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Research Article

REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM: AS A POTENTIAL TOOL FOR DISASTER MONITORING

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ABSTRACT

Disasters have become an issue of growing concern throughout the world. During the past five decades, natural hazards such as floods, earthquakes, severe storms and tropical cyclones, droughts, wild land fires, and also manmade disasters have caused major loss of human lives and livelihoods, the destruction of economic and social infrastructure, as well as environmental damages. Remote Sensing and Geographical Information System have been used as potential tools for disaster management as well as its monitoring especially during the pre disaster stage, during disaster stage and post disaster stages. In this article, we give an attempt to bring to your knowledge the applicability of GIS integrated remotely acquired imagery from Earth orbiting spacecrafts for monitoring and assessment of disaster in the notable disaster areas and this research paper also provides a brief guideline on possible future directions for the application of remote sensing and GIS in disaster monitoring. As a concluding remarks as a potential tool, the Remote sensing techniques along with GIS are of significant use in various disaster monitoring and management.

INTRODUCTION

Disasters have become an issue of growing concern throughout the world, whether it is natural disaster or through human factors [**1**]. During the past two decades, India's landscape and its infrastructure has been exposed to numerous hazards that has killed many people and destroyed their property. In addition to death or injury to humans, severe damage or loss of valuable goods and natural environment have been the common domains that are significantly affected. In order to reduce the extent of losses from the disasters, sincere effort is required to monitor and manage the risk from disaster, while emphasizing on hazard assessment, elements-at-risk mapping, vulnerability assessment and risk assessment. Disaster is the product of a hazard coinciding with vulnerable situation [**2**]. In general, disasters can be divided into natural, human induced, and human made disasters. Most of the natural and manmade disaster management activities can be accomplished faster by the help of Geographical Information System (GIS) [**3**]. Remote sensing imagery acquired by the camera's onboard Earth orbiting satellites and Geographic Information System (GIS) integrated with Global Positioning System (GPS) has proven to be an extremely useful tool for quickly assessing the severity and impact of damage caused by the disasters and help in finding one's bearings and in search and rescue procedures in the devastated regions. Satellite remote sensing is capable of providing information over large areas, and at short time intervals, that makes it an ideal tool for disaster management. Recent advancements in remote sensing and its application technologies made it possible to use remotely sensed imagery data for assessing vulnerability of an area and for capturing the damage distribution due to disasters [**4**]. We have illustrated with examples from different types of disasters, such as earthquake, flood, heavy rainfall etc. to demonstrate the role of remote sensing and how it can be significantly applied in defining a new trend and pattern for post-disaster damage assessment. We hope that the readers may enthusiastically support the idea of exploring the notion of remote sensing imagery in monitoring and managing the risks and losses from disasters in their regions and take forward our attempts for

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introducing applications of remote sensing and GIS as a potential tool from here to throughout the world.

Study Area: The present research paper are mainly focused on the following notable disaster Areas like – (A) Kedarnath Disaster due to Flash Floods (**Source:** Report published by Indian Red Cross Society**)**: Kedarnath town in Uttarakhand State, being located on the outwash plain between the Saraswati and Mandakini River. (B) Nepal Disaster due to Earthquake (**Source:** Emergency appeal final report, Nepal Earthquake, 2015): This area is located near Lamjung, about 50 miles northwest of Kathmandu and it is felt throughout central and eastern Nepal mainly. (C) Disaster in Northern India due to floods (**Source:** AP News, Lucknow, Uttar Pradesh, India): In June 2013, a mid-day cloudburst centered on the north Indian state of Uttarakhand caused devastating floods. (D) Chennai Disaster due to heavy Rainfall (**Source:** BBC News): It is located mainly all over Chennai city on the Coromandal coast region of the south Indian state of Tamilnadu.

