Research Article

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Geo-environment and related Disasters – a Geo-spatial Approach

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ABSTRACT

Natural disasters have become fast-growing epidemics around the world in general. The disasters like earthquakes, landslides, floods, cyclones and other coastal hazards are already crippling the development and growth of the country. In the recent decades, the "Earth Observing Satellites" are producing unparalleled pictures on various spectral, spatial and temporal resolutions, whereas the fast-emerging "Geospatial Technology" (GIS) has proved its credentials beyond doubt in storing, manipulating, modeling and visualizing various phenomena related to Earth System Dynamics. In this context, an attempt has been made in this work to map and discuss the disasters like earthquakes, landslides, soil erosion, floods and cyclone on their pattern and spatial variation. The geomatics-based integrated terrain analysis, leads to the detection of landslide-prone areas, causative factors, and predictive models. Flood is yet another major disaster causing a greater impediment to countries, which are aspiring to grow faster. Though methodologies have been developed for flood hazard zonation mapping, the geomatics has not been utilized to its fullest level. The geospatial databases are critical inputs for studies in the emerging area of environmental monitoring, global warming and climate change.

Keywords: Natural disasters; GIS; Soil erosion; Flood.

1. INTRODUCTION

Natural disasters are unavoidable, yet repairing the damage they wreak is often difficult. However, adopting early warning systems, formulating and executing developmental plans to give resilience to such disasters and assisting in rehabilitation and post-disaster reduction can all help to reduce the potential risk. Natural hazards like earthquakes, landslides, floods, cyclones, drought, forest fires and volcanic eruptions have been caused by the vagaries of nature, often aggravated by human intervention and they have widespread devastation. The geoinformatics of natural disaster management can be successful only when detailed knowledge is obtained about the expected frequency, character and magnitude of hazard events in an area. Huge economic losses attributed to such disasters in poor nations have been estimated to be as high as 10% of GDP in the past. Landslides, earthquakes, cyclones, floods, forest fire, etc., are the natural hazards that cause extensive damage in the country every year. Space technology can play a significant role in natural hazard prediction, assessment, monitoring and mitigation. India, with its varied geographical, geological and climatic conditions, is affected by major hazards/disasters - cyclones in the east and west coastal areas, floods in the river valleys of Ganga - Yamuna, Brahmaputra, Godavari and Krishna and earthquakes in the Himalayas, drought in the major arid and semi-arid tracts of Central/Southern India. Considerable understanding has been gained in recent times on the evolution and characteristic features of natural hazards. Although natural disasters have shown a drastic increase in magnitude and frequency in the last decades, it can be observed that there is a dramatic improvement in the technical capabilities to mitigate them.

Space technology creates a database from which the evidence left behind by previous disasters can be evaluated and merged with other data to create hazard maps showing potentially harmful areas. The variability of landscape features including vegetation, water and geology in place and time can be mapped using remotely sensed data such as imageries and aerial pictures. Disaster warning and relief mobilisation are provided by communication satellites, while Earth observation satellites offer the necessary database for both pre- and post-disaster preparedness programmes. They give real-time and regular coverage of huge areas which is comprehensive, synoptic and multi-temporal. The Geographic Information System (GIS) has made it possible to conduct a more complete and timely examination of natural disasters. GIS database may be utilised to provide detailed and effective Disaster Management Information. Environmentalists can use a GIS-based Decision Support System (DSS) to create and simulate additional information on environmental characteristics with the help of a sophisticated modelling system. Data warehousing and analysis is one of the most important aspects of a spatial DSS. GIS works as a front–

end for a disaster management database, giving it the ability to respond to user requests for precise information. GIS allows different types of geographical data to be combined with non-spatial data and characteristic data for use at various phases of catastrophe management.

