A comparative analysis between the Extreme flood events that wreaked havoc in Jammu and Kashmir in September, 2014 and the unusual confluence of monsoons that triggered mammoth-scale destruction in Uttarakhand in June, 2013

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Abstract:

Areas around all four pilgrimage centres (Gangotri, Yamunotri, Kedarnath and Badrinath) and the fifth one of Hemkunt Sahib experienced intense floods and rainfall during 15th-18th June 2013. In addition, areas of Pittoragarh (Goriganga basin), Himachal Pradesh (Kinnaur district, mainly Kashang area, a tributary of Sutlej) basin and adjoining parts of Nepal also faced flood disaster. It is strange to see such a vast area facing simultaneous rainfall. There was massive devastation all over but the largest impact has been at the temple town of Kedarnath, which was in the middle of the pilgrimage season, with tens of thousands of people thronging the town and the downstream region along the Mandakini valley.

Jammu and Kashmir and adjoining areas received heavy rainfall September 2nd onwards at the tail end of the monsoon season in India. This triggered floods and landslides in India and the adjoining areas of Pakistan. In Kashmir division, most of Srinagar city was submerged under water. Approximately, 50 bridges were reported to have been damaged across the state. In Jammu division, landslides damaged roads, bridges, buildings and crops. In Pakistan, 300 villages in Multan district and 350 villages in Jhang district were flooded.

This paper traces the vulnerability of the two regions to natural disasters, the sequence of events that led to such massive hydro-meteorological disasters and the constraints faced on the ground to prevent the large-scale devastation caused. Lessons learnt from the deluges will help future disaster management operations in the future. The role of Remote Sensing & Geographic Information System in disaster management and mitigation will also be highlighted. In particular, the use of ArcGIS10 in disaster management will be described.

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Introduction

Himalayas are the youngest mountain range of the world and still in the process of orogenesis.[1] The Indian plate separated from Gondwana about 120 million years ago and drifted northwards. As it drifted northwards, the Tethys Sea began to shrink and started to *subduct* beneath the Asian plate.[2] Subduction zones are characterized by volcanic activity, earthquakes and mountain-building processes (*orogenesis*). Around 80 million years ago, India was isolated but continued to drift northwards towards the Asian plate.[2] Approximately 50 million years ago, India collided with the Asian plate and the Tethys Sea completely disappeared. After collision, speed of the Indian plate decreased considerably from 15 to 5 cm a year.[2] However, India still pushed forward and the Earth's crust between India and Asia deformed (by faulting and folding) and uplifted and gave birth to the youngest mountains in the world. The Himalayas are still rising making the entire zone geomorphologically fragile and prone to natural disasters or geohazards such as earthquakes, landslides and floods.
The Himalayan region has witnessed some severe floods events and the frequency of such events seem to be on the rise.[3,4] The most recent ones prior to the ones being discussed in this paper are the Leh cloudburst of 2010[3] and the heavy rains and cloudburst events of Uttarakhand[5] in 2010 and 2012. A flood is an overflow of water that inundates usually dry land.[6] The European Union Floods Directive defines a flood as a "covering by water of land not normally covered by water".[7] it is usually caused by rain, heavy thunderstorms, and thawing of snow. It is considered to be a temporary condition of two or more acres of dry land either inundated with inland or tidal waters, runoff of surface waters or mudflows.[8] Flooding maybe caused by overflow of water from water bodies, such as river or lake or it may be caused by accumulation of rainwater on saturated ground. Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Major types of floods include areal (rainfall related), riverine, estuarine or coastal, urban and catastrophic (due to major infrastructure failures such as collapse of a dam, earthquake or volcanic eruption).