Objectives: The main objectives of the present study are as follows –

1. An attempt to bring to your knowledge about the applicability of Remote Sensing and GIS techniques integrated with GPS in disaster assessment.
2. To defining a new trends and pattern of post-disaster damage assessment and its management throughout the satellite imagery with the help of Remote Sensing and GIS techniques.
3. To introducing the applications of Remote Sensing and GIS techniques as a potential tools for disaster monitoring and its mapping.
4. To justify the analysis of Remote Sensing techniques along with GIS are of significant use in pre-post disaster monitoring and management.

Sources of Data, Data Collection and Research Methodology: The present research paper has been based on remote sensing satellite imagery as well as field observation. To analyze the disaster scenarios, mapping of disaster monitoring, to detect the changing pattern of before - after disaster areas and its impact on human life as well as proper management of disasters is based on the research methodology of remote sensing and GIS techniques with the help of satellite imagery of the study areas which is acquired by the Digital Globe Spacecrafts and LANDSAT 8 Onboard Operational Land Imager (OLI) sensor to give a visual look for the present study.

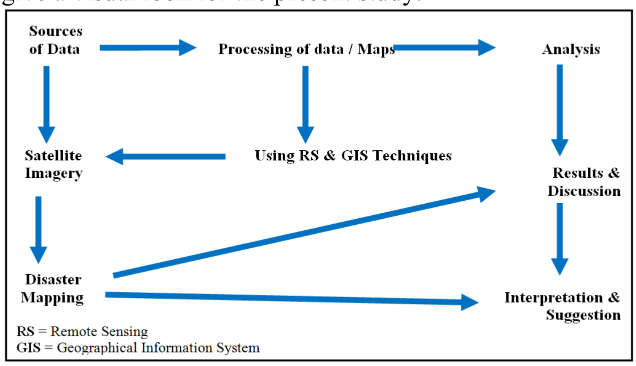

Figure no. 1 Flow Chat of Sources of Data, Data Collection and Research Methodology

RESULT AND DISCUSSION

In the following sections, use of remote sensing and GIS for four types of natural disasters is discussed. The images utilized here have been processed by GIS.

Kedarnath Disaster - Flash Flood: During 15th to 17th June 2013, excessive monsoon rainfall and outbursts from a moraine-dammed lake caused catastrophic flooding of Saraswati and Mandakini Rivers in the Indian state of Uttarakhand. Kedarnath town, being located on the outwash plain between the Saraswati and Mandakini rivers has undergone severe devastation, destroying hotels, rest houses and shops around the temple in the township, and resulting in severe casualties and severe deaths. In total, the death toll has reached around 5,700 with all those missing since flood devastated the town was presumed dead. Using the remote sensing imagery of 9th November 2011 and 14th December 2013 acquired by the Digital Globe spacecrafts, we try to demonstrate the pre-and-post scenario of the Kedarnath site (Figure no.2).

Source: Images are taken from 'Google Earth'

Figure no. 2: Scenarios of Kedarnath site before (left image) and after (right image) the flash flood.

Figure no. 2 Shows that the view of Kedarnath area and the town settlement before (left image) and after (right image) the flood. Note the devastation caused to the area on being washed away by the mud discharged during the flash flood. Arrow symbol (Yellow colour) denotes the location of Kedarnath temple.

Source: Photographs are taken from 'Google Earth'**.**

Photo. No. 1 Rescue operation by the military force (left photo.) and collapse of building (right photo.) into the water in Kedarnath site after the flash flood.

Nepal Disaster – Earthquake: On 25th April and May 12th 2015, Nepal was hit by massive earthquakes (also known as the Gorkha earthquake) measuring magnitude 7.8 and 7.3 respectively that killed more than 8,800 people and injured more than 23,000. Apart from Nepal, deaths were reported from India, China, Bangladesh, on Mount Everest (due to avalanches), and in the Langtang Valley (due to landslides). It is understood based on U.S. Geological Survey's explanation that the catastrophic earthquake in Nepal occurred as a result of convergence between two tectonic plates: the Indian plate and the overriding Eurasia plate to the north. Within Nepal, i.e. already not a very developed nation, several houses and lives were destroyed as a result of this earthquake, which subsequently left the survivors far behind the economy line from where it is difficult to raise and began their life.

