Term Paper

On

Flood Disaster Management in the North Indian Plains using GIS Application

(Final Paper)

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Abstract

GIS has the capability of providing quick and easy access to large volumes of data. GIS provides added quality and improved efficiency in updating maps this aspect is used to plan the control of floods in the Great North Indian plain which has one of the world's largest flood plains. Creating Flood Hazard Map by using GIS is a vital component for the appropriate land use in the planning of flood-prone areas. With the help of GIS easily-read, rapidly-accessible charts and maps can be prepared which will facilitate the administrators and planners to identify areas of risk and prioritize their mitigation / response efforts. A flood occurs when an area of land, usually low-lying, is covered with water. Floods happen when soil and vegetation cannot absorb all the water; water then runs off the land in quantities that cannot be carried in stream channels or kept in natural ponds or man-made reservoirs. These floods can take the role of a huge calamity if they happen in a plain which has been intruded by human beings and thus it can lead to huge amount of losses monetary as well as of life. To control this damaging effect of these floods, GIS can be used to asses the floods and help in proper planning so as to avoid these floods. Two Case studies have been reviewed in this paper which will show how the use of GIS can be helpful in Flood hazard management.

1. Introduction: -

Geography is information about the earth's surface and the objects found on it, as well as a framework for organizing knowledge. GIS is a technology that manages, analyzes, and disseminates geographic knowledge. GIS is a technology that is used to view and analyze data from a geographic perspective. The technology is a piece of an organization's overall information system framework (www.gisdevelopment.net).

GIS links location to information (such as people to addresses, buildings to parcels, or streets within a network) and layers that information to give a better understanding of how it all interrelates. Now a day’s most computer technology is designed to increase a decision-maker's access to relevant data. GIS goes beyond mining data to give us the tools to interpret that data, allowing us to see relationships, patterns, or trends intuitively that are not possible to see with traditional charts, graphs, and spreadsheets. GIS can provide us with powerful information on not just how things are, but how they will be in the future based on changes you apply. GIS is, therefore, about modeling and mapping the world for better decision making (www.env.gov.bc.ca).

GIS is composed of three main components the hardware and software, Database, and the Users. Its uses are very wide and vast; GIS can be used for a wide range of applications such as urban and regional planning, agriculture, emergency response systems, and wildlife and natural resource management. A GIS is capable of capturing, storing, manipulating, and displaying spatially referenced information to allow for efficient data organization and access. It can also be used to answer basic location based questions, identify resource distribution patterns, and to model complex environmental and ecosystem processes, making it an extraordinary tool for planning and decision-making.

The old adage "better information leads to better decisions" is true for GIS. As GIS is not just an automated decision making system but a tool to query, analyze, and map data in support of the decision making process. GIS has been known to help in various applications and Disaster management studies. Floods are the most common disaster which the world faces today. Flooding happens during heavy rains, when rivers overflow, when ocean waves come onshore, when snow melts too fast or when dams or levees break. Flooding may be only a few inches of water or it may cover a house to the rooftop (http://www.fema.gov/kids/floods.htm). Floods that happen very quickly are called flashfloods. Flooding is the most common of all natural hazards. This paper will be covering the Flood management aspect of GIS in reference to the North Indian plain.

2. Objective: -

Flood is very natural and common phenomena of the Great North Indian Plain. Every year floods occur on large scale. However, there isn't any solid preventive plan for the floods. With the technological advancement; now we can use GIS with relevant data and map, which has great accuracy and can be accessed in less time. Instead of short term measures and rescue program, we can have appropriate, preventive and long term schemes for the flood disaster management. The paper focuses on the study of various possibilities for the alternative methods for flood management and their applicability in North Indian plain emphasizing mainly on the two main rivers of this region namely the Ganga River and the Brahmaputra River, using the potential of GIS to meet the purpose.

