Role of Recent Technology in Disaster Management

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Abstract- Natural disasters are extreme events within the earth's system that result in death or injury to humans, and damage or loss of valuable goods, such as buildings, communication systems, agricultural land, forest, natural environment etc. For the management of natural disasters a large amount of multi -temporal spatial data is required. Satellite remote sensing is the ideal tool for disaster management, since it offers information over large areas, and at short time intervals. Although it can be utilised in the various phases of disaster management, such as prevention, preparedness, relief, and reconstruction, in practice up till now it is mostly used for warning and monitoring. During the last decades remote sensing has become an operational tool in the disaster preparedness and warning phases for earthquake, volcanoes, landslides, hurricanes, tsunamis, and floods. The use of remote sensing data is not possible without a proper tool to handle the large amounts of data and combine it with data coming from other sources, such as maps or measurement stations. Therefore, together with the growth of the remote sensing applications, Geographic Information Systems and Web Technology have become increasingly important for disaster management. This paper gives a review of the use of remote sensing, GIS, and Web technology for a number of major disaster types.

Keywords: Natural Disasters, Earthquakes, landslides, volcanoes, Remote Sensing, GIS, Web Technology.

1. INTRODUCTION

Geo-information Technologies (GIT) are playing a significant role for an efficient management of natural disasters all over the world. Among them space technologies are prominent for geo-information acquisition in an efficient and timely manner. This paper is focused on the potential uses of GIT for natural disaster management of various natural hazards and disasters. The GIT includes Remote Sensing (RS), Geographical Information Systems (GIS), GPS, Web technology etc. The use of remote sensing and GIS has become an integrated, well developed and successful tool in disaster management. Spatial analysis of hazard is a complex task, as a number of factors play important role in the occurrence of the disastrous event. Therefore, analysis requires a large number of input parameters for pre-disaster, disaster and post-disaster phases. The increased availability of Remote Sensing data and GIS functionalities in these times have created opportunities for a more detailed and rapid analysis of natural hazards. These enabling technologies are also the core of comprehensive natural disaster management system that covers disaster's monitoring, modelling, mitigation, rescues operation management, and rehabilitation strategies development etc. It is almost impossible to fully control the disasters, but a suitable strategy can be developed for disasters management using GIT in conjunction with conventional techniques. Numerous projects have been initiated in the country for these purposes. The proper structure of information system for disaster management should be available to tackle the disaster and to integrate all the data sets in all such projects.

1.1 Earthquakes

The earthquakes can occur in cycles of decades or centuries. Scientists of the U.S. Geological Survey (USGS) have operated seismographic stations throughout the world for more than 35 years. For the past few years, in cooperation with the Incorporated Research Institutions for Seismology (IRIS - a consortium of more than 90 universities), the USGS has upgraded the system into a state-of-the-art Global Seismographic Network (GSN). The GSN is designed for obtaining high quality data in digital form that can be readily accessed by data users worldwide. For some stations, the data is reported to orbiting satellites, and then to the Internet where information can be viewed using the World Wide Web.

Remote sensing techniques can add-up to the information available through seismic techniques. Generally, the faults associated with earthquakes can be identified on good resolution satellite imagery, whereas the volcanic related earthquakes are not all that obvious [7]. For this purpose land use and geological maps can give vital pointers towards potential earthquake zones. Satellite sensors that are active in the visible and near infrared spectral band would be useful. LANDSAT imageries are more popular because of the long historical data archives of the satellite and its cost effectiveness. Conventionally, aerial remote sensing (airborne radar) would be thought as more effective to delineate unconsolidated deposits sitting on fault zones, upon which most of the destruction occurs, and to identify areas where an earthquake can trigger.