Brief History of Major Floods in Uttarakhand and Jammu and Kashmir

(i) The geographical location and topography of Uttarakhand renders it ecologically fragile state. From the 1900s to 2003, the region has experienced approximately 30 extreme flood and landslide events.[10] In more recent times, heavy rains, cloudbursts and landslides in 2010 in Uttarkashi, Pittoragarh, Chamoli and Rudraprayag caused massive death and destruction.[11] In 2012, cloudbursts in Asiganga and Bhagirathi valley (Uttarkashi) damaged property worth 600 crore and claimed 39 lives.[11]

(ii) Jammu and Kashmir has had a long history of floods.[9] from 1905 to 1959, the state was hit by floods 14 times. In August-September of 1957, a major flood submerged the entire valley. Two years later in July 1959, the state witnessed a massive 'glacial' flood when four days of incessant rains lashed the valley. There were occurrence of floods in the following three decades but the floods of 1992 that hit the state were of unprecedented fury. The floods were devastating in terms of casualties. The cloudburst of August 6th, 2010 triggered flash floods after a night of heavy downpour. While the duration of the heavy downpour was only half an hour, the devastation caused by the cloudburst was massive.

Flood-affected Areas of Uttarakhand during June 2013 and Jammu and Kashmir during September, 2014

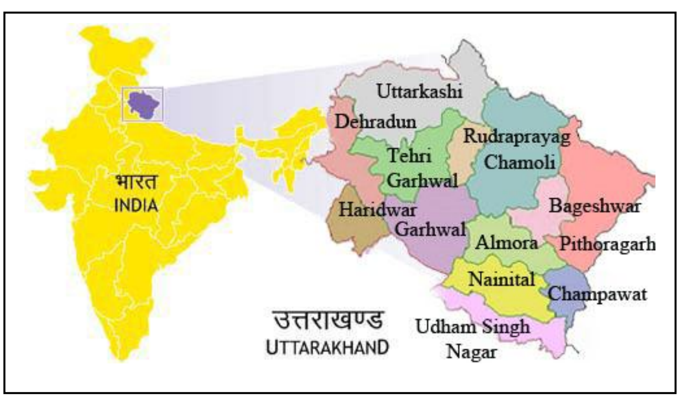
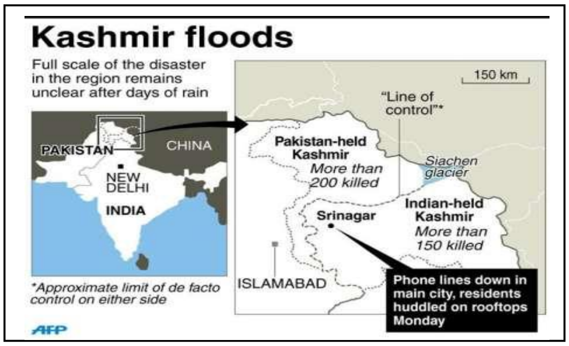


Fig.1: Location of Uttarakhand in India[12]

Fig. 2: Flood affected areas of Uttarakhand in June, 2013[13]



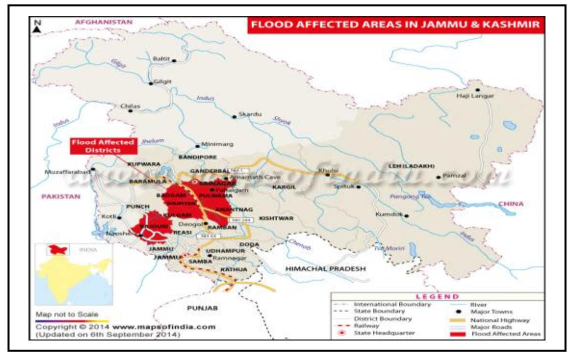


Fig. 3: Map locating the Kashmir region, affected by the Worst floods in half a century[14]

Fig. 4: Map showing the flood-affected areas of Jammu and Kashmir[15]

The Sequence of Events and Causes of Extreme flood Events in Uttarakhand, June 2013 and Jammu and Kashmir, September, 2014

(i) **Uttarakhand, June 2013**

The Kedarnath temple town is located in the Central Himalayas 30(44’6.7”N)); 79(04’1”E) in the Mandakini River valley which has a total catchment area of ~67km^2 (up to Rambara), out of which 23% is covered with glaciers.[16] Mandakini river originates from Chorabari glacier (3895m) near Chorabari Lake and joins Saraswati river which originates from Companion glacier at Kedarnath, passing through Rambara and Gaurikund. Overcrowding by pilgrims near the temple led to a change in the course of the Saraswati River which now flows behind Kedarnath town.