3. Literature Review: -

Rivers play a major role in the economy of a country by sustaining agriculture, industry, energy generation and providing biological resources. However, humans have grossly abused the rivers worldwide by extensive regulation of flows, habitat alteration and disposal of all kinds of wastes into them. The impacts of these activities are already appearing in declining fisheries, increasing incidence of floods (Gopal B. 2002). Flood is a natural process associated with river. It is an unusual high stage of a river due to runoff from rainfall and melting of snow. The inundate area which borders the stream channel, called flood plain. Due to occupancy of human beings in flood plain, floods resulted in loss of life, damage to property, crops and negative impacts on human welfare (www.mapindia.org). It takes the form of disaster. Floods are among most frequent disasters. Ever year, floods occur in many parts of the India. The area affected by flood is on eighth of countries geographical area (www.southasianfloods.org). Flood occurs due to natural as well as man made causes. Major causes of floods in India include intense precipitation, inadequate capacity within riverbanks to contain high flows, and silting of riverbeds. In addition, other factors are land slides leading to obstruction of flow and change in the river course, retardation of flow due to tidal and backwater effects, poor natural drainage, cyclone and heavy rainstorms/cloud bursts, snowmelt and glacial outbursts, and dam break flow (Singh,2005).

From a physical perspective, the key factors contributing to flooding generally fall within one of the following main categories:

• Excessive quantities of water

• Blockages within the drainage network

While each these fundamental dimensions of flood hazards occur naturally, they are also heavily influenced by human activities. Given this study's focus on the effects of environmental degradation on disaster risk, the following section outlines the physical parameters of flood risk while considering anthropogenic influences on those parameters (SIDA, 2004). For such a disastrous feature like flood, GIS can be used as a tool that can assist floodplain managers in identifying flood prone areas in their community. With GIS, geographical information is stored in a database that can be queried and graphically displayed for analysis. By overlaying or intersecting different geographical layers, flood prone areas can be identified and targeted for mitigation or stricter floodplain management practices (www.mde.state.md.us).

4. Study Areas: -

This paper is focusing on two separate case studies. The geographical location of both the study areas are in the Great North Indian Plain (Image. 2) and both the case studies are useful, so as to show and implement the use of GIS in there flood management.

4.1: Study Area: (<u>Case Study: 1</u>)

A Study of Floods in the Brahmaputra basin in India: **Case Study: I**: -

The Brahmaputra occupies eighth position in a list of 34 major rivers of the world on the basis of their annual average runoff (Rao, 1975). Amongst the largest river in the world, total length of Brahmaputra (Image. 1 and 2) from its origin in a glacier east of Manasarovar to its out fall at Bay of Bengal is 2880 km, out of which 918 km is in India. In Assam, the length is 640 km and its average width is just 80 km. Although two-third of its length and more than half of the catchments are in Tibet, about two-third contribution of its flow is from the drainage area in India. Floods in the Brahmaputra valley have been aggravated due to change of course of rivers, changes in bed topography, heavy landslides, siltation, etc. Floods have also been aggravated by considerable degradation of catchment areas by mindless earth cutting and road building activities all over.

