International Journal of Current Research in Science and Technology
Volume 1, Issue 3 (2015), 61-80.
ISSN: 2394-5745
Available Online: http://ijcrst.in/

International Journal of Current Research in Science and Technology

Causes and Disaster Risk Reduction Measures for Hydrometerological Disaster in Uttarakhand, India: An Overview

Review Article

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Abstract: The frequency and intensity of Hydro-meteorological disaster (HMD) in Uttarakhand are increasing from last 15 years. These catastrophic events have brought heavy toll to the human population, resources and the state infrastructure in terms of economy and societal. Casualties and damage due to hazards in Uttarakhand regions have increased due to climatic factor, geological factor and increasing human population. The unscientific and need based developmental activities causing the imbalance in the natural ecosystem and environment becoming more susceptible to natural disasters. Through this paper, we carried out a comprehensive analysis and study the causes, the time factor and Disaster Risk Reduction measures for HMD and summarized that these disasters by their nature difficult to predict and control but we can only minimize the impact of HMD by strongly implementation of Pre-disaster mitigation measures such as proper planning, public awareness, training, knowledge of mitigation measures, structural and non structural measures, monitoring the hazard prone areas and honestly follow the environmental and disaster mitigation rules by all of us including government as well as private developers with an early warning system measures.

Keywords: Hydro-meteorological disasters (HMD), climate change, geological factor, manmade disaster, mitigation measures.

1. Introduction

The mountain areas are more vulnerable to natural disaster due to its varying nature of relief where the developmental activities over the years has further accentuated the problem by upsetting the natural equilibrium of various physical processes operating in the mountain eco system. A disaster is defined as the outcome of a hazard negatively impacting a social ecological system [1], [2]. The magnitude of the disaster is directly related with the intensity of the hazard as well as with the exposure and the vulnerability of the socialecological system [3]. However the disasters could be assessed in many ways: number of deaths, number of building collapsed, kilometers of roads destroyed, money loss due to the disruption of economic activities. Disasters often nullify the efforts and hard work of several years in a matter of hours and even minutes and seconds. In the present scenario the state of Uttarakhand is more vulnerable to disasters and has been devastated

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repeatedly by a number of hazards that include both geological and HMD.

The climatologist and environmentalist are in the opinion that the frequency and amplitude of natural disasters have increased in last 30-40 years due to variations in the climatic parameters. The anticipated increase in precipitation, the melting of glaciers and expanding seas have the power to influence the Indian climate, with an incidence of floods, drought, flash floods, storms, cloud burst. The impacts on river flow, groundwater recharge, natural hazards, and the ecosystem, as well as on people and their livelihoods, could be dramatic, although not the same in terms of rate, intensity, or direction in all parts of the region [4].

The substantial portion of the annual precipitation falls as snow, particularly at high altitudes (above 3000m) feeding the Himalayan glaciers. The high Himalayan and inner Asian ranges have the most highly glaciated areas outside the Polar Regions [5], [6]. Globally, the climate change is very likely to increase the pressure exerted by non-seismic hazards. The high temperatures will enhance the hydrological cycle and it is predicted that they will alter rainfall patterns and intensity [7].

Effects will not be limited to changes in precipitation. Global warming reduces snow cover, melts away glaciers, and degrades permafrost [8]. There are evidences to indicate that Himalayas are warming at the higher rate than the global average rate [9], [10] and its impact are studied by many scientist [11]-[30] etc. An increase in the frequency of high intensity rainfall often leading to flash floods and land slides has been reported [31]-[33].

The state of Uttarakhand has experienced a large number of incidences of Hydro-meterological disaster (HMD) since 1816, but the middle of nineteenth century up to the present has proved the worst decades as both the magnitude and frequency of HMD have gone up. The disasters in 1970, 1986, 1991, 1998, 2001, 2002, 2004, 2005, 2008, 2009, 2010, 2012 and 2013 are the major natural calamities in Uttarakhand. These disasters events have brought heavy toll to the state as the losses was estimated in several thousand millions of rupees and also killed several hundreds of people besides large number of cattle heads. The purpose of this paper is to analyze the causes and the intensity of factors affecting the HMD and disaster risk reduction measures for state of Uttarakhand by review of previous studies of different scientists and forums.

1.1. Study Area

The north-westenn state of Uttarakhand lies between 28.44 to 31.28 N latitude to 77.35 to 81.01 E longitude. It was evolved after the separation of the hilly tract of Uttar Pradesh. The total area of this hilly state is 53,483square Km constituting 1.63% of landmass of the India [26].

The state is consists of 13 districts and 95 development blocks. This state has two divisions; western part is Garhwal and Eastern part is known as Kumaun. The state capital is Dehradun, located in Garhwal division. The Uttarakhand shares its boundary with Tibet of China in North, Nepal in East, Himachal Pradesh in North-West, Haryana in South-West and Uttar Pradesh in East.

Figure 1. **Location Map of Uttarakhand [34].**

1.2. Physiographic Features

Uttarakhand is a part of the Western Himalaya physiographic division. Geographers divide the state into five transverse zones . (a) The Terai: South of the Himalayan Frontal Fault. (b) The Doons: Between the Main Boundary Fault (MBF) and the Shivalik (Outer Himalayan) range. (c) The Middle Himalaya: Between the MBF and the Main Central Thrust (MCT) with ridges as high as about 3000 m. (d) The Inner (or Great) Himalaya: The zone north of the MCT including the permanently snowclad peaks at heights ranging up to just under 8000 m. (e) The Trans Himalaya to the north of the snow clad ridges. The states climate varies tremendously from the sub-tropical humid climate of the Terai region to the tundra-like climate of the Great Himalaya ridges. The variation is even more dramatic along the slopes of the mountain ranges. These variations give rise to tremendous biodiversity, particularly in the forest areas. More than 90 per cent of the people in the mountain districts live in rural areas. The Middle Himalaya region between the MCT and the MBF is the most densely populated Himalayan zone. The Great Himalaya region remains largely remote, sparsely populated and unspoiled. Over a million pilgrims and tourists annually visit the five prominent shrines Yamunotri, Gangotri, Kedarnath, Badrinath and Hemkund Sahib in this region. Other tourists visit the state for adventure, its wilderness and scenic vistas[35].