Kathmandu, the capital city of Nepal, regarded as one of the popular tourist places in the nation, has suffered extensive damage to its landmark buildings and temples, some in world heritage sites. Dharahara Tower (~ 62 meters tall), popularly known as Bhimsen Tower, built at the center of Ghiring Sundhara in Kathmandu was destroyed and now only the base of the tower remains after most of it collapsed in the 7.8-magnitude earthquake. We show the destruction of Dharahara Tower in Figure no.3 using the remote sensing imagery acquired by the Digital Globe spacecrafts on 25th October 2014 and 3rd May 2015 respectively.

Source: Images taken from 'Google Earth'

Figure no. 3 Situation of Dharahara Tower before (left image) and after (right image) the assive Earthquake in Nepal which is shown by the yellow arrow.

Figure no.3 shows that, Note the devastation caused to the famous ~62 meters tall Dharahara Tower that collapsed to its base in the 7.8 magnitude earthquake. The arrow symbol (yellow colour) points the location of the tower. The figures are not to scale.

Source: Image are taken from 'Google Earth'

Figure no.4 Epicentre of Earthquake.

Source: Photographs are taken from 'Google Earth'.

Photo. No. 2: Chaotic situation in Kathmandu city for Collapse the buildings (left photo.) and the main highway are damage (right photo.) due to the magnitude of earthquake in Nepal.

Floods in Northern India: Unusually rigorous monsoon rainfall has caused devastating floods in northern India in middle of June 2013. As a result, extremely high waters, particularly in the Uttarakhand, destroyed roads and houses, killed nearly 600 people, and left missing tens of thousands over remote locations on the edge of Himalaya. Using combination of false color images of visible and infrared wavelengths, acquired by Landsat 8 Operational Land Imager (OLI) sensor, we have tried to show the variations observed in the Ganges and Yamuna rivers. In the figures, water appears cyan to blue, vegetation, forest is in red, and the sediments appear bluish white. Traces of clouds appear in white.

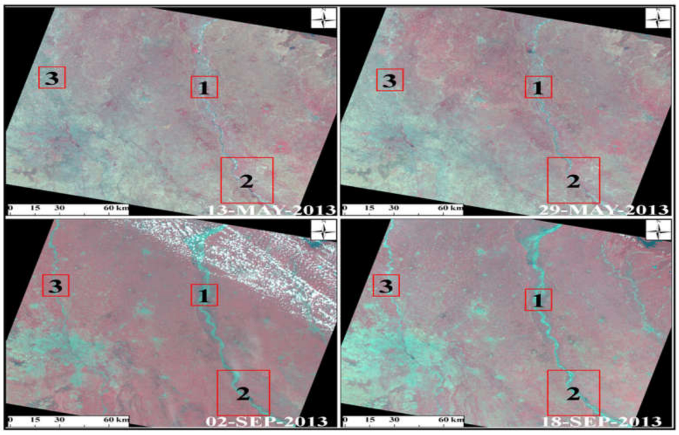

Figure no. 5 Significant changes in the river channel extent of Ganges and Yamuna due to floods.

On the basis of Figure no.5, the temporal images acquired by Operational Land Imager (OLI) sensor onboard the Landsat 8 spacecraft. The regions where we noted significant changes in the river channel extent is marked within red boxes as insets 1, 2 and 3. The expanded view of the insets is shown in Figure no.6.

To demonstrate the observed changes, we have utilised four false color images. We could decipher from our observations that later by the middle to end of September month, the flooded river channels have started to return to its original flow extents, as it was in the early May month images. While during the transition from May to September, i.e. during the end of May and in June to August to early September, the river channels have undergone severe flooding due to the unusual monsoon rainfall in the region. We present the changes from three portions of the Ganges and Yamuna river channels as shown in Figure no.5.