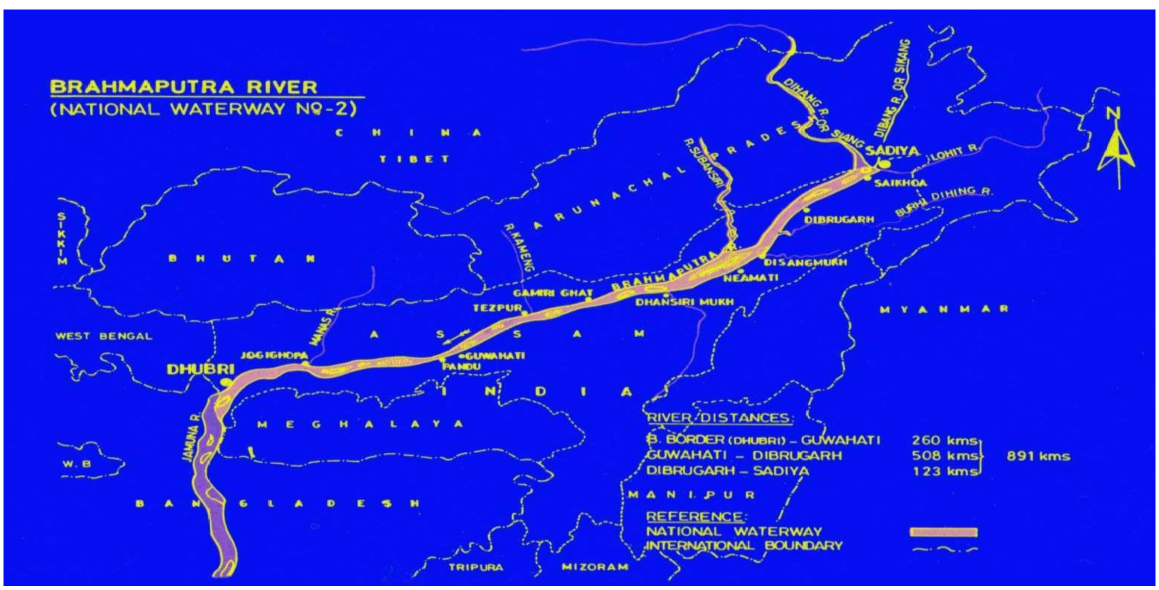

Image: 1: - Showing the Study area of Case study I. (Islam, MM and Sado, K, 2002)

Rate of erosion in the Brahmaputra catchment, 953 ton per sq km per year, is the highest in any catchment system in the whole world (K.R.Venkatachary, K. Bandyopadhyay, V. Bhanumurthy, G. S. Rao, S. Sudhakar, D. K. Pal, R. K. Das, U.Sarma, B. Manikiam, H. C. Meena Rani and S. K. Srivastava, 2001). Population has been growing rapidly in the plains. The steep increase in population has forced the people to encroach riverine areas resulting in constrained waterways, which also increases sedimentation, and in turn increases the floods of higher intensity. Abandoned channels and horseshoe lakes, which would otherwise absorb at least the initial impact of floods, have been reclaimed.

Image: 2: - Showing the study area's of Case Study I and II. (www.sdnpbd.org)

4.2: Study Area: (<u>Case Study: 2</u>)

An Alternative Plan for the Floods of North Indian Plain: **Case Study: II**: -

This case study constitutes of the Ganga River (Image 2 and 3), and its largest tributary the Yamuna, other Himalayan rivers- Ramganga, Gomati, Ghaghara, Gandak, Rapti, Gandak and Kosi, and some peninsular rivers, like Chambal, Son and Punpun. These rivers have been associated with dynamic fluvial plus erosional and depositional processes along with remarkable change of river courses and developments of flood plains and terraces. The oscillation of the river courses of the Ganga and its tributaries is most significant aspect of the fluvial dynamism. The past history shows that these changes have taken place during the high discharge condition and flood when vulnerability to the changes of river course is the maximum (Sen and Prasad 2002).