1.2 Volcanic Eruptions

There are some 500 active volcanoes around the globe, about 100 of which erupt every year Volcano monitoring is important simply because an unexpected awakening can imperil thousands of lives over a wide area. Remote sensing techniques can play an important role by providing the vital information with only limited fieldwork, which saves effort and money. Thermal infrared (TIR) imagery can capture the volcanic heat provided the spatial resolution is high enough. Also, PAN stereo-pair imagery, due to its 3-D capabilities, of moderate resolution would serve the purpose of finding out the evidence of hazardous activities. An IR pattern of geothermal heat in the vicinity of a volcano is an indication of thermal activity, which many inactive volcanoes display. Many volcanoes thought to be extinct may have to be reclassified if regular monitoring discovered any abnormally high IR emissions from either the summit craters or the flanks. Changes in thermal patterns can be obtained for a volcano only through periodic IR imageries of very high resolution, like that of IKONOS, taken under similar conditions of data acquisition. The temperature and gas emission changes, however, can be monitored, through a geostationary satellite, at ideal locations identified on the thermal imagery. In a case study conducted by [6], satellite thermal estimates from six scenes were first compared to ground measurements of maximum daily temperature. The results show that the estimated model parameters from the various methods are quite different and the fitting of the experimental points to the theoretical model is much better when using continuous satellite data. This finding has interesting implications for the more general problem of defining standard optimum interpolation methods, which would ultimately help in volcano monitoring methodology. LANDSAT, SPOT-4 and IRS-1D imagery is a valuable aid in detecting the volcanic activity. Once alerted by early-warning systems, specialists need to monitor levels of volcanic activity continuously so that timely precautions can be taken. The level of energy detected is the sum of reflected and emitted energy. The energy emitted by lava makes it visible in the NIR band but not in the red band. However, the fact that hot SPOTs are equally well detected at night shows that reflected energy only accounts for a small portion of the total energy measured. This property proves useful in determining the temperature of hot SPOTs, lava flows and intense volcanic activity. [5] has shown that water surface temperature and area can be measured simultaneously by using all seven spectral bands of LANDSAT Thematic Mapper (TM).

Volcanologists' were able to monitor rapid variations in volcanic activity when the volcanoes entered a dangerously active phase. The study was able to develop and test a methodology for monitoring volcanoes that is reliable, offers high performance, and enables volcanologists' to significantly reduce the amount of field work.

1.3 Tsunamis

Tsunamis are water waves or seismic sea waves caused by large-scale sudden movement of the sea floor (due to earthquakes; landslides; volcanic eruptions or man-made explosions). With increasing population and development along most coastlines, there is a corresponding increase in tsunami disaster risk in recent years. In the past, acquiring tsunami damage information was limited to only field surveys and/or using aerial photographs. In the last decade, remote sensing was applied in many tsunami researches, such as tsunami damage detection. Satellite remote sensing can help us survey tsunami damage in many ways. In general, the application of remote sensing for tsunami disasters can be classified into three stages depending on time and disaster-related information. In the first stage, general damage information, such as tsunami inundation limits, can be obtained promptly using an analysis combined with ground truth information in GIS. The tsunami inundation area is one of the most important types of information in the immediate aftermath of a tsunami because it helps estimate the scale of the tsunami's impact. Travel to a tsunami-affected area for field surveys takes a lot of time, given the presence of damaged roads and bridges, with much debris as obstacles. In the second stage, detailed damage interpretation can be analyzed; i.e., classification of the building damage level. Recently, the quality of commercial satellite images has improved. These images help us clarify, i.e., whether a house was washed away or survived; they can even classify more damage levels. The third stage combines the damage and hazard information obtained from a numerical simulation, such as the tsunami inundation depth. The damage data are compiled with the tsunami hazard data via GIS. Finally, a tsunami vulnerability function can be developed. This function is a necessary tool for assessing future tsunami risk. Satellite or aerial photography, especially when combined with a good GIS database of an area, can provide critical information for emergency managers, including damage to structures, transportation and communication links, and other "life-line" infrastructure components. Among the various sensors, SAR (Synthetic Aperture Radar) is remarkable for its ability to record the physical value of the Earth's surface [1]. Unlike passive optical sensors, SAR enables the observation of surface conditions day or night, even through clouds. SAR interferometric analyses using phase information have successfully provided quantification of relative ground displacement levels due to natural disasters [2].SAR images are widely used to determine tsunami-affected or inundated areas using the reflection property or backscattering coefficient.

1.4 Hurricanes

Remote sensing and GIS play an important role in the mapping and mitigation of hurricanes. There is always the fact that when a place is hit by a hurricane it becomes less feasible and less accessible. In this case we need to adopt the techniques of remote sensing and GIS. The data from different satellite sensors are obtained for this purpose. GIS software Arc GIS is essential in case of mitigation measures. As the hurricanes have proven to be one of the most devastating natural hazards, it’s indeed very essential to study its mapping and mitigation. Remote sensing techniques have increased the scope for effective mitigation of affected areas. Evaluation of the damage is important in case of restoration methods. The plight of the residents who remained in the city became evident as the storm passed and the extent of damage became known. Thousands of residents, most of whom did not have access to a personal vehicle or were housed in institutions such as hospitals or prisons, suffered in squalid conditions waiting for relief, while many others died in what were considered evacuation shelters.