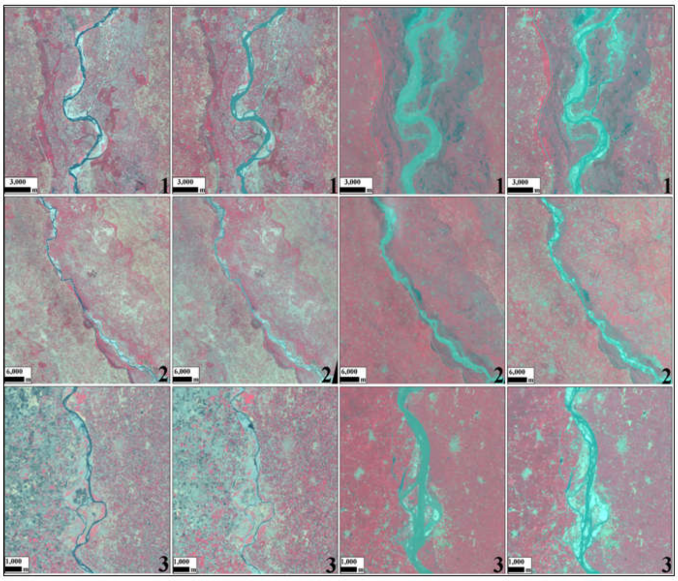

Figure no. 6 Expanded view of temporal changes in the width of the river channels by the cause of floods.

Figure no.6 shows that the detailed presentation of the changes observed along the river channels. The locations of parts 1, 2 and 3 are shown in Figure no.5. Parts 1 and 2 of the above figure demonstrate the changes in Ganges river portions and part 3 indicates the changes within Yamuna river portions. Note the significant temporal changes occurred in the width of the river channels during different times of image acquisition by the Operational Land Imager (OLI) sensor onboard the Landsat 8 spacecraft.

Source: Photographs are taken from 'Google Earth'.

Photo No. 3 Residential and parking areas are flooded (left photo.) due to the heavy monsoon rainfall in northern India and rescue operation of peoples (right photo.) in northern hilly regions.

Chennai Disaster - Heavy Rainfall: The unusual torrential rain on the first week of December over the Chennai city and in other part of Tamilnadu has led to a catastrophic disaster that never happened over the past 100 years. At least 250 people have died in this incident from the entire state. In Chennai, during the first week of December 2015 majority of the people started relocating themselves to high elevated region and especially away from the banks of the rivers. The heavy downpour on 1st December 2015 brought around ~272 mm rainfall. This seasonal rainfall filled almost all the water bodies in and around the Chennai city and especially the low lying areas in the region. The major water bodies in and around Chennai like Chembarambakkam, Cholavaram and Puzhal filled up quickly during this short span of time. The Adyar River, which flow across the entire Chennai city, was fed by the Chembarambakkam reservoir. The Chembarambakkam reservoir was open after it attained its full capacity, which led to a severe overflow in all the valleys and channels and especially in the Adyar River. The overflow from Adyar River caused severe damages to the settlement and buildings along the river boundary. Aftermath of 2004 Tsunami in Chennai, this severe rainfall has been the major cause for human relocation happened in recent past. The chaotic situation due to this heavy rainfall was felt by people who are living around the small/large water bodies. We have conducted temporal analysis of the Chennai city using the images acquired by Landsat 8 onboard Operational Land Imager (OLI) sensor (Figure no.7). We have chosen images acquired on 18th April 2014 and 2nd January 2016. In the false color images, water body appears cyan to blue, vegetation and forest appear red, settlement appear white to bluish white, and cloud appears white.

Figure no.7 shows that, the overall Chennai city along the coast of Bay of Bengal is shown. The areas that have been analyzed in detail are marked within red boxes as 1-5 and shown in the Figure no.8.

