GIS-based disaster management
A case study for Allahabad Sadar sub-district (India)


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Abstract

Purpose – This paper aims to demonstrate a Geographic Information System (GIS)-based study on development of District Disaster Management System for floods for Allahabad Sadar Sub-District (India).

Design/methodology/approach – An approach has been designed to explore the scope for the combination of Disaster Management and GIS. The flood-prone areas have been identified and their positions are marked using ArcView 9.1. GIS has been exploited to obtain the spatial information for the effective disaster management for flood-affected areas.

Findings – ArcView 9.1 has been used as a tool for storing all types of relevant data for analysis and decision making. The various thematic maps include road network map, drinking water sources map, land use map, population density map, ward boundaries and location of slums.

Originality/value – The paper proposes evelopment of a GIS-based early response system, and an emergency preparedness plan for the Allahabad Sadar sub-district and also analysis of the impact of flood disasters in the region and its relationship to infrastructure development with a view to identifying how local governing bodies could be helped in addressing these issues. The proposed GIS-based flood mitigation and management program would improve the current practices of disaster management process. If implemented properly, it would result in proper and quick decisions for the rescue and safety of the general public, which in turn would help in minimizing loss of life and property.

Keywords Geographical Information Systems, Disasters, Floods, India

Paper type Case study

1. Introduction

A disaster is defined as an event (happening with or without warning) causing serious disruption to the functioning of a community or a society, means of causing or threatening death, injury or disease, damage to property, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources (DKKV, 2002). Owing to increase in the amount of research going into disasters and their management and mitigation, almost all the definitions have more or less been talking about human sensitivity towards natural or man-made or environmental hazards. Disasters are classified into three types: natural, man-made, and hybrid disasters and they are mix of both physical factors (such as intense rainfall over a short period) and other social and economic factors (such as poverty, population growth, etc.). Disasters have different characteristics and impact; however, disasters
have a common element, which is their severity. People are described as vulnerable to disasters depending on the extent to which they are likely to be damaged or life disrupted by the impact of a disaster hazard. Vulnerability to a disaster usually follows a progression arising from such factors as poverty, a lack of infrastructure, and a fragile environment. Vulnerability to disasters is also closely linked to the history, politics, social and economic conditions that shaped the circumstances in which people find themselves.

On an average 4,888 people are killed and 59 million get affected annually from various types of disasters (International Federation of Red Cross and Red Crescent Societies, 1994). The recent document of Swiss Re reports that in 1999 alone, natural and man made disasters killed more than 1,05,000 people and resulted in US$100 billion economic loss. The ability to react to these disasters, whether by government or individual is not tested very often, and many times when it is, chaos usually reins for a short period until authorities can fully mobilise and take affirmative action. The importance of uncertainty in natural hazard risk management has received recent attention (Goodchild, 1991; Newkirk, 1993; Rejeski, 1993; Coppock, 1995; Handmer, 1995; Davis and Keller, 1997).

Figure 1 Presents both the manmade and the natural disaster victims during period 1970-2007. The observation is that there is continuous growth of man-made disasters due to human activities. The impact of natural catastrophes on societies has increased considerably over the last two decades, driven by climate change, population growth and expanded economic activity. While average insured catastrophe losses between 1970 and 1989 were USD8.3 billion per annum, these losses went up to USD32 billion per annum between 1990 and 2007.

The natural disasters have become fast recurring phenomena all over the world causing huge loss of human lives and crumbling impact on the economy of a country. Swiss Re’s latest sigma study, “Natural catastrophes and man-made disasters in 2006”, recorded 349 catastrophes. In 2006, natural catastrophes and man-made disasters
claimed more than 31,000 human lives worldwide. Unlike in the two previous years, natural catastrophes affected mainly developing countries where property values are low, resulting in comparatively light economic losses of USD48 billion. In 2007, a total of 335 natural catastrophes led to overall economic losses of USD64 billion across the globe in which 142 natural catastrophes and 193 man-made disasters occurred. Rudolf Enz, one of the authors of the study, states “Catastrophes claimed the most lives in Bangladesh, India, China and Pakistan in 2007. In countries with less financial resources, a catastrophic event can result in higher deficits and debt for the public sector, which not only shoulders the cost of relief efforts, but is also responsible for rebuilding public infrastructure. In Turkey, for example, an earthquake in 1999 caused an economic loss of 11 per cent of GDP. In 1986, an earthquake in El Salvador cost as much as 37 per cent of GDP.