Remote sensing systems have already proven their worth for observing storms and their effects on coastal communities [4]. However, to select the best set of remote sensing systems one must first define the requirements of key users, such as storm forecasters, emergency evacuation managers, coastal engineers, and various responsible officials at the city, county, state, and federal levels. With the wide variety of remote sensing systems available, choosing the proper data sources for tracking coastal storms and monitoring their impact on coastal urban communities can be challenging.

To predict the path and landfall of a hurricane or other coastal storm and assess the damage, emergency managers and scientists need continuous information on the storm’s path, strength, predicted landfall, and expected damage over large areas. Satellite and airborne remote sensors can provide the required information in a timely and reliable way, as demonstrated by a case study of hurricane Katrina’s impact on New Orleans and surrounding areas. Satellite images and hurricane hunter planes were used to track hurricane Katrina, with models predicting accurately its path, strength, surge level, and landfall location. Shore-based radars were used to confirm the data as the hurricane approached land. Medium- and high-resolution satellite sensors, helicopters, and aircraft were employed to assess damage to the city.

1.5 Landslides

Monitoring landslide activity over extensive areas is of paramount importance for landslide hazard and risk assessment. Landslide monitoring is generally accomplished by field-based geodetic, geotechnical and geophysical techniques complemented with aerial photo-interpretation [3]. Most field techniques, however, only provide point-based measurements of the landslides. In addition, they do not give information on past movement episodes. Although ground-based techniques are necessary to acquire very precise information on displacement or deformation at very specific locations in active landslides, especially when they might affect residential areas or major infrastructure, they do not provide information on the displacement fields or surface changes due to land sliding in a wider area. Moreover, their application to preliminary investigations of unstable areas may sometimes not be cost effective. From visual interpretation of sequential analogue aerial photo stereo pairs, evidence of recent slope movements over relatively wide areas can often be inferred [8]. This technique, although still useful, does not automatically and geometrically precisely determine the evolution of landslide features. The capability of non-photographic remote sensing to provide information on ground surface conditions over extensive areas is well accepted. Differential Synthetic aperture radar (SAR) interferometry from space borne platforms has been capable of measuring landslide displacement fields of centimetric order over relatively large areas.

Analytical and digital aerophotogrammetry has been used for measuring long-term landform evolution of rock glaciers and landslides from multitemporal digital elevation models (DEM) derived from sequential photo stereopairs.On non-stereoscopic digital imagery, efforts have thus mainly concentrated on extracting possible indirect landslide indicators such as land cover disruption patterns, specific sun-shading features of hummocky surfaces and scarps and a typical lithological occurrence patterns .The recent advent of IKONOS and Quickbird satellite imagery at very high spatial resolution, together with that soon to be delivered by similar missions, opens new perspectives for monitoring landslides. An image processing method has been developed to map ground-surface changes caused by slope movements, using multitemporal high-resolution optical remotely sensed imagery. The method includes change detection and thresholding of suitably pre-processed images acquired before and after the slope movement episode. It could be applied over extensive areas in most common mountain landscapes to complement information derived from well-established field techniques.

1.6 Floods

Application of remote sensing and GIS is convincingly a very efficient and cost effective way of flood management. Use of very high resolution imageries like IKONS or SPOT 5 have not been very popular yet in the field of flood management due to its high price, but it is likely that with these imageries would be available at a reasonable price and would be widely used for flood mapping. In the age of internet, GIS has assumed new dimensions, especially for coping with natural disasters like river flooding. The most important advantage of using internet based GIS is that it has opened the door of GIS technology to the end users who would not like to install expensive GIS software. One of the numerous examples is Arc IMS Technology. This technology has been used to develop a web enabled application named Map Action Processing Digital Interactive Geo Resource (MAPDIGR) for providing very recent information regarding flood risk to an analyst via internet [9]. This technology is at present at an embryonic stage of development but has great potential for expand the user base of GIS technology for flood management by substantially reducing the cost of operation. Since the problem of flood is very acute in the developing countries of monsoon Asia, special attention should be given to deal with this problem in the regional context. GIS models having low cost and simple data requirement are likely to attract the local authorities in the developing countries to adopt this technology as an essential input towards a comprehensive flood management system. In the age of all embracing flood plain management, these sophisticated technologies can be very useful for the planners to formulate effective strategy for combating the perpetual natural disaster of river flooding.