1.3. Drainage Systems

This region is the birth place of several perennial rivers of the Northern Great Plane of India. The entire State is dominated by three river systems;

The Ganga System: Maximum part of the Garhwal region is being drained out by the Ganga river system expects the northwestern part of the Uttarkashi district. The Ganga, river system constituted by two mighty rivers commonly known as Bhagirathi and Alakananda. The Bhagirathi and Alakananda both are originated from opposite direction of Chukhamba peak (7138 m). The source of Bhagirati is Gamukh (3892 m) at the bottom foot of Gangotri glacier and the source of Alakananda is the bottom foot of the Satopanth and Bhgirathi Kharak glacier[26]. After meeting with each other at Dev Prayag the name of the common channel is known as the Ganga. Though Bhagirathi is considered as Main River in religious faith of Hinduism but Hydrologically Alakananda is main stream due to its amount of discharge and length.

Yamuna-Tons River System: Yamuna, the major tributary of Ganges, is evolved from the Yamunotri glacier, lying on the southwestern peak of Bandar Punch Peak (6387m). Tons is the main tributary of the Yamuna which is originated from the northern slope of Bandar Punch Peak and flowing northwest of Yamuna and meets with it at Kalsi near Dheradun.

Kali River system: Kali is the main river system of the Kumaun Division of the Utatrakhand state, the entire Pithoragarh district and eastern part of the Nainital, Almora districts. Kali has two headwaters, Kalapani (3600 m) is the eastern headwater and Kuti-yankti is the western headwater originated from snow-fields of Himadri range. The tributaries of Kali are Pancheswar, Lohawati and Ladhiya.

1.4. Geology

The Western Himalaya can be divided into five morphological zones of varying width, each having distinct physiographic features and geological history. The zones from South to North are the Outer (sub Himalaya), the Lower (Lesser Himalaya) the Greater (Higher) Himalaya, the Tethys (Tibetan) Himalaya and the Trans Himalaya. The Outer Himalaya, predominantly comprising continental molasses of the Middle Miocene to upper Pleistocene age, is delimited by Himalayan Frontal Fault (HFF) in the south and the Main Boundary Thrust (MBT) in the north. The Lesser Himalayan zone is considered to be a tectonic zone sandwiched between MBT and MCT.

It comprises Precambrian sedimentary rocks overlain and covered by crystalline thrust sheets in the form of large klippen masses. The Higher Himalayan zone consists of 15-20 km thick slab of crystalline rocks, which has been thrust southwards along the MCT, overriding the Lesser Himalayan formations. The northern boundary of the Greater Himalaya is marked by Trans Himalayan Fault. The Tethys Himalaya lies further north of the Greater Himalaya. The northern margin of Tethys Himalaya is sharply defined by a thrust called the Indus-Tsangpo Suture against which lie the rocks associated with the Indus suture or the Trans-Himalaya zone [36]. The Garhwal-Kumaun Himalaya is seismotectonically an active region of the Himalayan arc. The main central thrust (MCT) as the base of Crystalline zone [37] is a zone of intense shearing.

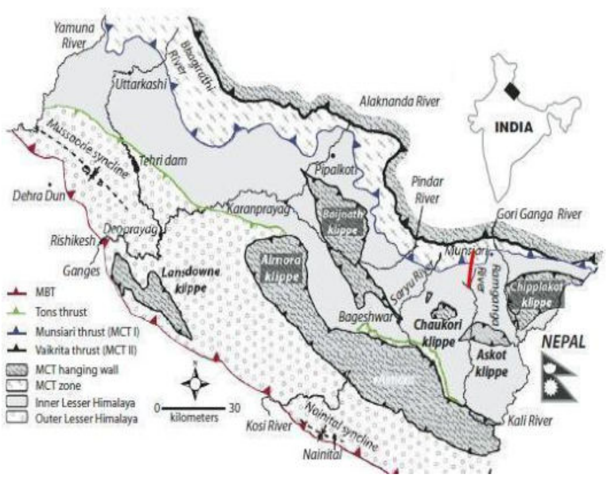


Figure 2. **Geological Map of Uttarakhand [38].**

1.5. Climate

The climatic condition is marked by different in high altitudinal areas and the lower basins in Uttarakhand. Temperature varies not in different seasons but also with the altitude. Uttarakhand lies on the southern slope of the Himalaya range, and the climate and vegetation vary greatly with elevation, from glaciers at the highest elevations to subtropical forests at the lower elevations. The highest elevations are covered by ice and bare rock. Below them, between 3,000 and 5,000 metres (9,800 and 16,400 ft) are the western Himalayan alpine shrub and meadows. The temperate western Himalayan subalpine conifer forests grow just below the tree line. At 3,000 to 2,600 metres (9,800 to 8,500 ft) elevation they transition to the temperate western Himalayan broadleaf forests, which lie in a belt from 2,600 to 1,500 metres (8,500 to 4,900 ft) elevation. Below 1,500 metres (4,900 ft) elevation lie the Himalayan subtropical pine forests.

The Upper Gangetic Plains moist deciduous forests and the drier Terai-Duar savanna and grasslands cover the lowlands along the Uttar Pradesh border in a belt locally known as Bhabhar. These lowland forests have mostly been cleared for agriculture, but a few pockets remain[39] . The State is bestowed with a relatively high average annual rainfall of 1229mm. Normally rain starts in the State in late April and continues up to September. However, the intensity of rainfall increases during the months of June to September. Higher rainfall occurring during first week of July. Rain continues through August until the first week of September. Nowadays, cloud bust during the Monsoon and pre-Monsoon is a regular matter in high altitude area of the Himalayas as well as in Northern part of Uttarakhand.

2. Discussions

The hydro-meteorological disasters deal with the study of natural hazards of hydro-meteorological origin. These hazards are the results of natural processes or phenomena of atmospheric, hydrological or oceanographic nature such as floods, flash-floods, tropical cyclones, drought and arid conditions. Many countries have established an operational hydro-meteorological capability to assist with forecasting, warning and informing the public of these developing hazards [40]. Following events causes due to HMD and Geological disasters:

Hydro-meteorological Disasters

1. Flash floods / Floods
2. Hailstorms
3. Cloud Burst
4. Heat Wave and Cold Wave
5. Snow Avalanches
6. Droughts
7. Thunder and Lightning

Geologically Related Disasters

1. Landslides and Mudflows

2. Earthquakes

3. Dam Failures/ Dam Bursts

Rainfall is the most common cause of landslide. The more customary assumption is that the landslide body becomes saturated from below when rainfall infiltration starts[41] but slope saturated is not always that simple phenomenon. Debris slides can burst explosively out of a slope if groundwater flowing in pedological horizons is discharged quickly to the surface[42]. If high water pressure is locally generated near a spring, little displacement can be induced in the soil and small area can liquefy and flow down slope. If landslide triggered by high intensity short duration rainfall are considered, the intensity grows exponentially as duration decreases and landslide are mainly shallow soil slips and debris flows at higher intensity, whereas lower intensity result in larger and deeper debris avalanches and slumps. So it shows that landslide and mudflows are the Geological disaster which causes by HMD.