The Indian subcontinent is prone to all types of natural disasters, e.g. earthquake, flood, drought, cyclone, tsunami, landslides, avalanche, forest fires, etc. Of all the natural hazards, floods occur most often and are the most widespread in scope and severity in India. According to World Bank estimate, reported direct losses are on the order of $ 30 billion over the past 35 years. In 2005 alone, disasters in India caused direct losses approaching Rs 87.5 Billions. Table I presents a comparison of occurrence of some of great natural disasters in India. It is observed that there is a four-fold rise during last 50 years. Floods continue to pose the greatest threat to the property and safety of human communities among all natural hazards in the India. A commonly accepted definition of a flood is that it is the accumulation of water within a water body and the overflow of excess water on to adjacent flood plains. The term “flooding“ is also understood to mean the temporary inundation, either partial or complete, of normally dry land with water, suspended matter and/or rubble caused by the overflowing of rivers, streams, channels, lakes, etc., precipitation, storm surge, tsunami, waves or seawater, mudflow, failure of water-retaining structures (dams, dikes), groundwater seepage and water backup in sewer systems. Floods and high winds account for 60 per cent of all disasters in India.

Severe losses were also caused by floods in recent past, e.g. heavy monsoon rains triggered landslides and flooding in India in July, 2006, specifically in the regions around Mumbai. Over 1,100 people lost their lives, and the insured property damage amounted to USD0.8 billion. Published Swiss Re reports in the year 2007 related to

<table>
<thead>
<tr>
<th>Year</th>
<th>Floods</th>
<th>Cyclones/floods</th>
<th>Hailstorm</th>
<th>Earthquakes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1991</td>
<td>1,320</td>
<td>979</td>
<td>–</td>
<td>–</td>
<td>2,299</td>
</tr>
<tr>
<td>1991-1992</td>
<td>1,185</td>
<td>304</td>
<td>–</td>
<td>768</td>
<td>2,257</td>
</tr>
<tr>
<td>1992-1993</td>
<td>1,193</td>
<td>497</td>
<td>–</td>
<td>–</td>
<td>1,690</td>
</tr>
<tr>
<td>1993-1994</td>
<td>1,690</td>
<td>318</td>
<td>–</td>
<td>7,938</td>
<td>9,946</td>
</tr>
<tr>
<td>1994-1995</td>
<td>2,038</td>
<td>247</td>
<td>59</td>
<td>–</td>
<td>2,344</td>
</tr>
<tr>
<td>1995-1996</td>
<td>2,072</td>
<td>361</td>
<td>31</td>
<td>–</td>
<td>2,464</td>
</tr>
<tr>
<td>1996-1997</td>
<td>2,069</td>
<td>1,719</td>
<td>40</td>
<td>–</td>
<td>3,828</td>
</tr>
<tr>
<td>1997-1998</td>
<td>1,560</td>
<td>216</td>
<td>247</td>
<td>39</td>
<td>2,062</td>
</tr>
<tr>
<td>Total</td>
<td>15,694</td>
<td>5,933</td>
<td>377</td>
<td>8,851</td>
<td>30,855</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Government of India
20 worst catastrophes in terms of victims has also indicated that India is one of the most victim-prone countries compared with others (Swiss Re reports, 2006, 2007). The number of people affected in the rest of the world were 111,159, in Asia the number was 554,439 and within Asia, 24 per cent of deaths due to disasters occurred in India (Shashi Shankar, 2007). Of the total of 62 major rivers in India, 18 are flood prone and flood an area of 150 million hectares. The maximum damage recorded due to floods in India was about Rs. 6.54 billion in 1980, while in 1965, it was only Rs. 110 million.