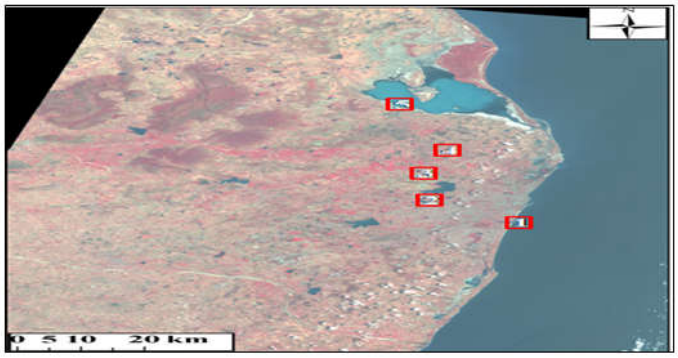

Figure no. 7 Site of Chennai city along the coast of Bay of Bengal.

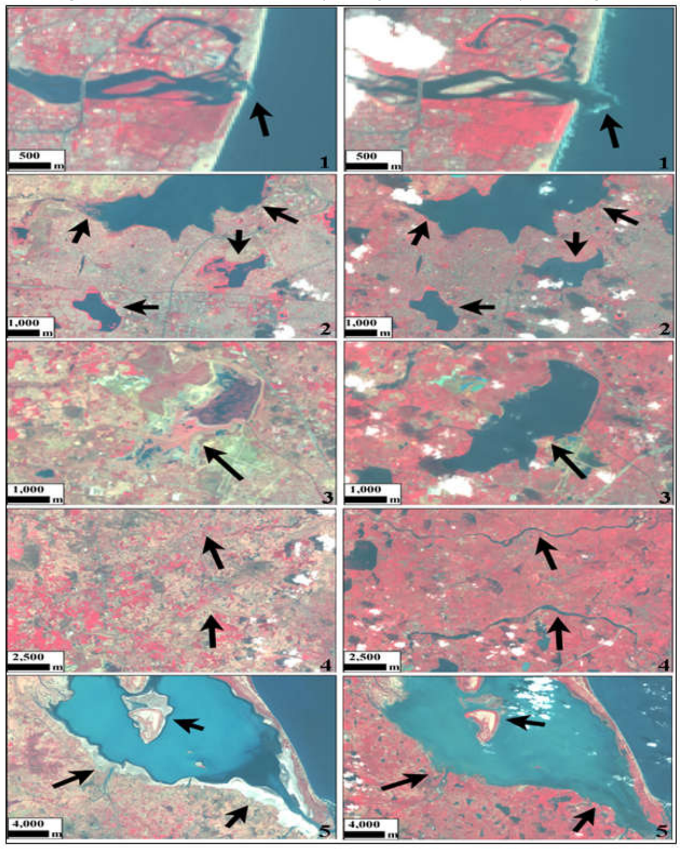

Figure no. 8 Adverse conditions in the overall Chennai city along the coast of Bay of Bengal after the heavy rainfall.

Figure no. 8 explain the following features

1. Due to this heavy rainfall the Adyar River was over flowing for a week and this steady water flow made the river mouth to widen, which later drains into the Bay of Bengal.
2. The Puzhal Lake is one of the major sources of water supply to the Chennai city. The heavy downpour filled the lake and severely affected the settlements in and around the water body.
3. The Cholavaram Tank on the NE part of the Chennai city also supplies water to the city. The reservoir shows a drastic increase in the water level subsequent to the rainfall.
4. Small River channels showing considerable increase in the inflow subsequent to the heavy rainfall in the region.
5. Pulicat lake, known for its brackish water, shows diverse changes after the heavy rainfall in the region.

Source Photographs are taken from 'Google Earth'.

Photo. No. 4 Shift of the peoples from flood affected areas by the rescue operation volunteers (left photo.) and high run-off surface of water due to heavy rainfall over the main road (right photo.) in Chennai city.