2. NATIONAL AND GLOBAL SCENARIO

Understanding the dynamics of earth surface processes requires the use of remote sensing (RS). Remote sensing has a wide range of applications in monitoring the effects of human activities on the environment. RS is a useful method for identifying high-temperature earth phenomena including coal mine fires, surface fires and volcanoes. Satellite data is being used to monitor a number of environmental threats, including a coal fire and subsidence due to mining operations. Periodic monitoring of coal fires in coal fields in India, China and Africa can be aided by satellite-based thermal data from medium resolution thermal channels like ASTER. Microwave data (ERS data, Radarsat-2) acquired in tandem can aid in identifying the subsidence caused by mining activities. Furthermore, microwave data (ERS data, Envisat ASAR, Radarsat-1 and 2) are extremely useful for mapping natural and man-made oil slicks. The most common use of thermal remote sensing lies in identifying coal fires and calculating their geographic extent and temperatures. Remote sensing-based coal fire detection and monitoring became practical in the 1960s, when airborne thermal sensor data and then satellite-borne thermal scanner data became accessible (Gangopadhyay *et al.* 2005). Pixel-integrated NDVI data collected from medium to high-resolution space-borne sensors such as TM/ETM, IRS/LISS and others have been shown to be suitable for calculating average emissivity of land surface classes in a later stage of study. The average value of thermal emissivity and the normalized difference vegetation index (NDVI) for varied surface covering are shown to have an empirical relationship (Van de Griend and Owe, 1993). This empirical relationship has been proved from the field measurement of both the parameters.

2.1 Earthquake and Environment

Earthquakes are known to cause extensive damage and are among the most unpredictable of natural disasters. It is estimated that about 50% of Indian sub-continent is subjected to varying degrees of earthquake hazard, which is simply demonstrated by the fact that more than 750 earthquakes in excess of the magnitude of 5 have been recorded in this domain during the last century. Majorities of these are located in the Himalayas, seismically one of the most active intercontinental regions in the world. Remote sensing data has been found quite useful in assessing the surface changes subsequent to the earthquake, damage assessment and morph structural zoning. It is also mapping of active faults using neotectonic studies with the use of LANDSAT TM / SPOT, IRS or Radar and in the measurement of fault displacements using SLR and GPS. In seismic micro-zonation, the use of satellite remote sensing is very limited as the data is derived from the accelerometer, geotechnical mapping, groundwater modeling and topographic modeling at large scales.

Earthquake risk assessment include gathering geological/structural, geophysical and geo-morphological data, as well as mapping known seismic events in the area, to identify seismic zones.

In the phase of disaster relief, pre- and post-remotely sensed data, PAN and IKONOS data are useful in assessing the surface changes subsequent to the earthquake and damage assessment like landslides, major fissures and cracks and land use/land cover changes; structural damage to buildings are also observed. A comprehensive GIS-integrated remote sensing visualization models on the earthquake scenario, the demarcation of seismic corridors, micro-seismic zonation of vulnerable cities etc. are possible. For landslides, GIS-based models so for done have led to the invention of new genetic slope mapping and slope stability analysis.