1.1 Floods disaster
High magnitude floods during the monsoon season are considered to be India’s recurring and leading natural disaster (Kale et al., 1994). The country has to face loss of life and damage to property due to severe floods time and time again. Heavy flood damages were experienced in the country during the monsoons of 1955, 1971, 1973, 1977, 1978, 1980, 1984, 1988, 1989, 1998, 2001 and 2004. Central Water Commission has compiled the damage figures due to flood from 1953 to 2004 on the basis of which yearly average loss to life is reported to be about to 1590 and the damage to public utilities Rs. 8.068 billion (*USD 184 Billion). Apart from this, there have been damages to standing crops, dwelling units, livestock, etc. Figure 2 shows yearly flood damaged affected area and Table II shows maximum damage between 1953 and 2004.

Planning for disaster management involves three elements – prevention, mitigation and rehabilitation. The necessity of disaster management and mitigation methodologies has become much more evident in recent years. Thus, flood disaster prevention and vulnerability reduction are topics of major concern for local, national, and international organisations. The role of local governing bodies for disaster
management including suitable infrastructure development is essential, not only to cope with the impacts but also to help ensure that the region sustains its economic growth. The implementation of disaster management strategies and their effective impact in sustainable infrastructure development and management is possible by the latest technological advancement in the field of Geoinformatics. Geographic Information System (GIS) is a tool that can assist floodplain managers in identifying flood prone areas in their community. By overlaying or intersecting different geographical layers, flood prone areas can be identified and targeted for mitigation or strict floodplain management practices after all of the information has been collected and organised in a GIS database. Figure 3 Shows the tools and the importance of the organisational framework for working with local actors.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Average during 1953-2004</th>
<th>Max. damage (Year)</th>
<th>Damage during 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area affected</td>
<td>Million hectares</td>
<td>7.63</td>
<td>17.50 (1978)</td>
<td>8.47</td>
</tr>
<tr>
<td>Population affected</td>
<td>Million</td>
<td>32.92</td>
<td>70.45 (1978)</td>
<td>34.19</td>
</tr>
<tr>
<td>Human lives cost</td>
<td>No.</td>
<td>1,597</td>
<td>11,316 (1977)</td>
<td>1,650</td>
</tr>
<tr>
<td>Cropped area affected</td>
<td>Million hectares</td>
<td>3.56</td>
<td>10.15 (1988)</td>
<td>2.92</td>
</tr>
<tr>
<td>Value of damaged houses</td>
<td>Rejeski, 1993</td>
<td>2.51</td>
<td>1.308 (1995)</td>
<td>8.707</td>
</tr>
<tr>
<td>Value of damaged public utilities</td>
<td>Rs. billion</td>
<td>8.137</td>
<td>56.04 (2001)</td>
<td>22.28</td>
</tr>
<tr>
<td>Value of total damage to houses, crops and public utilities</td>
<td>Rs. billion</td>
<td>18.17</td>
<td>88.645 (2000)</td>
<td>38.54</td>
</tr>
</tbody>
</table>

Notes: a1 USD ~ 44 Rs (year 2008)
Source: CWC (2006-2007)

Table II. Maximum damage between 1953 and 2004 in India

Figure 3. Local actors in disaster prevention

Source: Bollin (2003)
2. GIS as a tool for disaster management

GIS is a computer-based system capable of assembling, storing, manipulating, and displaying geographically referenced information. GIS technology supports spatial data handling and analysis efficiently and can be used to create an integrated geo-database on biological (agriculture), meteorological (rainfall), hydrological (water resources), socio-economic (population) indicators for their subsequent use in modelling the simple/complex disaster related indices to reflect the vulnerability of an area to the disaster. Remote sensing from satellites provides another important source of data, often used in GIS, e.g. observational data on stream flow, climate, water quality, and groundwater levels, together with remote sensing/GIS data and weather/climate grids. Advances in information technology such as fibre optics technology for river monitoring provide additional sources of data.

