length or width). This is in keeping with the provisions of the building codes that suggest that the building should have a simple rectangular plan and should be symmetrical both with respect to mass and rigidity so as to minimize torsion and stress concentration [20].

4.4. Small openings

Openings in the walls reduce structural strength and therefore reinforcement is often resorted to around these [20]. Most traditional houses of the region are observed to have single small entry and relatively small openings. Doors and windows in these houses are few and small and symmetrically placed away from the corners. Strong wooden empanelment is also provided around all the openings to compensate for the loss of strength. Small and few openings and thick walls provide refuge from the cold conditions outside while conserving inner heat [42]. The floor of the traditional houses is made of wood plastered with mud that enables insulation. Hence, besides ensuring seismic safety traditional houses of the region are also energy efficient.

4.5. Elaborate walls

Experimenting with the precepts of seismic safety the people of this region mastered the art of meticulously using locally available wood and stone pieces of different shapes and sizes for the construction of the walls of the houses in a manner that improved their seismic performance.

Provision of wooden beams is observed in most of the traditional structures together with through stones and corner stones. Both housing and nailing techniques were resorted to in these for joining the wooden components (Fig. 8). This allows for minimal angular displacement and has advantages of both pin and rigid joints. This acts as a semi rigid joint that is an additional advantage for shock resistance [36,37,40].

The art of raising walls of traditional multistoried structures was particularly elaborated. These were raised by placing double wooden logs horizontally on the edge of two parallel sides of the platform. The thickness of the walls was determined by the width of the logs. The other two walls were raised with well-dressed flat stones to the level of the logs placed on the other two sides. The walls were further raised by placing heavy, flat, dressed stones upon the wooden logs on the two sides and by placing another pair of wooden logs upon the stones on the other two opposite sides [36,37,40].

The four walls of the structure were thus raised using the wooden logs and dressed up flat stones alternately. The structure was further reinforced with the help of wooden beams fixed alternately running from the middle of the walls of one side to the other, intersecting at the center. This arrangement divided the structure into four parts and provided for joists supporting the floorboards in each floor of the building. This resulted in a mixed structure with two types of load sharing mechanisms where vertical load was taken care of by thick walls running in all the four directions, while horizontal load was taken care of by interconnected wooden joists running in both directions.

Fig. 8. Photograph showing housed and nailed joints used for fixing the wooden components of traditional houses.

On the two sides of the structure, particularly the tall ones wooden beams are observed to be provided from outside. These beams inserted from above are identified as shear keys that were part of a special provision devised by the people of the region to enhance structure's seismic performance [36,37,40].

Salient features of the technology used in the construction of traditional houses of the region thus includes, (i) assessment of site suitability, (ii) firm foundation, (iii) simplicity, (iv) small openings, (v) use of wooden beams, (vi) logs on adjacent walls joined together by hammering thick wooden nails at the corners which turns the structure into a single piece construction and (vii) all the windows, doors, ventilators and floor joined to these well-secured pairs of logs.

4.6. Transmission of knowledge across generations

In contrast to other natural hazards earthquakes have long return period and therefore it does not provide opportunity of frequently observing and studying seismogenic damages. Long periods of quiescence between successive earthquakes also makes it difficult to validate the effectiveness of the changes made in the structural design of buildings for improving their seismic performance. This mandates detailed documentation of both, changes made in the structural design or the structural design utilized for construction of buildings and performance of these buildings during subsequent earthquake or losses incurred to these buildings.

Due to transmission losses, doing so through oral tradition alone is not feasible. Lack of written documentation related to earthquake induced losses or design characteristics of the traditional buildings makes it difficult to comment on the methodology used by the people of this region for evolving the design of earthquake safe structures. They certainly would have resorted to some form of documentation that is required to be researched and unearthed.

5. Drought management

Agriculture is the major economic activity in the hills. In the lower reaches of the valley irrigation is resorted to by a network of unlined canals called *gool* in local parlance that are fed by the water of the small streams draining the watershed. Water of the main streams is generally not used for irrigation purposes as these traverse through geomorphic low of the watershed and have gentle gradient.

Most agriculture in the region is however dependent upon atmospheric precipitation and variation in the timing and intensity of rainfall often results in crop failure or depleted production. In response to this problem that has major adverse impact on the well being of the community the people of the region resorted to a practice that assured minimal returns even during times of water stress or pest infestation. The people thus deliberately fragmented familial landholdings in a manner that ensured that all the households have some irrigated fields together with some rainfed. This ensured that all the families have at least minimal returns in case of crop failure in a particular area.

The people using their knowledge of plant breeding at the same time developed crop varieties that could sustain prolonged spells of water deficit. These varieties are well adapted to harsh conditions of the hills and ensure good returns. These are at the same time highly nutritious.

Lately use of traditional grains has come to be associated with lower social status and consumption of these has reduced

significantly. With little appreciation in the prices of the traditional agricultural produce, reduced consumption and low demand in the market, farmers have no incentive for growing these. Ready availability of cheap foodgrains through public distribution system of the state is another reason for low demand of traditional produce. This has resulted in reduced agricultural diversity of hill farming and seeding material of a number of indigenous varieties has already become unavailable.

Diversification of crops plays a significant role in maintaining long-term stability by minimizing crop loss due to insect pests, drought or other adverse conditions. It also inhibits or suppresses weed growth, produces a varied diet, diverse types of fodder and straw for livestock and preserves soil from erosion on steep slopes. It is therefore highly required that gene pool of different traditional varieties be conserved.