2.GEOGRAPHIC INFORMATION SYSTEM

Population increase and migration into areas under threat of natural hazards is a global concern. Earthquakes, tsunamis, volcanoes, cyclonic storms and floods endanger increasing populations and their sustaining agriculture. Geographic Information System (GIS) is a vital tool for making use of remotely sensed data for disaster mitigation. High resolution visible and SAR images are good for extracting topography and preparing land use maps of any area. Digital Elevation Model (DEM) and land use map are important inputs to flood simulation models. The remaining issues include different resolution scales, which are associated with data observed by the available sensors and their hydrological interpretation. The joint use of the various sensors is proposed in order to address the problem of quantitative precipitation forecasting at the small scale. The GIS data handling capability plays a major role in supporting the effectiveness of automated procedures eventually developed for flood hazard control in highly urbanized areas. Studies addressing the role of remotely sensed geographic information in mitigating "instantaneous" disasters, such as floods, have resulted in the following list of potential applications [13]:

- Establishment of susceptibility of the land and vulnerability of the society
- Mapping potential hazard areas for use in physical planning (hazard zoning maps)
- 3-Monitoring potentially hazardous situations and processes, providing advanced warning

- Improvement in management of emergency situations following a disaster.

3. WEB TECHNOLOGY

The fast developing web-technology has prompted the scientists, experts and educators to start developing web-based decision support tools that allow planners and other government decision makers to utilize a high-resolution DEM and floodplain related GIS data layers in making floodplain management decisions. Weather forecasts are based on satellite-captured images, which can be accessed through the Internet. Cyclones, tsunamis and hurricanes can be seen coming through the satellite images. Movement of high/low pressure winds can be monitored at 5-minute interval to help scientists simulate the future scenario. Forecasting and warning regarding natural disasters can easily be made available on the Internet. When any disaster seems to be occurring at one geographic location, Internet tools help the other locations in the world, where people and property might get affected by the same disaster in due course of time, take precautionary actions. Knowledge of flow rate and speed of an occurring flood helps predict its impact in other downstream areas. Similarly, cyclones, forest fires and volcano lava flow can be observed and monitored in real time using Internet tools. Thus the Internet technology has become a vital tool in disaster management through sharing of information. [10] coined the concept of Virtual Data Base (VDB) for the management of floods making use of the Internet technology.

The idea of VDB was conceived after the 1997 Red River floods, which prompted several other flood management and mitigation studies. Red River Basin Decision Support System (REDES), introduced by [11] was developed to enhance preparedness planning, response, and recovery with emphasis on flood prediction and monitoring, emergency response, and public involvement. According to the International Red River Task Force, use of passive and active microwave satellite images visible and infrared images are recommended for flood management and damage assessment.[12] have developed a tool using data for a small subdivision in St. Charles County in Missouri using digitally scanned National Aerial Photograph Program (NAPP) photos in conjunction with highly accurate ground control from a rapid-static Global Positioning System (GPS) survey. The design and Web technology part was done using Arc View and Map Server GIS software, Java, JavaScript, HTML and Avenue programming. This Web-based interface would allow users to interactively display and query different floodplain-related GIS layers so as to know whether a parcel is within or outside the 100-year floodplain and determine the elevation of a particular point as well.

4. CONCLUSION

Natural disasters cause damage to life and property all over the world in various forms. The pressure on the earth's resources caused by increased population has resulted in increased vulnerability of human and their infrastructure to the natural hazards, which have always existed. The result is a dynamic equilibrium between these forces in which scientific and technological development plays a major role. Recurring occurrences of earthquakes, floods, landslides and tsunamis need to be studied using today’s advanced technology to find effective preventive measures. Space technology can help the disaster mitigation process through better future scenario predictions; detection of disaster prone areas; location of protection measures and safe alternate routes etc. Post-disaster satellite data acquisition helps in disaster recovery; damage claim process and fast compensation settlement. Various satellites and sensors on-board provide with numerous possibilities of analyzing the data for disaster prediction and mitigation purposes. The nature of the natural disasters determines the suitability of sensor types, spectral bands, active or passive radar data and their spectral, temporal and spatial resolutions. Impact of land use on natural disasters and ability to predict them would be one of the main contributions of remote sensing technology in this century.

Integration of remote sensing with GIS and web technology makes it an extremely powerful tool to identify indicators of potential disasters. Information sharing through Internet reduces data acquisition time and thus providing efficient way to carry out real-time disaster predictions (floods, earthquake, landslide, tsunami and hurricane etc.). Changing land use and assessment of its impact on the system in general within reasonable time frame and with greater degree of accuracy becomes possible with new technology. Investment towards making use of the space technology is worth because improvement in instrumentation and real time prediction will bring about reduction in disaster damages; better prediction; accurate and timely damage estimation; and improved decision making in planning stages.

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