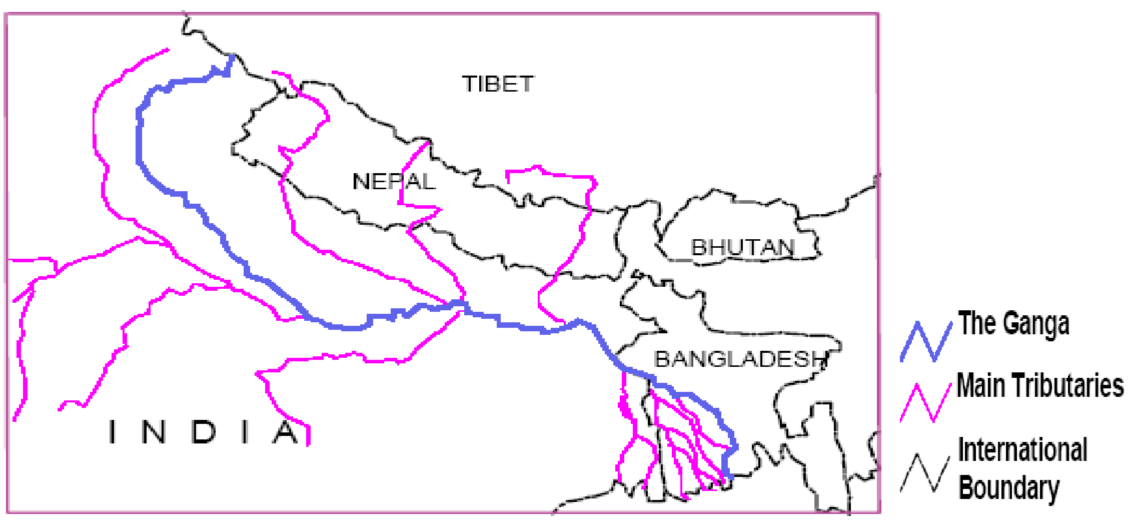

Image: 3: - Image showing the Study area II (http://www.mapindia.org/2005 /183.pdf)

The Ganges or the Ganga is India's principal river. It is 2,510 km long and is a symbol of India's culture and civilization. The Ganges is rising in the Gangotri glacier in the Himalayas in Uttaranchal state of India, and flowing generally southeast through North East India across a vast plain to the Bay of Bengal in Bangladesh. The fertile Ganges plain is one of the world's most densely populated regions; rice, grains, oilseed, sugarcane, and cotton are the main crops. Because of its location near major population centers, however, the river is highly polluted.

5. Methodology of Study: -

The Methodology of study for the two areas has been similar as they are taken care by the same authority in the Government; hence for both the areas the applications were same even though the plains varied in their geography and topography.

5.1 Methodology in Case Study 1: -

In this area the major cause for floods was the rain water and the melting of ice which took place from the month of June to September. For flood mitigation measures, structural approaches have been given prime importance in India. These measures require engineering ability and bulk investment to modify the natural flow of the river. The bulk investments have been made in multi purpose projects. But our ability to manipulate nature from catastrophic flood is limited. At present, the enormous water resources of the Brahmaputra River are not fully utilized and practically most of its flood water is being lost into the Bay of Bengal through Bangladesh after causing enormous damage by way of ravaging floods in Assam and Bangladesh (O.N. Dhar and Shobha Nandargi, 2000). Structures more often degrade the environment by altering the natural hydrology of the river.

5.2 Methodology in Case Study 2: -

The Ganga River basin has one of the largest flood plain with highly dense population. Every time losses get increase instead of decreasing. In Ganges Plains, mitigation measures have been in practice since independence. However, there was increase in flood frequency in the alley even after all these structural measures. This can be justified by numbers of reasons. First of all increase of population in flood prone areas together with a higher standard of living results in high damages. The river Ganga also suffers from mass pollution it has only 9% of water output of the Amazon River; however it carries a total suspended load twice of Amazon. These damages in turn have been aggravated by the complete lack of flood awareness of the general public. Secondly, to minimize the immediate loss posed by flood, nothing with long term permanent efforts has been done.

In both the Case Studies, existing measures that are being taken are not appropriate for long term planning. The planning is mostly done with regards to structural measures whereas while planning for Structural measures, the river ecology and other natural resources are hardly taken into account. The present approach has many drawbacks-

1. Planning is based only on problem solving attitude, problem understanding attitude is missing in existing mitigation measures.

2. Present approach is curative instead of preventive.

3. Flood mitigations plans don’t take account of the natural flooding process; they are moreover ‘wait and see’ kind of manifestation.

4. The main emphasis is given to short term emergency relief measures.

5. Structural measures require not change in individual or collective human behavior, thus create lack of awareness of risk in affected population.

6. Structural approach encourages the more development in flood risk area. This increased further demand of flood proofing structures. Thus, a cycle of structural mitigation, development and more demand for structural mitigation begins, with increasing economic and environmental costs. (Brikland T.A. et al 2003).

The role of GIS and Remote Sensing in existing flood mitigation procedure is very limited. Despite the technological ability, we have very few examples of flood management using these tools. Hardly, hazards maps are created and decision has been taken accordingly. Land priority maps are not created for the flood plain. Even in prediction and emergency actions, planners use conventional and time consuming methods.