2.1. Causes and factors that affecting intensity of HMD

The disaster risk and climate change are two threats to human well-being that adversely reinforce each other. Disaster risk is an intrinsic characteristic of human society, arising from the combination of natural and human factors and subject to exacerbation or reduction by human agency [43]. While the adverse impacts of climate change on society may increase disaster risk, disasters themselves erode environmental and social resilience, and thus increase vulnerability to climate change. Although the relationship between climate change and extreme events remains uncertain, it is difficult to distinguish variability and changes in climate-related hazards from the impacts of long-term climate change. Following three factors that affecting the intensity of HMD (Ref. Table no 1)

(a) **Climatic Factors:** The Sun is the source of the energy that causes the motion of the atmosphere and thereby controls weather and climate. Any change in the energy from the Sun received at the Earths surface will therefore affect climate. From historical and geological records we know that the Earths climate has always been changing. Eddy [44] (1976) provided the first thorough study of long-term (century scale) variations in solar activity and climate. This study indicated a very strong link which he hypothesized could be accounted for by small changes in the solar total irradiance [44]. Accordingly [45]- [53] had studied the effect of solar variation on Atmospheric ionization & clouds, Asian rainfall pattern.

Mukherjee S [29], (2014) had studied the relationship between cloudburst in Kedarnath area in June 2013 and solar variation, he found that prior to cloudburst in Kedarnath area of Uttarakhand Himalaya in June 2013, the abnormal rise of the atmospheric temperature in this area was initiated by the release of heat energy from the trapped proton drift in the magnetic field line from Sun. The proton flux has the potential to be trapped for a long time in the geomagnetic field enhanced the ionization process and heating of the upper part of the atmosphere in the proximity of the Uttarakhand area. After this event anomalous rise in cosmic ray was recorded. Changes in ionization affect the abundance of aerosols that serve as the nuclei of condensation for cloud formation. Rise in cosmic rays were instrumental in condensation of the cloud leads to the cloudburst in Kedarnath.

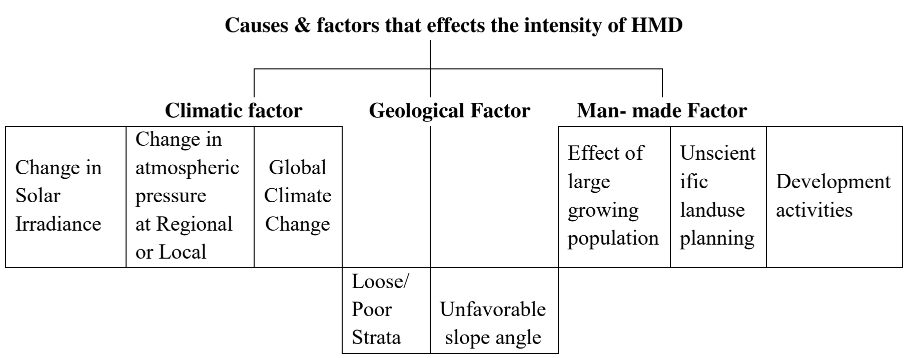
The pattern of global warming will be more pronounced at high altitude zones, especially those in the tropics and sub tropics upto 3 to 5 times faster warming than the rest of world [54]. There are evidences to indicate that Himalayas are warming at the higher rate than the global average rate [9], [10]. The global warming might severely affect the river connection between the Himalayas and Gangetic Plains, and climate regime of the entire region. At high elevations in the Himalaya, an increase in temperature could result in faster recession of glaciers and an increase in the number and extent of glacial lakes - many of which have formed in the past several decades. The rapid growth of such lakes could exacerbate the danger from glacial lake outburst floods (GLOFs), with potentially disastrous effects [55].

Retreat in glaciers can destabilize surrounding slopes and may give rise to catastrophic landslides [56], [57] , which can dam streams and sometimes lead to outbreak floods. Excessive melt waters, often in combination with liquid precipitation, may trigger flash floods or debris flows. In the Karakoram, there is growing evidence that catastrophic rockslides have a substantial influence on glaciers and may have triggered glacial surges [19] . An increase in the frequency of high intensity rainfall often leading to flash floods and land slides has been reported[31], [32].

(b) **Geological Factors:** Himalayas are young mountain chain with tectonically active. Continues internal stress applied on Himalayan belt thats why rocks of Himalayas are unstable & fractured. The whole of the Himalayan region is very sensitive and active, due to its complex geological factors, the state of Uttarakhand is comparatively more prone to disasters. The various tectonic features like thrusts, faults, shear zones, etc. are very common in the Uttarakhand part of the Himalayas. The major tectonic features of Himalayas, i.e., Himalayan Frontal Fault, Main Boundary Thrust, Main Central Thrust, and Trans Himalayan Thrust are the main characteristic of the region making the region tectonically more active and unstable [25].

Rock/soil condition, topography and slope angle of the areas are affecting the intensity of HMD. Area would be covered by overburden material, moraine (Glacier) deposit, highly weathered rock, Schist rock or unstable/steep slope; intensity of HMD increases rapidly

Table 1. **Causes and factors of HMD**



(c) **Man- made Factors:** As the century begins, natural resources are under increasing pressure, threatening public health and development due to increase in rapid rate of human population. As we human, exploit nature to meet present needs and we destroying resources needed for the future. Mankind is becoming ever more susceptible to natural disasters, largely as a consequence of population growth and globalization. Human activities are also a critical issue in exacerbating vulnerability to natural hazards, ranging from anthropogenic climate change at one extreme[58] to local deforestation and changes in land use at the other[59].

Unscientific development and land use pattern, poor socio-economic conditions, deforestation, increasing human and cattle population pressure, increasing tourism etc. have been increasing the vulnerability of the region to disasters. Poor economy, low per capita income and significant poverty contribute to the vulnerability of the people and push them to settle in marginal and more vulnerable areas. The poor accessibility to infrastructure increases the vulnerability of the population during disasters.