***Event 1*[16]**

On 16th June 2013, at 5:15 p.m, **intense rainfall** flooded Saraswati River and Dudh Ganga catchment area and resulted in overflow in all channels. Subsequently, active erosion began in all gulleys causing excess water and sediment accumulation in the major rivers. The wall of water along with debris from surrounding regions and glacial moraines moved towards Kedarnath town, washing off the upper the part of the city**.** Wadia Institute of Himalayan Glaciology meteorological stations near Chorabari glacier recorded 325 mm rainfall at the base of the glaciers in two days on 15th and 16th June 2011. Due to heavy rainfall, the town of Rambara was completely washed away on 16th June evening.

***Event 2*[16]**

The **second event** occurred on 17th June 2013 at 6:45 a.m. after overflow and collapse of the moraine dammed Chorabari Lake which released large volume of water that caused another flash flood in Kedarnath town leading to massive devastation downstream. Due to heavy rainfall the right lateral basin of the glacier, which was thickly covered by snow rapidly melted leading to large accumulation of water in Gandhi Sarovar. Suddenly millions of gallons of water accumulated in the moraine dammed lake within 3 days, which increased the potential energy of the water and reduced the shear strength of the dam. Ultimately the loose-moraine dam breached causing large-scale devastation in Kedarnath valley. Fig. 5 shows the pre and post-flood images of Kedarnath area.

***Causes*[16, 17]**

Unusual confluence of two branches of monsoon - Bay of Bengal and Arabian Sea

On June 14, the monsoon front was located over eastern India. It was a little slower than the normal progress of monsoons. **However, within a day the front advanced right across Uttar Pradesh and western regions to cover the entire country by June 15th, exactly a month prior to its normal date of July 15th**. While the monsoon front was advancing northwards from the East, a system of westerly winds from the Arabian Sea had also been active in the same period and had covered Pakistan. It was the interaction between the **well-formed low pressure system of the south-west monsoon from east to west** and the **upper air westerly trough running from north-west Rajasthan to the east** that led to intense rainfall in Uttarakhand.

Geophysical Dynamics
Post-flood images of Kedarnath town around the temple revealed that the massive destruction was caused by large-scale debris carried by huge volume of water from above the town.
Excessive snowfall
National Remote Sensing Centre scientists say the pictures indicated that the glacial regions above Kedarnath had received fresh and excess snowfall when heavy rainfall hit the region.[2] The sum of the heavy rain and runoff from snow melt resulted in a huge water flow that carried with it a huge debris flow and struck the town with enormous ferocity.
Double whammy-
Just like there was a confluence of two monsoon streams in the atmosphere, there was a coincidental reinforcing of two massive debris flows from above, one from the north-western side of the Kedarnath temple and the other from the north-eastern side.