The experiences say that structural mitigation measures are unable to cope up with floods in both the study areas.

5.3 Application of GIS as an Alternative to the existing Methodology of Case Study I and Case Study II: -

The alternative mitigation measures are inclusive of both short term as well as long term plans. GIS along with Remote Sensing can play important role at all levels of plan formulation and implementation for alternative measures. To understand the causes of the floods, distributed hydrologic modeling at the scale of a large river basin is a very useful tool. Physically modeling at the scale of an entire river basin requires large input databases. Therefore, a Geographical Information System is a very useful environment to model because of its advantages of data storage, display and maintenance

Having networks of near-real-time monitoring, India has better facilities to integrate various information and quick assessment of flood. The data from diverse back ground are required to construct flood hazard map, land development priority map for long term adjustment plans. High resolution satellite images (Image.4 and Image.5), real time weather monitoring, and spatial analysis using GIS tools, enable planners to have comprehensive data base for the purpose. Indian Remote Sensing (IRS) Satellite series are very useful for the flood information. The on-board sensors of IRS series satellites LISS-I, LISS-II, LISS-III and PAN and WiFS collect information which can be use to estimate the

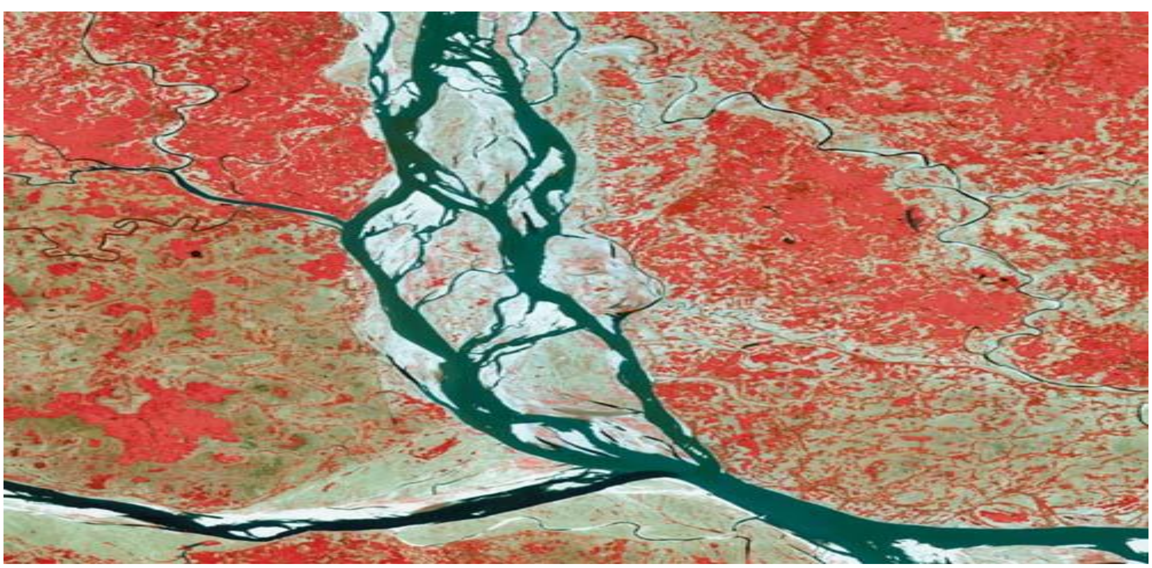

Image: 4: - This is a colored Imagery of the study area taken by the Indian Remote Sensing Satellite,showing the Brahmaputra River of the Study Area: 1. (www.southasianfloods.org)

Image: 5: - This is a colored Imagery of the study area taken by the Indian Remote Sensing Satellite, showing the Ganga River of the Study Area: 1. (www.ibaradio.org/Rudra.pdf)

inundated area, depth of flood water, and estimation of likely to inundate area. Data from National Oceanic and Atmospheric Administration (NOAA) also can be use for the purpose.