The increasing population and tourism pressure in Uttarakhand is leading to ecological disturbance, which is the one of main basic reason for making the region vulnerable to natural. As per census, the average population density in 2001 in Uttarakhand was 159, which has increased to 189 in 2011. The population has increased from 84.89 lakh in 2001 to 101.16 lakh in 2011. The extensive growth in population over the decade has adversely disturbed the already fragile ecosystem of the hilly state by increasing the demand for developmental activities and forcing the people for more agricultural and other developmental activities in sensitive areas[25].

The number of tourists going to Uttarakhand has grown by 300% in a decade between 2000-2010 from 1.11 crores to 3.11 crores[60] . The infrastructure to cater tourists facility in the state has grown disproportionately and mostly without much planning. Due to the increase in the tourist inflow, several multi-storied hotels, and other amenities have been constructed even in the eco-sensitive zones of the area. Some of the hotels are constructed on the banks of the rivers for tourists/pilgrims and even in flood plain area. In order to cater better services to the tourists/pilgrims, several other developmental activities like construction of roads, bridges and other infrastructures etc. together up to some extent are responsible for increase in the ecological imbalances in the region.

The vegetation cover serves as a carpet and is very helpful in protecting land from soil erosion. The degradation of forest is known to extensively increase the soil erosion, as is evident from frequent landslides, siltation in river and other drainage channels, deterioration of agriculture land, etc. The increased eroded sediments in the area are filling reservoir and choking the streams. Springs in many parts of the State have dried up or have become seasonal. The floods in hilly region have become a frequently occurring phenomenon even in case of small or medium level rainfall.

2.2. Previous HMD in Uttarakhand

The state of Uttarakhand has experienced a large number of incidences of HMD. Though the state has faced severe flood disaster but the last decade (1997-2013) has proved one of the worst decades as both the magnitude and frequency of floods have gone up. These disasters events have brought heavy toll to the state as the loss was estimated in several thousand millions of rupees and also killed several hundreds of people. The major HMD have been tabulated as under table 2.

Table 2. Mitigation measures for HMD

S. No.	Date/Year	Location	History of Damage Occurred	Type of Disaster
1	1867 & 1880	Nainital	Two major landslides on the Sher-ka-Danda slope in Nainital. The 1880 landslide took place due to rainfall and an earth tremor, destroying buildings, and permanently filled a portion of the Naini lake.	Hydro meteorological disaster
2	1893	Alaknanada	Floods in the Birehi Ganga river near its confluence with the Alaknanda river triggered landslides, causing major blockage of the river with a 10-13 m afflux. A girder bridge was bypassed and another one was destroyed.	Flash Flood with landslide
3	1968	Rishi-Ganga	The Rishi Ganga river in Garhwal was blocked due to landslide at Reni village.	Landslide
4	Jul 1970	Patal Ganga	The Patal Ganga (a tributary of the Alaknanda river) got choked and a reservoir was created. The bursting of this choked reservoir resulted in flash floods in the Alaknanda river, triggering many landslides.	Geological disaster created flash flood
5	1971	Kanauldia Gad	A major landslide on the bank of the Kanauldia gad, a tributary of the Bhagirathi river upstream from Uttarkashi formed a debris cone which impounded water to a height of 30 m. Its breaching caused flash floods downstream.	Geological disaster created flash flood

6	Aug 1978	Uttarkashi	The Kanauldia Gad, a tributary joining the Bhagirathi river upstream from Uttarkashi in the Uttarakhand formed a debris cone across the main river, impounding breaching caused flash floods, creating havoc. A the river to a height of 30 m. Its 1.5 km long and 20 m deep lake was left behind as a result of the partial failure of the landslide dam.	Geological disaster created flash flood
7	1920, 1952, 1963, 1964, 1965, 1968, 1969, 1970, 1971, 1972 & 1985	Kaliasaur	Kaliasaur is one of the most persistent and regularly occurring landslides areas, located along the Rishikesh-Badrinath road. Landslides in this region results into frequent road blockage and land damage.	Geological disaster created flash flood
8	Sep 1989	Karanprayag, Chamoli	Three People died and Two injured	Flash Flood
9	Dec 1991	Uttarkashi	Three People died	Flash Flood
10	Jul 1994	Chaukhutia, Almora	Four People died	Flash Flood
11	Aug 1997	Near Neelkanth, Haridwar	Eight People died	Flash Flood
12	Aug 1998	Okhimath	Sixty nine people were killed due to several landslides near Madhmaheshwar valley. The landslides caused huge devastation in villages.	Geological disaster created flash flood
		Malpa, Kali River	More than 210 people were killed. The heap of debris created was about 15 m high. The village was wiped out in the event.	
13	Jul 2001	Near Meykunda, Rudraprayag	Twenty seven people died	Flash Flood
14	2002	Khetgaon, Pithoragarh	Four People died	Cloudburst
15	Jul 2003	Didihat, Pithoragarh	Four People died	Flash Flood

16	Sep 2003	Varunavat Parvat, Uttarkashi	Incessant rains triggered massive landslide in the area, causing the burial of numerous buildings, hotels, and government offices located at the foot of the hill slopes.	Hydro meteorological disaster causes landslide
17	2004	Ranikhet	One People died	Cloudburst
18	21 May & 09 June 2004	Kapkot, Bageshwar	Six People died	Flash Flood
19	Jul 2004	Badrinath, Chamoli	Sixteen persons killed, 200 odd pilgrims stranded, 800 shopkeepers and 2,300 villagers trapped as cloudburst triggered massive landslides washed away nearly Badrinath road cutting off Badrinath area 200metre of road on the Joshimath.	Hydro meteorological disaster causes landslide
20	29-30 June 2005	Govindghat, Chamoli	A cloudburst/landslide occurred in which a huge quantity of debris and rock boulders were brought down along a seasonal nala. Eleven people were killed and property lost.	Hydro meteorological disaster causes landslide
21	21-Jul 2005	Vijaynagar, Rudraprayag	Four People died	Flash Flood
22	13-Aug 2007	Didihat, Pithoragarh	Four People died	Flash Flood
23	06-Sep 2007	Village Baram/Sialdhar, Dharchula, Pithoragarh	A landslide due to excessive rainfall resulted in 15 fatalities and loss of livestock.	Hydro meteorological disaster causes landslide
24	2007	Pithoragarh & Chamoli	Twenty three People died	Cloudburst
25	2008	Pithoragarh	One People died	Cloudburst
		Amru Band	Total 17 people killed21, huge damages to roads and houses.	Hydro meteorological disaster causes landslide