Flood Decision Support System (DSS) is a comprehensive flood management system. Flood DSSs have the potential to mitigate flood disasters though improved data collection and the rapid dissemination of information to affected areas. Development of flood DSS has been focused now days for effective management of flood disasters, like some initiatives globally have recently emphasised the importance of DSS development for flood planning and management, including the European Union’s River Basin Modelling Management and Flood Mitigation project, Agenda 21 (United Nations Conference on Environment and Development), and the European Union’s Sixth Environment Action Programme. Flood Decision Support Systems (DSS) include a customised, interactive computing environment (with interlinked models/analytical tools, databases, graphical user interfaces, and other systems) designed to help hydrologists, stakeholders, government officials, and other decision makers use data and models to evaluate flood risk management problems. In general, digital flood data are easy to process, highly accessible, and less expensive than traditional approaches to the delineation of floodplain boundaries. Flood DSSs improve the decision-making process not by prescribing a particular course of action, but rather by providing data displays, analytical results, and model output to summarise critical flood information.

Frank (1993) notes that “the user interface is the system”. DSS display capabilities include spatial data handling, the editing of flood inundation maps, sensitivity analyses of flood model parameters at a variety of spatiotemporal scales, analysis of complicated levee systems, and the animation of hydrologic and hydraulic phenomena. Maniruzzaman et al. (2001) described the preliminary development of a prototype Response Estimation System for Cyclones Under Emergency (RESCUE), a GIS-based aid intended for disaster management personnel involved with cyclone response in Bangladesh. As an example an exercise for optimally locating storage facilities for relief goods is described. Miller et al. (2004) outline four important challenges for developing effective DSSs related to information technology: ensuring the interoperability of technologies (including computer applications, platforms, and operating systems); providing the widest accessibility possible (with particular consideration to geographic information systems (GIS)–internet architecture, required plug-ins, and bandwidth); ensuring internet security; and addressing data ownership issues. Levy et al. (2005) has proposed models to improve flood risk management and a flood decision support system architecture is proposed that capitalises on the latest advances in remote sensing, geographic information systems, hydrologic models,
numerical weather prediction, information technology, and decision theory in the context of flood management and planning in the Yangtze River valley, China. Customised flood DSS modules by Simonovic and Ahmad (2005) are capable of solving spatially explicit flood modelling equations and addressing complex flood risk management problems such as flood evacuation emergency planning and flood risk mitigation and control (Mysiak et al., 2005). Shi et al. (2005) illustrates the relationship and the interactions between urbanisation in the metropolis and the process of flood disaster changes. Furthermore, a solution is proposed to alleviate fluctuations in flood disasters through the adjustment of the land use structure and pattern in metropolitan areas. The GIS can also help identify risk areas and plan long-term measures for disaster management. Disaster planning, response, mitigation, and recovery all become more efficient through the use of GIS (Suresh et al., 2005).

The above discussion gave the comprehensive idea that GIS-based systems can be used as an integrated administrative and decision support system to respond to the immediate humanitarian and disaster relief operation during and after the event. In view of considering these developments happening in disaster management, an attempt has been made to develop GIS-based framework for flood disaster for a study area of Allahabad Sadar sub-district (India).

3. GIS-based conceptual framework for Allahabad district
The disaster management is a multi-disciplinary endeavour, requiring many types of data with spatial and temporal attributes that should be available to district administrators in the right format for decision-making. The volume of information needed for natural disasters far exceeds the capacity to deal with them manually and thus there is a need for a GIS-based information system.

Figure 4 shows the proposed organogram for Allahabad district. According to District Disaster Management Authority (DDMA), Ministry of Home Affairs,
Government of India, disaster management authority is governed by a chairman (District Magistrate) and nominated officers and the co-chairman is elected member of Zila Panchayat i.e. district level court (Adhyaksh Zila Panchayat). The whole disaster management plan is proposed to run through 11 committees. These committees are supported by 26 district level departments which are represented by A-Z alphabets.