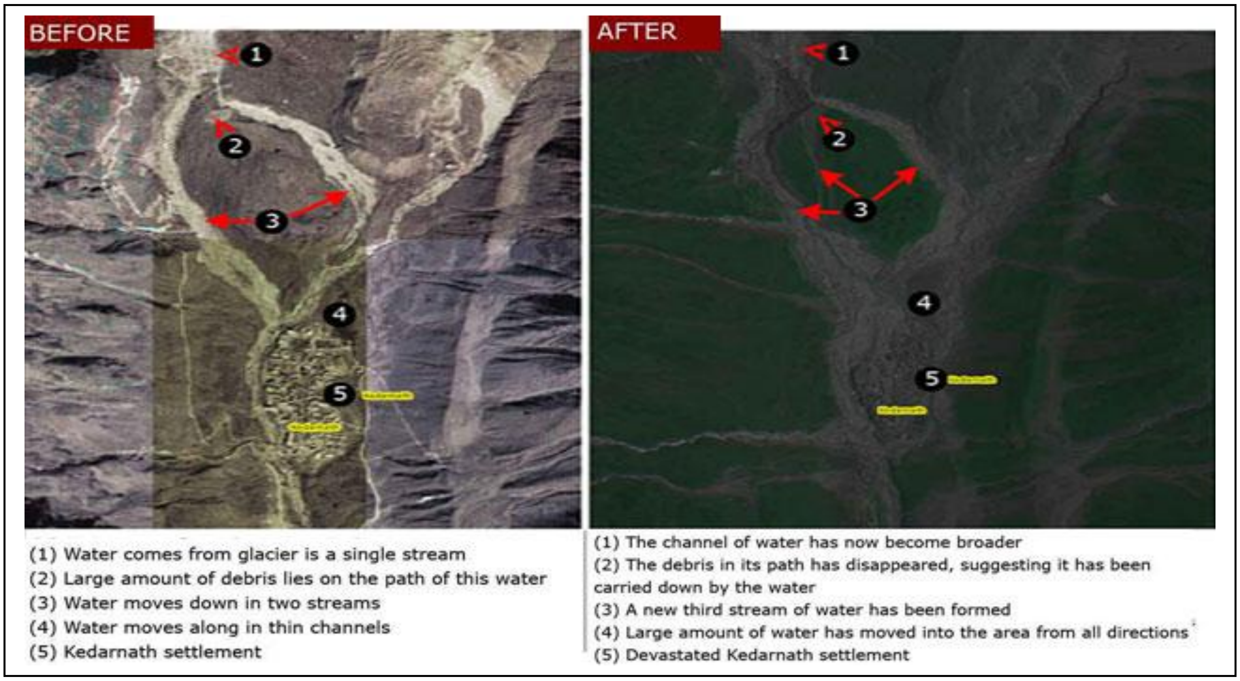


Fig. 5: Pre- and post-flood CARTOSAT images of Kedarnath area released by National Remote Sensing Centre- Indian Space Research Organization[18]

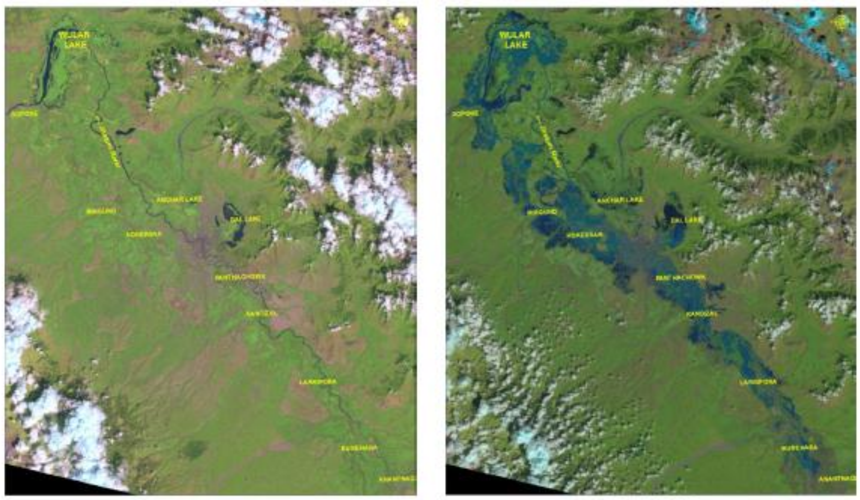
(ii) **Jammu and Kashmir, September 2014**
Based on the study conducted by the Department of Environment, Ecology and Remote Sensing (DEERS) on satellite-based rapid assessment on floods in Jammu and Kashmir in collaboration with National Remote Sensing Centre, Indian Space Research Organisation, Hyderabad, a report was presented to the government, which claimed that Jammu and Kashmir faced unprecedented floods of the century (Fig. 6 shows pre- and post-flood images of Jammu and Kashmir).[3,19] The report revealed that the floods were a result of the excessive rainfall or cloudbursts in the catchment areas over a short period of time. A combination of the extreme event and less capacity of the drainage system to contain the excess water overflowing the banks ultimately led to floods. There were incessant rains on September 4th for 30 hours and in three days, the amount of rainfall touched an unusual high of 450mm. On September 4th, Doodh Ganga, a tributary of Jhelum River flowing through Srinagar, breached its embankment as a result of cloudbursts in its catchment area. On September 5th, Tawi, Chenab and Jhelum Rivers breached their respective embankments. Flood control bunds were washed away, bridges collapsed and agricultural lands were inundated. There was a confluence of three main rain bearing monsoon systems over Punjab that led to heavy rains in Kashmir.