26	2009	Munsiyari Tehsile, Pithoragarh	Forty three people died	Cloudburst induceed flash flood & Landslide
27	July to Sept 2010	Kot, Pauri; Rudrapur, Udham Singh Nagar; Dehradun, Nainital, Chamoli, Champawat, haridwar,	fifty nine people died and 2 missing & 17 injured	Cloudburst induceed flash flood & Landslide
28	21-Jul 2010	Almora	Thirty six people died in cloud burst induced flash flood	Cloudburst
29	18-Aug 2010	Kapkot, Bageshwar	Eighteen school children were buried alive and 8 injured due to massive cloudburst	Cloudburst
30	18-21 Sept 2010	Ganga-Alaknanda valley	Sixty eight people killed in the landslides, which caused extensive damages to the buildings, agricultural lands and roads at several places.	
31	06-May 2011	Raipur, Dehradun	Three People died	Flash Flood
32	15-Aug 2011	Tuneda, Bageshwar	Twenty One People died & one injured	Flash Flood
33	03-Aug 2012	Asi Ganga Valley, Uttarkashi	The worst affected areas were Gangotri, Sangam, Chatti and Bhatwari. About 7,389 people from 1,159families in 85 villages were affected. Nearly 28 people were killed in flash floods and landslides.	Flash Flood
34	13-14 Sept 2012	Okhimath, Rudraprayag	Sixty eight people killed in the landslides, which caused extensive damages to the buildings, agricultural lands and roads at several places.	Cloudburst induceed flash flood & Landslide
35	16-17 June 2013	Bageshwar, Chamoli, Pithoragarh, Rudraprayag & Uttarkashi	Flash flood induced landslide. 68026 people died, and 4,117 missing. Huge devastation to infrastructures and other properties mainly in 5 districts of Uttarakhand	Cloudburst induceed flash flood & Landslide

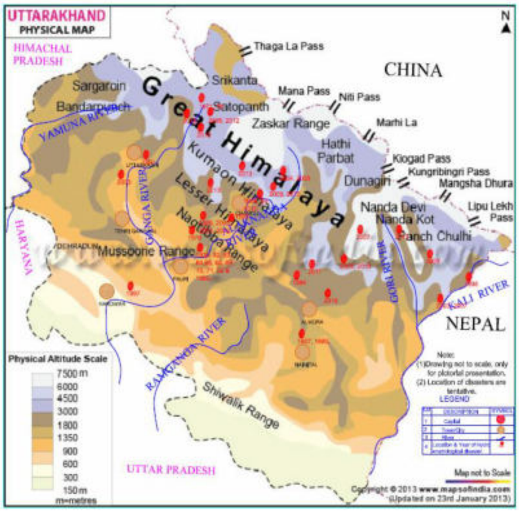


Figure 3. **HMD Map of Uttarakhand[34].**

2.3. Disaster Risk Reduction/Mitigation measures for HMD

The major lesson from extreme natural events is that a better job to be done to identify systematically areas at risk and to establish more effective ways to communicate with authorities and communities likely to be affected. According to [61], most HMD i.e. Flash flood, flood and GLOF; events take place in remote, isolated catchments where the governments reach is limited or non-existent. When the flash floods strike, external help may take several days to each affected communities, during which time they are left to cope on their own. The technological advances and institutional arrangements for disaster risk management are gradually improving in the Himalayan region. In areas where HMD can be expected, it is essential to build the capacity of communities to manage the risks from disaster by themselves. The individual households usually have strategies in place, but the effectiveness of these individual efforts can be enhanced many fold if they are coordinated.

The HMD are by their nature difficult to predict and control but it is possible to reduce the risk to lives and property through following different measures as shown in table 3.

2.3.1. Pre Disaster Mitigation measures

The geology of Uttarakhand is ridden with numerous fault lines and thrusts. According to recent scientific researches, climate change is known to aggravate the frequency of high intensity rainfall, including cloud bursts causing flash floods, Glacial Lake Outburst Floods (GLOFs) and landslides, increasing peoples ecological and socio-economical vulnerability. State is on a path of massive economic and infrastructure growth with various projects including large number of hydropower projects, buildings, roads, tourism related infrastructures, dams, tunneling, diversion structures, mining, de-siltation of river beds etc. Disaster and development are very inextricably linked. The vulnerability of a region or a country to natural hazards is mainly result of prevailing conditions of the region or society, which are the result of the developmental pattern. The most of these developmental activities unfortunately did not give due consideration to local geological, geo-morphological and ecological conditions.

Table 3. **Mitigation measures for HMD**

Mitigation measures					
Pre Disaster				Post Disaster	
Locate the hazard prone area	Planning and implement the structural and non structural measures to minimize the impact of disaster	Physically mark the hazard prone area & Public awareness	Honestly follow /monitor the mitigation rules by government & Public	Social and economical redevelopment of area depending upon intensity of disaster	Medical facilities

It is difficult to predict the exact location, magnitude, and extent of most HMD. But there are many measures that can help to reduce the impact of HMD, ranging from land use planning, construction codes, soil management and acquisition policies, through insurance, awareness raising, public information, and emergency systems, to post-catastrophe recovery plans.

(i) **Locate the hazard prone area:** First of all, we have to identify the previous and upcoming hazard prone area and its origin causes with the help of modern science and local public.

(ii) **Planning and implement the structural and non structural measures to minimize the impact of disaster:** The forecast and warning systems would be helpful to reduce the impact of disaster. Government authorities and Disaster Mitigation expects who have enough experience in academic as well as practical in handling this, such as Masters Degree/Post Graduate Diploma in Disaster Mitigation, Engineering & Environmental Geologist, Environmentalist, Civil Engineers, Hydrologist etc. would be helpful to prepare the mitigation plan in a best way. After the planning, we have to use a combination of small-scale structural and non-structural measures for minimize the impact of HMD.