Details for organogram notations:

1. Law and order committee.
2. Rescue committee.
3. Traffic control committee.
4. Advisory committee.
5. Fire control committee.
6. Communication committee.
8. Water supply committee.

Figure 5.
Map of study area – Allahabad district
(9) Transportation arrangement committee.
(10) Awareness, education committee.
(11) On site emergency committee.

Supporting departments:
A. Police;
B. Intelligence;
C. Army;
D. Fire brigade;
E. Public Works Department (PWD);
F. Irrigation;
G. Jal Nigam (Water Corporation);
H. Nagar Nigam (City Corporation);
I. Development Authority;

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Figure 6. Villages affected by flood due to river Yamuna
J. Jal Sansthan (Water Board);
K. Media;
L. Non Governmental Organisations (NGOs);
M. Telecommunication;
N. Electricity Supply;
O. Railways;
P. Medical department;
Q. District Industries;
R. Petrol/Gas departments;
S. Transport department;

Figure 7.
Villages affected by flood due to River Ganga

Key
- River_new
- VILLAGE_BOUNDARY_NEW

Legend for distances:
- 3,600 Meters
- 1,800 Meters
- 0
4. Case study

4.1 Study area

The present study area is Sadar sub-district of Allahabad (India) which is surrounded by river Ganga and Yamuna and located between 81°45′ to 82°0′ latitude and 25°15′ to 25°30′ longitude (Figure 5). All the Mohalla/Villages considered are highly populated giving high revenues and wealth to district administration and located between two rivers, which are frequently affected by flooding. Five major flood occurrences have...
happened in Allahabad in the years 1948, 1956, 1967, 1978 and 1983. Causes of flood in Allahabad is due to rise in level of river water at sub-districts Sadar, Meja, Soraun, Phoolpur, Handia, Karchana, Bara due to Meja Dam water release at Meja Urva, Manda, Koraune blocks of Meja sub-district and due to heavy rains over low lying areas of nine localities in Allahabad City. Major dams of Allahabad are Baxi Dam, Charchar Nala Dam, and Meja Dam.

Figure 5 shows Allahabad district Map and Sadar sub-district village boundary map. Of the Sadar sub-district, 80 per cent comes under urban area all education institutions, district administration, state and government offices are situated in this area.

5. Methodology
The map of Allahabad Sadar sub-district is prepared using ArcGIS 9.1. The disaster management efforts, namely, prevention, reduction, mitigation, relief and rehabilitation require precise maps with spatial data and non-spatial data. The

![Image of population density map]

**Figure 9.** Population density in flood-prone areas of Sadar sub-district
various stages involved in the preparation of a comprehensive disaster management strategy for study area include the following:

- development of an integrated geo-database consisting of various thematic maps, demographic data, socio-economic data and infrastructural facilities at village level under GIS environment;
- the utilities like education facilities, medical facilities, road connectivity, cinema hall, news paper, telephone and telegraph facilities, irrigated and un irrigated area facilities, electricity, etc. and other information from Census 2001 available for the district are represented spatially using GIS;
- the Survey of India (SOI) maps are suitably supplemented for information relating to specific and individual disasters as well as for planning of developmental programmes; and
- the various thematic maps prepared include road network map, water supply network map, fire control office map, urban sprawl map, drainage map and land use map of different of the study area.

6. Development of GIS-based maps for disaster management
Various maps were generated for the analysis in the GIS platform. Some of these maps are flood-affected areas of Sadar sub-district (Figures 6-8), population density

Figure 10.
Map showing paved and mud road connectivity in villages of flood affected areas
distribution in flood prone areas (Figure 9), villages having road connectivity (Figure 10), hospital facility in flood affected areas (Figure 11), route of relief map (Figure 12 and 13).

Figure 6 shows that there are 88 revenue villages that are under Sadar sub-district jurisdiction. Out of 88 villages 22 villages are affected by river Yamuna. With the help of above GIS generated map one can find out villages that are affected when floodwater of the river Yamuna exceeds a particular level, and this map also shows neighbouring villages, which may be affected due to further rise in flood water.