Both Flood Events were accelerated by Anthropogenic Factors

(i) Uttarakhand, June 2013

***Roads*[21,22]**

State's geological features and water channels are well-mapped and documented. But engineers and builders choose to overlook them. Geologists identified four different ways by which scientific norms were violated. **Seismic fault lines of this earthquake-prone state were not kept in mind while building roads and buildings.** These tectonic fault-lines, which are active and experience back and forth movements, have been cut in various places by roads. Road engineers seldom provide **drainage** for rain water. Devastating landslides were caused by road construction on **fragile slopes.** Receding water levels built up pore water pressure inducing slips. Such failures continue progressively to upper levels.



PRE-FLOOD
LANDSAT-8 Satellite Image showing Floods as on 25 August, 2014

POST-FLOOD
LANDSAT-8 Satellite Image showing Floods as on 10 September, 2014

Fig. 6: Pre- and Post-flood images in Jammu and Kashmir, September 2014[20]

***Dams/Hydroelectric project*[23,24]**

Dam construction involves blasting, excavation, debris dumping, movement of heavy machinery, diversion of forests and rivers. This has a cumulative impact on the Himalayan ecology. Due to construction of dams, rivers are not allowed to flow their natural course but have to be rerouted through tunnels cut through mountains, leaving long stretches of the rivers dry. Indiscriminate dumping of debris and muck along the river banks aggravated the situation further. This increased the erosive capacity of the river, which increased the river's water level and caused extreme destruction in the downstream area.

***Tourism*[25]**

From 2001 to 2012, there has been a 240% increase in tourism in Yamnotri, 250% increase in Gangotri, 378% in Kedarnath and 136% in Badrinath. Massive expansion of tourism brings in huge revenue but the tourism industry has not kept in mind the basic norms of disaster management and the state finds itself ill-equipped to manage such huge numbers.

***Buildings*[21]**

One of the reasons for devastation at Kedarnath was that people had constructed houses on the river bed of the Mandakini River that had been dry for decades. When the river returned to its old course following the deluge, these constructions were washed away. After the August, 2012 Uttarkashi disaster and the September 2012 Ukhimath disaster in Rudraprayag district, the state disaster mitigation and management centre made a series of recommendations regarding construction of buildings but nobody bothered to implement them.

***Deforestation*[26]**

While heavy rainfall and haphazard development are the two main culprits behind the Uttarakhand floods, deforestation is another key factor. **The worst affected districts of Chamoli, Pittoragarh, Rudraprayag and Uttarkashi are the areas where**

maximum forestland have been diverted for developmental activities. 68% of the forests have been diverted after formation of the state in 2000. Regions with intact forests have suffered much less damage than where forests have been diverted. For example, Kedar valley with its native oak forests has suffered few landslides mainly due to cloudbursts. The oak forests have great soil-binding capacity and water retention power.