2.2 Landslides and Environment

The landslide can be rampantly disastrous in mountainous systems of several parts of the world (Davison, 1889; Wentworth, 1943; Varne, 1958; Bartarya and Valdiya, 1989; Kelarestaghi, 2003). This phenomenon is being witnessed more in mountainous systems of faster urbanization, tourism and industrial developments. Hence, scientists, technocrats and planners have concluded that anthropogenic activities, in general, are the prime contributors to landslides (Ramasamy and Muthukumar, 2008). Various earth system processes and the related land systems *viz*, lithology, structure and tectonics including neotectonic, geomorphology, land use/land cover dynamics and hydrological dynamics assign different grads of landslide vulnerability to the terrain systems and rainfall and other anthropogenic activities act only as the triggering parameters for landslides. The Geostationary operational environmental satellites in combinations with land measurement sensors such as AVHRR (Advanced High-Resolution Radiometer) aid delineation of disaster events aftermath. The Synthetic Aperture Radar (SAR) Interferometry has provided the opportunity for preparing Digital Elevation Model for landslide-prone areas. The LIDAR holds a tremendous promise as it can provide very high-resolution terrain information and terrestrial photogrammetric survey: a technique of preparing large-scale maps during landslide hazard zonation mapping in the hilly areas; normal satellite data and infrared imagery and Orthophots are also being used for landslide studies. There are numerous approaches for hazard zonation mapping. The study area landslide types are mapped by large-scale spatial data, pale scars and field survey in GIS environment. From the distribution data, all the landslide morphology can be measured through spatial data and ground measurement and then the thematic layers are generated for landslide controlling parameters. The following are the contributing parameters to be generated - subsurface geology, lineaments, geomorphology, slope, soil types, drainage, groundwater, rainfall, area of toe removal and land use/land cover. After the preparation of this database, weightages for individual variables related to their vulnerability index are assigned. After assigning the weightages, all the thematic databases were classified into vulnerable and non-vulnerable for individual parameters. For example, after generating geo-morphologically controlled landslide vulnerable data, the parameters using GIS overlay function were integrated. The final integration will give a number of polygons by means of a piece of land with multivariate parameters loaded. Based on those parameters, the entire area will be regrouped and can be classified into, most vulnerable, moderately vulnerable and least vulnerable zones. The GIS will provide each parcel of land with what type of parameter is loaded. Based on the parameter loaded, the remedial measures can be suggested. Usually, remedial measures are adopted based on the influencing parameters loaded in the polygon. The remedial measures include - surface drains, placement of netting, construction of peripheral walls, creation of fractured filled vegetation, afforestation, parallel piping with perforated pipes and interconnecting catch water drains, nailing and concrete grouting, terracing, drainage channelling and stabilizing the bottom of the slopes.

2.3 Soil Erosion and Environment

Soil erosion is a natural geological phenomenon occurring due to the removal of soil particles by water, wind and human activities, transporting them elsewhere depending upon rainfall, topography, vegetation, soil and land-use practices. Soil erosion begins with detachment, which is caused by the breakdown of aggregates by raindrop impact, sheering or drag force of water and wind. Detached particles are transported by flowing water (overland flow and inter-flow) and wind and deposited when the velocity of water or wind decreases by the effect of slope or ground cover. Soil erosion estimate and spatial distribution are now possible with acceptable prices and greater accuracy across broader regions because to RS and GIS technologies (Millward and Mersey, 1999; Wang *et al*., 2003). Nuket Benzer (2009) has developed a geographic information system technique for spatial soil erosion evaluation based on the universal soil loss equation (USLE) and assessed the applicability of GIS in soil erosion mapping. Babita Pal and Sailesh Samanta (2011) have demonstrated how RS and GIS approaches can be used to predict soil loss based on a variety of characteristics. Tagore *et al.* (2012) has carried out investigation on mapping the areas with erosion using remotely sensed data (Kharif, Rabi and Summer Season) from the Indian Remote Sensing (RS) satellite (IRS P-6) LISS III sensor. For assessing the soil erosion-prone area of the study area, various thematic layers are considered. Each theme has different importance in the context of determining the soil erosion zones. The terrain parameters of each layer having different ranks zones of GIS and images were integrated using overlay function of Arc GIS by assigning suitable weightage factors. The weights are assigned to each category of the thematic layer. Hence, each thematic layer is assigned a rank, based on its influence on soil erosion. The different classes in each theme are assigned knowledge-based weightages. The lower weightage indicates a poor factor in causing soil erosion. The prevention of soil erosion, which means reducing the rate of soil loss to approximately the extent which would occur under natural conditions, relies on selecting appropriate strategies for soil conservation; this, in turn requires a thorough understanding of the processes of erosion. In the study area, each thematic layer was superposed with the soil erosion data one by one and their causative factors were detected through GIS; the high-rank areas are classified as vulnerable zone and the remaining areas as un-vulnerable zone for soil erosion for the concerned parameter. Based on the induced/influenced parameters, the remedial measures were suggested for individual or combinations of parameters such as rainfall, slope, drainage density, lineament, geo-morphology, soil types and land use. Pattern-controlled areas were identified accordingly; common remedial measures are sowing and planting, checking bunds, checking dams, gully plugs and water harvesting structures. Conservation of cultivable land can be achieved through preventive and remedial measures in order to control land erosion and degradation, by using alternative innovative agricultural technologies which involve the use of organic farming or green manures, bio-fertilizers and biological pest control. For the development activities in the built-up areas, the authorities should monitor and strictly adhere to the rules and regulation of construction of houses and buildings in the town areas and also other economic activities.