Figure 7 shows the location of villages that are affected when river Ganga flood water rises. The trend of river Ganga affected villages is different from river Yamuna. Generally, flood affected river Yamuna villages are contiguous but flood affected river Ganga villages are not contiguous. The main reason behind this is that the geography of the land is different in the two cases.

Figure 8 shows the total villages which are affected when water levels of both the rivers Yamuna and Ganga exceed a particular level. The effected villages and the unaffected villages are shown through different shades of colors. There are
54 villages are affected when floodwater reaches 84.5 meters, High Flood Level (HFL).

Figure 9 shows the population of the flood-affected villages. With the help of this, district authority will be in a position to decide how much relief material is required by a particular village, how many boats are required for rescue of the flood affected villages. If any government agency or any non-governmental organisation wants to provide any type of help to the affected people, they can follow above generated map for having idea about the requirement. If they want to provide blankets, clothes, food packet, the above information is very useful for management. With the help of the developed GIS-based management system district administrator can monitor all flood management operations. One can also verify the rescue budget utilisation. Presently, flood effected villages report is being prepared by lekhpal (village level staff). They also distribute rescue item, which is provided by state and central government or other agencies. Some times the malpractices by these village level staffs can be verified directly monitoring of through the rescue distribution programme.

Figure 10 shows the road network of villages that are more vulnerable and are not been connected by main road as well as metal road. Those villages that are not having transport connectivity can be identified, and there is no chance to escape quickly because of difficulty in transport mobility. With the help of above information, one can provide rescue first to those villages not connected through metal road and after that provide transportation to metal road connected villages.

Hospital facilities play very important role for rescue and life saving during post disaster. If any village has hospital facility, then epidemics can be controlled very
quickly using above generated map (Figure 11). When flood occurs there is possibility of out breaking of number of epidemics. If district administration is in a position to provide facility to transport doctors, they show willingness to reach remote villages that do not have any medical facility. With the help of above map and database the authorities can give priority to villages that do not have hospital or dispensary facilities.

When flood occurs low lying areas are flooded but some areas which are situated at higher level is not affected, so locations of relief camp for temporary safety and stay can be identified. Authorities can increase or decrease the number of relief camps also with the help of above generated map (Figure 12). If any village has more victims then one can increase the number of shelters and if villages have less number of victims then the number of relief camps can be reduced. District disaster management officials can also make surprise visits to any relief camp. They can also check the relief camp facility actually provided.

Figure 13 shows position of relief camp and route from district head quarter. With the help of GIS, one can identify shortest route for relief camp, one can develop the networking of relief camp with the help of above information and monitor any relief
camp rescue activities and authorities can provide the map to all rescue agencies that are engaged in helping of flood victims.

Conclusions
The results show that in that sub-district Sadar of Allahabad 54 villages are affected by flood when high flood level reaches up to 84.50 meters one can identify the villages that are affected by this danger mark. With the help of GIS-based maps the requirement of food, camps, water, and required relief shelter can be provided for the selected study area. District Magistrate can verify the arrangement of relief camp with the help of GIS information. The results show that 33 villages are affected by river Ganga and 21 villages are affected by river Yamuna. The GIS generated map shows that out of 54 villages only seven villages have mud road and 47 villages have paved road. Mud road villages require more attention than villages with paved road. Thus, GIS tool can be beneficial for getting all the relevant information at the time of occurrence of the disaster, and can help in planning and prioritizing infrastructure development effort in the study area. Further basis for damage allocation assessment and consequent provision of compensation and fund allocation for required infrastructural improvement can be developed using the present GIS-based disaster management strategy.

References
DKKV (German Committee for Disaster Reduction) (2002), Journalists’ Manual on Disaster Management 2002, DKKV, Bonn.
International Federation of Red Cross and Red Crescent Societies (1994), World Disaster Report, International Federation of Red Cross and Red Crescent Societies, Geneva.


Further reading


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