(ii) **Jammu and Kashmir, September 2014**

Disappearance of wetlands[3]

Kashmir valley is dotted with wetlands, which include natural ponds, lakes, rivers, streams, riverine wetlands, human-made ponds and tanks. The Department of Environment and Remote Sensing has reported that there are 1,230 water bodies in the state- 150 in Jammu, 415 in Kashmir and 665 in Ladakh. Dal, Anchar, Manasbal and Wuler Lakes are some of the major wetlands. Wetlands act as sponges during times of excessive rainfall and floods. Rapid urbanisation had led to rapid disappearance of these wetlands. Wetlands like Batamaloo Nambal, Nadru, Narkara Nanibal, Hokarsar, Rekh-i-Gandallah, Rakh-i-Arat, Rakh-i-Khan, streams of Doodh Ganga and Mar nalla have shrunk considerably or completely lost to urbanization. Dal Lake used to be one of the largest natural lakes in the world covering an area of 75 sq. km, 1200A.D. The Lake was reduced to one-third its size in the 1980s, one-sixth of its size in recent times and lost 12m in depth.

Lack of drainage[3]

Srinagar is in the shape of a bowl with no outlet for water. There are two distinct water channels flowing through the city- the River Jhelum and an artificial flood channel created in 1904 to drain excess water from the Jhelum. After the floods, both channels had merged into a big, brown lake.

Silting[3]

Silt has accumulated in all of the major tributaries reducing the water storage capacities of the flood channels. In addition, **deforestation** in the Jhelum basin has led to excessive siltation in most of the lakes and water bodies.

Urbanization[3]

Construction in flood plains and river beds, loss of natural water storage areas or low-lying areas that were previously drainage basins has led to inadequate drainage systems. Impervious roads, pavements and buildings reduce water absorbing capacity. There is also the problem of encroachment due to urbanization. Besides, people in the city have connected their sewage lines directly to drains that are meant for disposal of storm water resulting in choking of drains.

Disaster Management in both States was Poor

(i) **Uttarakhand, June 2013**

The Central Water Commission (CWC) under the Union Ministry of Water resources, the premier flood forecasting body in the country, failed to make flood forecasts that could have helped the people and administration of Uttarakhand.[27,28] In the CWC website only three flood forecasting sites are listed for Uttarakhand – Srinagar, Rishikesh and Haridwar. So, the CWC does not make flood forecasts for the most vulnerable regions of Uttarakhand.

First principle of disaster management is prior warning. The only forecast CWC made this June 2013 were for Haridwar and Rishikesh in June 18th, 2013. Even here CWC's callousness is reflected. Normally low flood forecast (where water level is between warning and danger level for this site) is made first followed by medium flood forecast (water level is above danger level). However, in case of both Rishikesh and Haridwar, CWC made medium flood forecasts.

A Doppler Radar System that could have predicted even an event like a cloudburst at least 3-6 hours in advance was not in place.[29] The system and money for it was sanctioned for Uttarakhand since 2008 but due to lack of coordination between Uttarakhand government, India Meteorological Department (IMD) and National Disaster Management Authority (NDMA), the system was not available.

The Uttarakhand Meteorological department made a warning of heavy to very heavy rainfall on June 15th, 16th and 17th and even warned pilgrims to postpone their trip to the char dham (Gangotri, Yamnotri, Kedarnath and Badrinath) for four days.[29] The response of the Uttarakhand administration towards this warning has been callous. Even after rainfall started there was no immediate monitoring of the heavy rainfall and prompt dissemination of information about the same downstream and among the people. Kedarnath, epicenter of the disaster, has no rain gauge.

As the Comptroller and Auditor General (CAG) report of March 2013 shows, the State Disaster Management Authority (SDMA) of Uttarakhand was constituted under the chairmanship of state Chief Minister in 2007, but has never met.[30] There are no rules, regulations, policies or guidelines for disaster management in Uttarakhand. This indicates that agencies like IMD, CWC, NDMA and SDMA have failed to put in place basic systems of warning, forecasting, monitoring and information dissemination that can greatly reduce disaster potential of any area.