2.4 Flood and Environment

Flooding, on the other side, is a major geohazard which causes a series of damages on man and his properties. Flooding is mostly due to natural causes. However, it can be controlled by certain catchment treatment or drainage treatment mechanisms. In flooding, geology, geo-morphology and slope substantially contribute to the flooding. At some places, they accelerate run-off, and certain places reduce the run-off depending upon the terrain architecture. Sometimes the nature of rivers and their migratory pattern causes flooding (for example, Brahmaputra River). Human activity is another major influencing factor in flooding and related hazards; for example, construction of dams in improper sites, lack of a proper regulatory mechanism in water storage and release, deforestation, obstruction of drainage network, etc. Improper land use/land cover also contributes to flooding; in some of the coastal areas, deforestation of the mangroves has caused extensive flooding due to the storm surge.

The areas affected by floods are generally large in size. Many different types of flooding exist, with different requirements as to the satellite imagery. River floods can be seasonal floods related to large rivers or flash floods in the smaller catchment areas. Flooding is caused by a variety of circumstances, including rainfall intensity and duration, snow-melt, deforestation, poor agricultural practices, silt in the river bed and natural or constructed impediments. The following flow factors should be considered when assessing flood hazard: flood depth, duration, flow velocity, rate of rise and decrease and frequency of occurrence. The geo-spatial data provides timely, comprehensive and reliable information on flooded areas such as inundation phases, including duration, depth of inundation and direction of current, extent of damages to crops and property and prepare the flood hazard zonation mapping. This can be done with automated classification from IRS WIFS images. Furthermore, PAN merged data can be used in the geo-morphological mapping of the potential flood area; however, the most crucial data is derived from the calculation peak discharges and return periods from gauging stations. Radar images are very useful for mapping peak flood inundation areas, crop damage assessment.

2.5 Cyclones

In India, cyclones hit the east and west coast almost every year, resulting in severe loss of life, infrastructure and property. In our country, cyclones normally occur during April-May and October-December, though they may occur during the rainy season. The geo-spatial data can be utilized in three major aspects of cyclone hazard and its mitigation, such as tracking, monitoring and forecasting, damage assessment and preventive measures. The satellite observations in the tropical region are useful in tracking and monitoring of tropical storms. The economic benefit of providing early warnings of cyclones has more than amply justified the cost of the entire meteorological program. Tropical cyclone forecasting involves locating the position of the cyclone, assessing the present strength and predicting the future movement of cyclones in terms of speed and direction. INSAT system is being used routinely for forecasting cyclone activity and for emergency communication. However, the damage assessment capability of the Indian satellite is rendered ineffective due to persistent cloud cover during the period of the cyclone. SAR data from Radarsat has been effectively used for crop damage assessment. The same was useful in the study the environmental changes due to the impact of Thana cyclone in 2014 and Gaja cyclone in 2018.

3 CONCLUSION

The geo-spatial approach has advanced virtues in geo-environmental and natural disaster mapping and management for earthquakes, landslides, floodings, soil erosions and forest fires. Given the fact that hazards inflict severe damage to ecology, environment and economy of a region, apart from the loss of human lives, this technology has made a significant contribution in preparedness, prevention and relief.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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