RS and GIS are use as a Potential tool for Disaster Monitoring, Assessment and Management

In this article, we have been able to bring out certain significant landscape differences using the remotely acquired temporal images of Kedarnath, Kathmandu, Ganges and Yamuna rivers, and Chennai after the disaster event. We could justify from our analysis that remote sensing and techniques along with GIS are of significant use in disaster monitoring and management. Remote sensing can be used as a tool of mapping flooded area [**5**]. We suggest the following for the readers from state universities, institutes, colleges, and government and semi government organizations:-

- The remotely acquired images from LANDSAT 5-8 and TERRA ASTER spacecrafts are freely available for download on the web. Interested readers should develop action plans for utilizing them in monitoring and management of the natural and human made disaster events. This will help to a greatextent in reducing the extent of loss to life and property in the region.
- Techniques like remote sensing and GIS, which help to identify the disaster prone regions, should be zoned according to the magnitude of risks to life and infrastructure, and plans should be developed to carry out imulation based analysis of the extent of damage that may happen subsequent to different types of disaster events. This would assist to a great extent in providing help during the initial stages of search and rescue operations subsequent to the disaster event.
- Communication networks should be developed for providing warnings before the disaster, and for helping in creating certain level of awareness that may help in reducing panic, confusion, and the induced mental stress.
- There is still a lot of study and research to be carried out for developing a robust, fully functioning and efficient Spatial Disaster Information System (SDIS) that may provide initial assistance prior to the onset of the natural calamities such as earthquakes, cyclones, floods, rainfall etc. From our efforts to form small disaster monitoring and management groups within the colleges, universities and organizations, the global dream of making a capable team for an immediate prevention, preparedness, relief, rehabilitation, reconstruction, and mitigation for any disaster and disaster affected areas could be definitely realized in the near future.
- Integrate damage assessment methodologies using remote sensing into internet- based visualization platforms, such as Google Earth or virtual Earth. By offering the results of these assessments via the internet, a much broader audience for these applications is possible [6].

Space systems can make substantial contributions in providing virtual information and services towards all three phases of disaster management [7]. Disaster management consists of two phases that take place before a disaster occurs; disaster prevention and disaster preparedness, and three phases that happen after the occurrence of a disaster; disaster relief ,rehabilitation and reconstruction. Disaster management is represented here as a cycle, since the occurrence of a disaster event will eventually influence the way society is preparing for the next one [8].

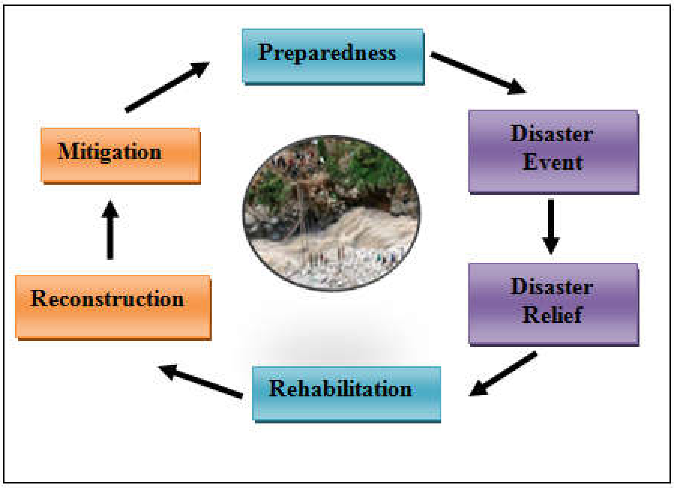

Figure no. 9 The Disaster Management Cycle

CONCLUSION

Many disasters caused damage to human life and property all over the world in various forms. The scientific and technological development plays a significance role for overcome the present as well as upcoming disasters scenarios. On the basis of above discussion we can say that the recurring occurrences of disasters such as Kedarnath Flash Floods, Nepal Earthquake, floods in Northern India and Chennai Heavy Rainfall need to be studied using today's advanced technology to find out the effective preventive measures. As an advance technology remote sensing and GIS along with GPS has applicable as a potential tool for the disaster monitoring in such above cases and its applications not only at global scale but also at local scale.

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