(iii) **Jammu and Kashmir, September 2014[19]**

Three hydrological stations on the Jhelum River had detected serious danger. Less than 50km upstream of Srinagar, the Sangam station, operated by Central Water Commission (CWC) indicated water levels had risen by 5.7m on 3rd September to 10.13m on September 4th, the Ram Munshi Bagh station nearer the capital registered an increase of 3m in the water level between the afternoons of September 3rd and 4th and the Safapora hydrological station also reported a similar jump on the same days. This abnormal rise in water level information was passed on to the local administration but they did not take this warning seriously as these CWC stations are not supposed to be flood forecasting stations. They are only supposed to monitor the water flow between India and Pakistan under the Indus Water Treaty of 1960. Effectively, CWC stations in J&K are mere hydrological data collection centres.

According to Indian Meteorological Department, J&K is supposed to receive an average rainfall of 100mm in September but the figure recorded in the initial days of the month was 400mm. However, there was no one to interpret the data and issue a warning.

The National Disaster Management Authority (NDMA) maps for flood-prone regions does not include J&K despite the state being flood-prone.

Role of GIS in Disaster Management

(i) Disaster Mitigation and Management Centre (DMMC) of Uttarakhand Government has provided detailed drainage, habitation, road, irrigation, health infrastructure, wireless communication facilities and health maps for all districts of Uttarakhand prepared in GIS.[31]
NRSC has prepared **Landslide hazard maps** for all the char dham routes using GIS.[32]

(ii) For J&K, the Ministry of Environment and Forests in collaboration with Indian Space Research Organization has compiled a National Wetland Atlas in which detailed wetlands, settlements, roads, railways, and drainage maps have been created in GIS.[33]
The above information should be made available to Disaster Management bodies, Public Administrative bodies and local people for planning, resource mobilization, and rapid and coordinated response when natural disasters strike at the individual and community level.

Comparative Analysis

(i) Both flood events (Uttarakhand in June 2013 and Jammu and Kashmir in September 2014) were triggered by confluence of monsoon systems. However, while heavy rains hit Uttarakhand an entire month prior to the expected date for monsoons, heavy rains hit Jammu and Kashmir at the tail end of the monsoon season.

(ii) Floods in Uttarakhand occurred in the upper reaches of the Himalayas whereas floods in Jammu and Kashmir was more a case of urban flooding, where the city of Srinagar and surrounding areas were submerged. Besides, glacial regions above Kedarnath area had received fresh snowfall when heavy rains hit the region. Runoff from snow melt contributed to the huge water flow.

(iii) Clearly topography had a major role to play in the spread of flood waters and the devastation that followed. Kedarnath was hit by a huge wall of water along with debris flow from above whereas the deluge in Srinagar was caused by inadequate drainage and disappearance of wetlands which would otherwise have absorbed the excess water.

(iv) The course taken by rivers coming down from the upper reaches of the Himalayas provide ideal sites for dam construction and generation of hydroelectricity. However, indiscriminate dumping of debris and muck increased the erosive capacity of rivers and caused further damage downstream in Uttarakhand.

(v) The devastation caused by the floods was accelerated in both states by construction in river beds, floodplains and low-lying areas. In addition, impervious roads and pavements reduce water-absorbing capacity. Road engineers seldom provide drainage for rain water.
(vi) In Uttarakhand, the death toll was higher because the downpour coincided with the peak of the tourist season.
(vii) Finally, both states were not prepared for disaster management. There was lack of communication and coordination between IMD, CWC, NDMA and SDMA and these disaster management agencies have failed to put in place basic systems of warning, forecasting, monitoring and information dissemination that could reduce the disaster potential of any area.
(viii) In conclusion, the deluge in both states were triggered by confluence of different monsoon streams but the devastation caused was multiplied by anthropogenic factors. There is an enormous potential for GIS to be developed as an important tool in disaster management by way of data management, planning and analysis, raising awareness about potential situations and actual field operations.

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