(iii) **Physically mark the hazard prone area & Public awareness:** The desk work is not enough without implementation on ground level. The hazard prone areas (Landslide, Flood plain etc) should be physically marked and mentioned by signee board Disaster prone area. Municipal Corporation/ Gram Panchayat/NGOs never allow building any structure in this area. The awareness and knowledge among the local communities about the impacts of global warming, natural disasters and the threat to the ecosystem, communities, and infrastructure are generally inadequate. The media and academia together can play a significant role in public education, awareness building, and trend projection.s They have a right to information and materials in their own languages and ways of communicating.

(iv) **Honestly follow /monitor the mitigation rules by government, Project authorities, society & Public**: The various studies has been carried out by government, non government and private agenesis, on the basis of their recommendations government authorities not only prepare the rule and regulations but appoint the monitoring authorities also. But the most of the project agenesis as well as monitoring authorities have not follow the proper rules and regulations with lots of excuses.

For example the Hydro electric projects have muck disposal plan, with proper site for muck disposal, transportation of muck to the designated sites above the high flood levels and approved by authorities. But due to poor implementation, monitoring, these become havoc during HMD. River Bed Mining issue is to be tackled systematically based on the scientific investigations. The proper report has been approved by state Geology & Mining department with recommendations of safety but rarely monitored by authorities regarding implementation of rules. There are clear directives from Honble High Court of Uttarakhand that no constructions can be allowed within the 200 m in the both sides of the rivers. In spite of these directives of the Court, there are hundreds of buildings constructed in the riverbed itself. The NIDM team during its visit also observed that such buildings are constructed in sensitive areas, including in river beds and also on steep slopes.

The IIT Roorkee (Feb, 2013) carried out a detail study about the road conditions in Uttarakhand and reported that the most of the roads have been constructed in Uttarakhand ignoring local geological and environmental conditions. The report released at the International Conference on Energy Resources and Technologies for Sustainable Development at Howrah, Kolkata. The management of debris generated due to road construction is also a major challenge. This debris is mostly left unattended and usually dumped in the river beds, reducing rivers water carrying capacity and thus increasing the chances of flash floods/floods more frequently[25]. Construction of buildings and structures on unstable hill slopes and young flood plains must be restricted. The multi storied buildings on high terrain area should not be developed, this type of structures put excessive load on lithology that causes landslide.

We cannot blame any development activity for HMD, only human error/ negligence is responsible for increasing the intensity of HMD. If rules, regulations and suggestions should be followed honestly, the impact of disasters would be less.

2.3.2. Post Disaster Mitigation measures

The actual disaster results in substantial damage to the population in terms of loss of life and property. This direct result can be termed the first disaster. The another wave of damage triggered by a chain of cause-and-effect events relating to the first disaster results in indirect damage to people which is remotely related from the original disaster. For example, the people cannot repay their loans, resulting in losses to money lenders. Such events can also result in higher incidences of problems relating to health (heart attacks, strokes), emotional responses (suicides) and crime (homicides). This is called the second disaster and can be in greater magnitude than the first disaster. The appropriate rehabilitation and care of the victims in first disaster can break the chain of events leading to the second disaster[62].

The main factors of risk are given by the high velocity and high depth associated with debris, which involve a loss of stability in the water and increase the risk of drowning. Time lag is also crucial as it constrains the potential time of warning and evacuation. The local circumstances (e.g., presence of shelters, type of buildings, time of the day, seasonality, warnings) play a strong role[63].

Beside the economic loss, potential impacts on individuals are: mortality, injuries, and diseases (e.g., diarrhoeal, vectorborne) and infections, chemical pollution, nutrition and displaced population[64]. Only a small part of these impacts is captured by direct health costs. The Psychological or mental health impacts are also recognized and are related to various flood impacts such as the stress of the flood itself, the evacuation, the disruption to life and household and the loss of memorabilia and personal belongings. The loss of cultural heritage is a further potential impact which can be associated too, but it is barely approximated by the damages to historic physical assets, as certain disasters might affect the folklore, traditions, language, and knowledge of the involved communities However, social benefits can also arise from the redistribution of assets and income in a community after a disastrous event[65].

According to [62], there is a phenomenal increase in the incidence of psychiatric disorders in the flood affected population. The common problems include:

1) Acute stress disorder;

2) Post traumatic stress disorder;

3) Anxiety disorders;

4) Depression;

5) Alcohol and drug abuse.

During Uttarakhand disaster June 2013, there were many victims who had escaped death but witnessed hundreds, including their loved ones, die in front of their eyes. The people recounted sleeping on dead bodies and family members seeing their loved ones being washed away. The doctors said that the trauma remains for very long with those who survived such disasters and psycho-social care help is needed to deal with such trauma. In case of a family member being lost, people also suffer from survivors guilt. The impact was the huge and professional interventions were important. The good number of doctors (both Private and Govt.) and nurses rushed to the scene to treat physical injuries, but limited psychosocial staff was available at disaster scene. On account of the preventive measures taken, no outbreak of epidemic or infectious disease has occurred in the State, in spite of the fears that floating dead bodies of both humans & animals, mass cremation of dead bodies and disposal of animal carcasses might generate contamination and result in some epidemic/ outbreak of infectious disease [25].

3. Conclusions

The Frequency and intensity of HMD is unpreductable and previously Uttarkhand had suffered a lot in refernce to loss of social, economical, agricultural, infrastructural and offcourse human sentimentes. Flashflood of Uttarakhand in 2013 is one of the devastating disasters in Himalaya as well as world history. We have to make development with environmental safety concern.

Only local society/community first affects by HMD and we cannot expect that government will be able to intervene everywhere. Government help cannot save us direct & long term impact of HMD. On the basis of above study it is concluded that Intensity & frequency of HMD in Uttarakhand are increasing since year 1997. Uttarkashi, Rudraprayag and Chamoli districts have faced more prominent disasters. The climate change, geological factors such as unstable slope & poor rock condition and high rate of human population growth are the main factors that increases the intensity & frequency of HMD. We could only minimize the impact of HMD by strongly implementation of Pre-disaster mitigation measures such as planning, public awareness & knowledge about it, structural & non structural measures honestly follow the environmental and disaster mitigation rules by all of us including project & monitoring authorities (government as well as private developer) with the early warning systems.

The state agencies could also issue the guide lines to the tourist, pilgrims and mountaineers how to make their visit to Uttarakhand safe and peaceful suggesting them in terms of clothing, medicines, fooding and weather they carry during their visit. These could be easily implemented by NGOS and electronic Media, distributing the pamphlets, monographs, weather charts and news flash in E-media.