6. Road accidents

Road accident is increasingly becoming a major cause of concern for the people of the area and human lives lost due to these surpass that by natural disasters, mostly landslides and flash floods that are common in the region (Table 2). The area houses a number of high altitude shrines of Hindus and Sikhs that include Gangotri, Yamunotri, Badrinath, Kedarnath and Hemkund Sahib. People in large numbers thus visit the state every year, particularly during the pilgrimage season that coincides with the monsoon period. Most of these people are not acquinted with driving in the hills. Fatigue associated with driving in the hills together with steep gradient and high sinuosity is held responsible for increased incidences of road accidents in the region [38].

In order to tackle the menace of road accidents the people of the region have lately resorted to construction of temples of local deities at identified road accident prone places. The motorists often stop at these places to pay their regards and those not sopping invariably slow down the speed and bow their heads. The response of the indigenous people thus reduces the chances of accidents at these places.

7. Discussion

Human response to their surroundings and emerging exigencies have together helped in fine tuning resource management practices as also life support strategy of the masses so as to ensure optimal utilization of available resources and safety from natural hazards. Based upon experience, experimentation, accumulated knowledge and ingenuity human populations evolved innovative practices that ensure their survival despite all odds. Natural hazards are no new phenomenon for humans and they have been successfully devising ways of overcoming the challenges put forth by nature.

Table 2
Comparison of loss of human lives in Uttarakhand due to road accidents with that by debris flow, landslide and flood in the period 2005–2014. (Source: State Emergency Operations Centre, Government of Uttarakhand).

Year	Deaths due to road accidents	Deaths due to natural calamities
2005	90	74
2006	202	19
2007	400	57
2008	543	77
2009	278	66
2010	354	220
2011	251	68
2012	361	176
2013	290	4218
2014	203	66
Total	2972	5041
Average (2005–14)	248	420
Average (2005–12 and 2014)	244	75

In depth analysis of the traditional practices of the inhabitants of Uttarakhand Himalaya in India suggests that in response to the challenges put forth by nature these people devised ground rules for effective resource management as also for disaster mitigation. Besides maximizing water availability in the rugged Himalayan terrain these people understood the reasons of various common hazards that include flood, landslide, earthquake and drought and devised ways of ensuring minimal losses due to these. Compliance of these rules was ensured by invoking social sanctions and religio-magical rites.

Fragmentation of the community, modernization and reducing dependence upon the community bonds together with fast pace of migration from the region and increasing dependence upon the state are observed to be responsible for breakdown of the traditional practices that depended upon community solidarity and social sanctions for their continuity.

Disruption of traditional water harvesting and management practices and overdependence upon tapped water are together having adverse impact upon the groundwater regime and the region is faced with severe water scarcity, particularly during summers and for ensuring water availability the state is often forced to provide water by tankers and mules at many places across the state.

Traditional landslide management practices have already become defunct and people of the region have stopped growing traditional grains and using traditional crop management practices. Lack of maintenance of traditional agricultural terraces, due to migration and reduced economic viability of hill agriculture, is making the region more vulnerable to mass wastage and landslides. Lure of economic opportunities is observed to force people to settle down near roads that are mostly aligned along the rivers and streams. Besides floods this exposes people to the threat of landslides that are often triggered by road construction and toe erosion by the streams and rivers. The decision to settle down close to the road is observed to be related to ease of access and convenience. This at the same time reportedly saves the cost of site development and material transportation. This however is a major compromise on safety and is not in keeping with the tradition.

Traditional rules pertaining to settlement pattern are thus being increasingly flouted and people have started to settle down over alluvial terraces as also in close proximity of streams and rivers. Alignment of roads in the vicinity of streams is observed to be responsible for the same. Inflow of tourists and pilgrims in large numbers has already resulted in the growth of a number of human agglomerations by the river side. The vulnerability of the region to both floods and landslides is thus on the rise.

Situation with regard to seismic safety is observed to be the worst and the studies undertaken in the region suggest that seismic vulnerability of the region is on the rise [40] and in case of a major earthquake in the region the losses could well be more than stipulated by these studies. Despite having rich tradition of earthquake safe construction proliferation of cement based construction, observed even in remote areas, is largely held responsible for the same.

Most people covered under the present study however accept that traditional houses are more cozy, comfortable and better suited to the climatic conditions of the region. High social status attached to the new type of construction is deduced to drive people to tear down their traditional houses, roofs in particular and replace the same with concrete slabs. Non-availability of

traditional building material, stone and wood, due to growing environmental consciousness is also held responsible by some for this trend.

With masses losing interest in the traditional construction elements of local architecture are fast getting lost and lack of patronage is forcing the traditional masons to switch over to new construction practices. The masons are however just changing the building material without any exposure to the technical intricacies of the new material; brick, cement, concrete and RCC. Moreover there exists no formal mechanism for training the masons and all of them learn it by doing. This is adding to the seismic vulnerability of the region whereby masons competent to build safe houses using stone and wood are constructing with material that they are not technically competent to handle.

Increasing disaster induced losses in the previous some years, particularly those in 2010, 2012 and 2013, clearly suggest that ignorance of traditional mitigation practices and proliferation of infrastructure at places traditionally considered unfit for human habitation are together responsible for this unusual trend. Loosening community bonds, growing pace of migration and increasing dependence upon the state for various services are observed to be responsible for the decay of the traditional system.

Traditional practices of the people of the region have ensured sustained and adequate resource availability for generations besides saving the masses from the wrath of natural hazards that are common in the area. In case sustainable management of disasters in the region is intended one has to therefore take stock of the traditional practices of the region and amalgamate these with modern knowledge so as to put forth locally relevant, practical, time tested, economically viable and sustainable solutions. Appeal to little tradition and religio-cultural beliefs of the people would help in popularization and voluntary compliance of the measures so put forth.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at: http://dx.doi.org/10.1016/j.ijdrr.2015.07.004. These data include Google maps of the most important areas described in this article.

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