References

[1] Y.Okuyama and S.Sahin, *Impact estimation of disasters: a global aggregate for 1960 to 2007*, World Bank Policy Research Working Papers, (4963)(2009), 1-42.

[2] EEA. *Mapping the impacts of natural hazards and technological accidents in Europe, an overview of the last decade*, Luxembourg: Publications Office of the European Union, (2010).

[3] D.Crichton, *The risk triangle- In Natural disaster management*, (ed. J. Ingleton), London, UK: Tudor Rose (1999), 102103.

[4] M.Eriksson, Xu.Jianchu, A.B.Shrestha, R.A.Vaidya, S.Nepal and Sandstrom, *The Changing Himalayas- Impact of climate change on water resources and livelihoods in the Greater Himalayas*, Perspectives on water and climate change adaptation. ICIMOD, (2009), 1-22.

[5] L. A.Owen, R.C.Finkel and M.W.Caffee, *A note on the extent of glaciation throughout the Himalaya during the global last glacial maximum*, Quaternary Science Reviews, (21)(2002), 147157.

[6] MB.Dyurgerov and MF.Meier, *Glaciers and the Changing Earth System: A 2004 Snapshot*, Institute of Arctic and Alpine Research, Occasional paper, (2005).

[7] Thomas Kohler and Daniel Maselli, *Mountain & Climate Change from understanding to Action*, 3rd Edition. Published by the Centre for Development and Environment (CDE), Rome, Italy (2012).

[8] M.Bavay, M.Lehning, T.Jonas and Lwe, *Simulations of future snow cover and discharge in Alpine headwater catchments*, Hydrological Processes (23-1)(2009), 95-108.

[9] IPCC: *Climate Change*, The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (2007a).

[10] M.Y.Du, S.Kawashima, S.Yonemura, X.Z.Zhang and S.B.Chen, *Mutual influence between human activities and climate change in the tibetan plateau during recent years*, Global and Planetary Change, (41)(2004), 241249.

[11] J.N.Holeman, *Sediment Yield of Major Rivers of the World: Rivers and Lakes of Xizang (Tibet)*, Science Press, Bejjing, (1984).

[12] J.S.Singh and S.P.Singh, *Forests of Himalaya*, Gyanodaya Prakashan, Nainital, India, (1992).

[13] Y.Ageta and T.Kadota, *Predictions of changes of glacier mass balance in the Nepal 36 K. Higuchi Himalaya and Tibetan Plateau: a case study of air temperature increase for three glaciers*, Annals of Glaciology, (16)(1992), 89-94.

[14] D.B.Zobel and S.P.Singh, *Forests of Himalaya: their contribution to ecological generalizations*, Bioscience, (47)(1997), 735-745.

[15] T.Yamada, *Monitoring of glacier lake and its outburst floods in Nepal Himalaya*, Japanese Society of Snow and Ice, Monograph No. (1). Tokyo, (1998).

[16] K.Fujita, T.Kadota, B.Rana, RB.Kayastha and Y.Ageta, *Shrinkage of Glacier AX010 in Shorong region, Nepal Himalayas in the 1990s*, Bull. Glaciol. Res, (18)(2001), 5154.

[17] P.Singh and L.Bengtsson, *Hydrological sensitivity of a large Himalayan basin to climate change*, Hydrological Processes, (18)(2004), 23632385.

[18] M.Beniston, *The risks associated with climatic change in mountain regions. In: Huber U., Bugmann H. and Reasoner M. (eds) Global change and mountain regions: an overview of current knowledge*, Springer, Dordrecht, (2005), 511-520.

[19] K.Hewitt, *The Karakoram anomaly? Glacier expansion and the elevation effects Karakoram Himalaya. Mountain*, Research and Development, 25(4)(2005), 332340.

[20] M.Phillips, *Avalanche defense strategies and monitoring of two sites in mountain permafrost terrain. Pontresina, eastern Swiss Alps*, Natural Hazards, (39)(2006), 353-379.

[21] S.P.Singh, *Climate change an overview*, Fifteenth national symposium on environment (NSE-15). Mitigation of pollutants for Clean environment BARC Macmillan India Ltd. Mumbai, (2006), 24-29.

[22] R.Kumar, A.K.Shai, K.Krishna Kumar, S.K.Patwardhan, P.K.Mishra, J.V.Rewadhar, K.Kamal and G.B.Pant, *High resolution climate change scenario for India for the 21st century*, Current Science, (90)(2006), 334-345.

[23] V.Kumar, P.Singh and V.Singh, *Snow and glacier melt contribution in the Beas River at Pandoh Dam, Himachal Pradesh, India*, Hydrological SciencesJournal des Sciences Hydrologiques, 52(2)(2007).

[24] K.Kumar, S.Joshi and V.Joshi, *Climate variability, vulnerability, and coping mechanism in Alaknanda catchment*, Central Himalaya, India, AMBIO, (37)(2008), 286-291.

[25] *Report on Uttarakhand Disaster National*, Institute Of Disaster Management, Govt Of Uttarakhand, (2013)

[26] PK.Das, *The Himalayan Tsunami-Cloudbrust, Flash Flood & Death toll: A Geographical Postmortem*, Jornal of Environmental Science, Toxicology and Food Technology, 7(2)(2013), 33-45.

[27] R J.Pandey, *Landslide and Risk Assessment in Uttarakhand with Special Refernce to Malpa*, International Journal of Innovation Research & Development, 2(3)(2013), 197-205.

[28] Kumar Ami, D*emystifying A Himalayan Tragedy: Study of 2013 Uttarakhand Disaster*, Journal of Indian Research, 1(3)(2013), 106-116.

[29] S.Mukherejee, *Extra Terrestrial Remote Sensing and Geophysical Applications to Understand Kedarnath Cloudburst in Uttarakhand, India*, Journal of Geophysics & Remote Sensing, 3(3)(2014).

[30] AKL.Asthana and H.Asthana, *Geomorphic control of Cloudbrusts and Flash Floods in Himalaya with Special reference to Kedarnath Area of Uttarakhand, India*, International Journal of Advancement in Earth & Enviromental Sciences, 2(1)(2014), 16-24.

[31] S.R.Chalise and N.R.Khanal, A*n introduction to climate, hydrology and landslide hazards in the hindu kush-himalayan*

region, Landslide Hazard Mitigation in the Hindu Kush-Himalayas, Kathmandu. ICIMOD, (2001), 5162.

[32] ICIMOD, *Flash Flood Hotspot Mapping in Hindu Kush-Himalayan Region ICIMOD*, International Journal of Climatology, 20(2007), 1729-1742.

[33] R.K.Iafiazova, *Climate change impact on mud flow formation in Trans-IlI Alatay Mountains*, Hydrometeorology and Ecology, (3)(1997), 1223.

[34] Uttarakhand Location Map, http://www.mapsofindia.com

[35] Chopra Ravi, *Uttarakhand: Development and Ecological Sustainability*, Publisher Oxfam India, June (2014).

[36] Paul Ajay, *Evaluation and Implications of Seismic Events in Garhwal-Kumaun Region of Himalaya*, Journal Geological Society of India, (76)(2010), 414-418.

[37] A.Gansser, *Geology of the Himalayas*, London:Willey Interscience, (1964).

[38] J.Celerier, T.M.Harrison, A.A.G.Webb and A.Yin, *The Kumaun and Garwhal Lesser Himalaya, India: Part 1. Structure and stratigraphy*, Geol. Soc. Am. Bull., 121 (910)(2009), 12621280.

[39] S.S.Negi, *Uttarakhand: land and people*, New Delhi: MD Pub (1995).

[40] D*isaster Preparedness and Mitigation*, http://www.unesco.org/new/en/natural-sciences/special-themes/disaster-preparedness-and-mitigation/natural-hazards/hydro-meteorological-hazards/

[41] P.Lumb, *Slope failure in Hong Kong*, Eng. Geol., 8(1975), 31-65.

[42] M.Govi, G.Mortara and P.F.Sorzana, *Eventi idrologici e frane*, Geol.Appl. & Idrogeol, 2(1985), 359-375.

[43] International Training Centre of the ILO. Disaster risk reduction: a call to action. Prepared with the international recovery platform (IRP) and UNISDR. Issue No.(3), (2006). http://www.adpc.net/ddrcca/book/Chapter2/

[44] Jack A.Eddy, *The Maunder Minimum*, Science, 192(1976), 1189-1202.

[45] LSHingane, K.Rupa Kumar and BV.Rama Murthy, *Long-term trends of surface air temperature in India*, Internat Jour of Climat, 5(1985), 521-528.

[46] V.Ramanathan, PJ.Crutzen, JT.Kiehl and D.Rosenfeld, *Aerosols, Climate, and the Hydrological Cycle*, Science, 294(2001), 2119-2124.

[47] MS.Reddy and C.Venkataraman, *Inventory of aerosol and sulphur dioxide emissions from India. Part IIbiomass combustion*, Atmosph Environ, 36(2002), 699-712.

[48] N.Rastogi and MM.Sarin, *Chemical characteristics of individual rain events from a semi-arid region in India: Three-year study*, Atmos Environ, 39(2005), 3313-3323.

[49] KM.Lau, KM.Kim, *Observational relationships between aerosol and Asian monsoon rainfall, and circulation*, Geophysical Research Letters, 33(2006).

[50] AB.Tinsley and Yu.Fangqun, *Atmospheric Ionization and Clouds as Links Between Solar Activity and Climate*, In Pap, Judit M.; Fox, Peter. Solar Variability and its Effects on Climate. Geophysical monograph series American Geophysical Union, 141(2004), 321339.

[51] S.Sajani, MK.Krishna, K.Rajendran and SN.Ravi, *Monsoon sensitivity to aerosol direct radiative forcing in the community atmosphere model*, J Earth Sys Sci., 121(2012), 867-889.

[52] B.Sarkar, *Disaster in Kedar Valley: A Retrospection. India Geospatial Digest (Oct 2013)*, http://geospatialworld.net/Paper/Application/ArticleView.aspx?aid=30699

[53] JF.Davies, RE.Miles, AE.Haddrell and JP.Reid, *Influence of organic films on the evaporation and condensation of water*

in aerosol, Proc Natl Acad Sci 110(2013), 8807-8812.

[54] http:// en.wikipedia. org/ wiki/ IPCC_Third_ Assessment Report.

[55] G.C.S.Negi, P.K.Samal, J.C.Kuniyal, B.P.Kothyari, R.K.Sharma and P.P.Dhyani, *Impact of climate change on the western Himalayan mountain ecosystems: An overview*, International Society for Tropical Ecology, 53(3)(2012), 345-356.

[56] C.K.Ballantyne and D.I.Benn, *Paraglacial slope adjustment and resedimentation following recent glacier retreat, Fabergstolsdalen, Norway*, Arctic and Alpine Research, 26(3)(1994), 255269.

[57] S.J.Dadson and M.Church, *Postglacial topographic evolution of glaciated valleys: a stochastic landscape evolution model*, Earth Surface Processes and Landforms, 30(11)(2005), 13871403.

[58] J.F.B.Mitchell, J.A.Lowe, R.A.Wood and M.Vellinga, *Extreme events due to human induced climate change*, Phil. Trans. R. Soc. A. (364)(2006), 21172133.

[59] H.S.Wheater, *Flood hazard and management: a UK perspective*, Phil. Trans. R. Soc. A. (364), (2006), 21352145.

[60] Anonymous, *Uttarakhand disaster got magnified due to heavy pilgrim rush*, Enews Times of India, 21 June 2013. http://articles.timesofindia.indiatimes.com/2013-06-)(2013)

[61] A.B.Shrestha, C.P.Wake, P.A.Mayewski and J.E.Dibb, *Maximum temperature and trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal from period 1971-1799*, Journal of Climate, (12)(1999), 2775-2787.

[62] F.Ahmad, S.F.Kazmi and T.Pervez, *Human response to hydro-meteorological disasters: A case study of the 2010 flash floods in Pakistan*, Journal of Geography and Regional Planning, 4(9)(2011), 518-524.

[63] C.Green, C.Viavattene and P.Thompson, *Guidance for assessing flood losses [online]*, Middlesex University. ConHaz Project, Deliverable 6.1. (2011) Available from: http://conhaz.org /project/cost- assessment-work-packages/wp1-8-final-reports . [Accessed 31 January 2013].

[64] R.Few et al., *Floods, health and climate change: a strategic review*, Tyndall Centre for Climate Change Research Working Paper, 63(2004), 1-138.

[65] K.Mc Sweeney and O.Coomes, *Climate-related disaster opens a window of opportunity for rural poor in northeastern Honduras*, PNAS, 108(13)(2011), 5203-5208.