The North Indian plain where the stress in increasing over land, the proper attention is required for natural resources management, which will go simultaneously with flood mitigation measures. To meet this purpose, conventional and Remote Sensing data integration is required (Figure.1). This integration provides a digital representation of hydrological characteristics, socio-economic structure, natural resource potential and inherent development problem of the river basin.

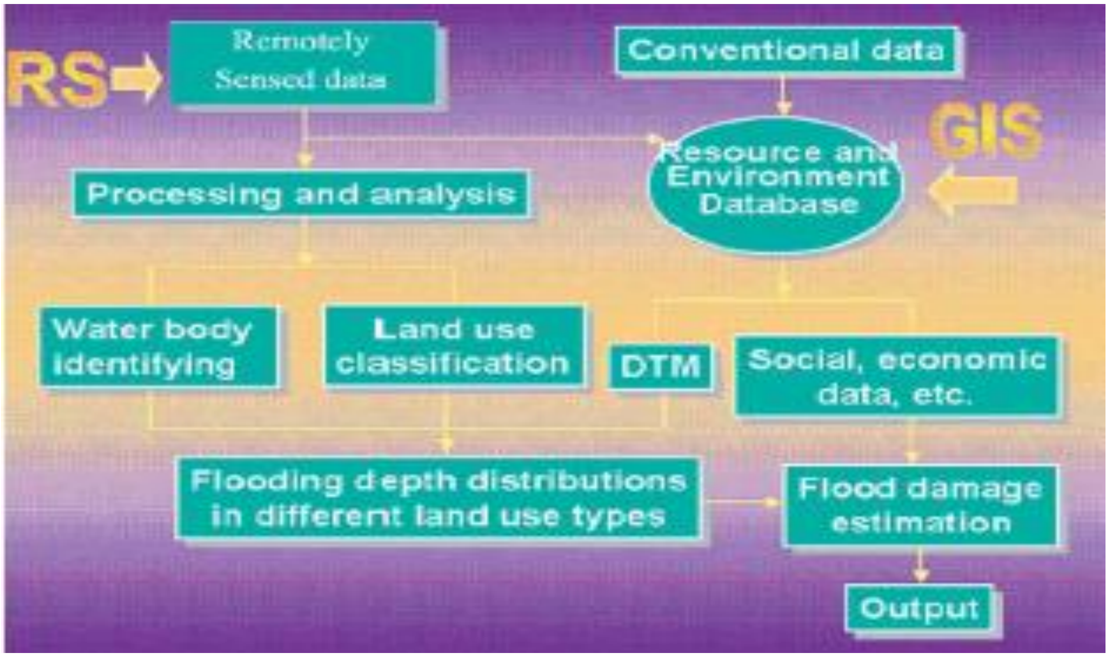

Figure: 1: - Flow chart from the input of data to output after GIS use. (SIDA)

The spatial impact of alternative plan can be evaluated with the use of GIS for the selection of appropriate development plan. GIS oriented system handles the flood forecasting services.

This includes:

1. Real-time data base management including telemetric data collection.
2. Real-time flood forecasting of water level and flood extent.
3. Post-processing of results and formulation of flood warnings.
4. Dissemination of flood warnings and flood information to end users through media.

Continues monitoring and GIS analysis can help decision support system for flood plain planning. This plan includes these analysis and measurements-

1. Hazard zone analysis.

2. Existing flood control vulnerability identification.

3. Analysis of River Morphology and Channel Management.

4. Flood Damage assessment.

5. Rehabilitation and land reforms

These measures that must be address and incorporated in development plan for the region. The long term measures like change in land use at large scale, and short term measures like embankments must not be in contrast of each other. Rather the emergency measures should be a stepping function for long term perspectives. The main land use changes are to be done in normal days, according to Land Priority map created by using GIS (Figure.2). The capability to handle large set of data, time efficiency and visual presentation are some advantages of GIS techniques, which make is appropriate for regional planning. Flood conditions also provides a golden chance to execute the land reforms, which has not done properly till now. Thus, long term perspectives have long lasting positive impact on society also (www.mapindia.org).

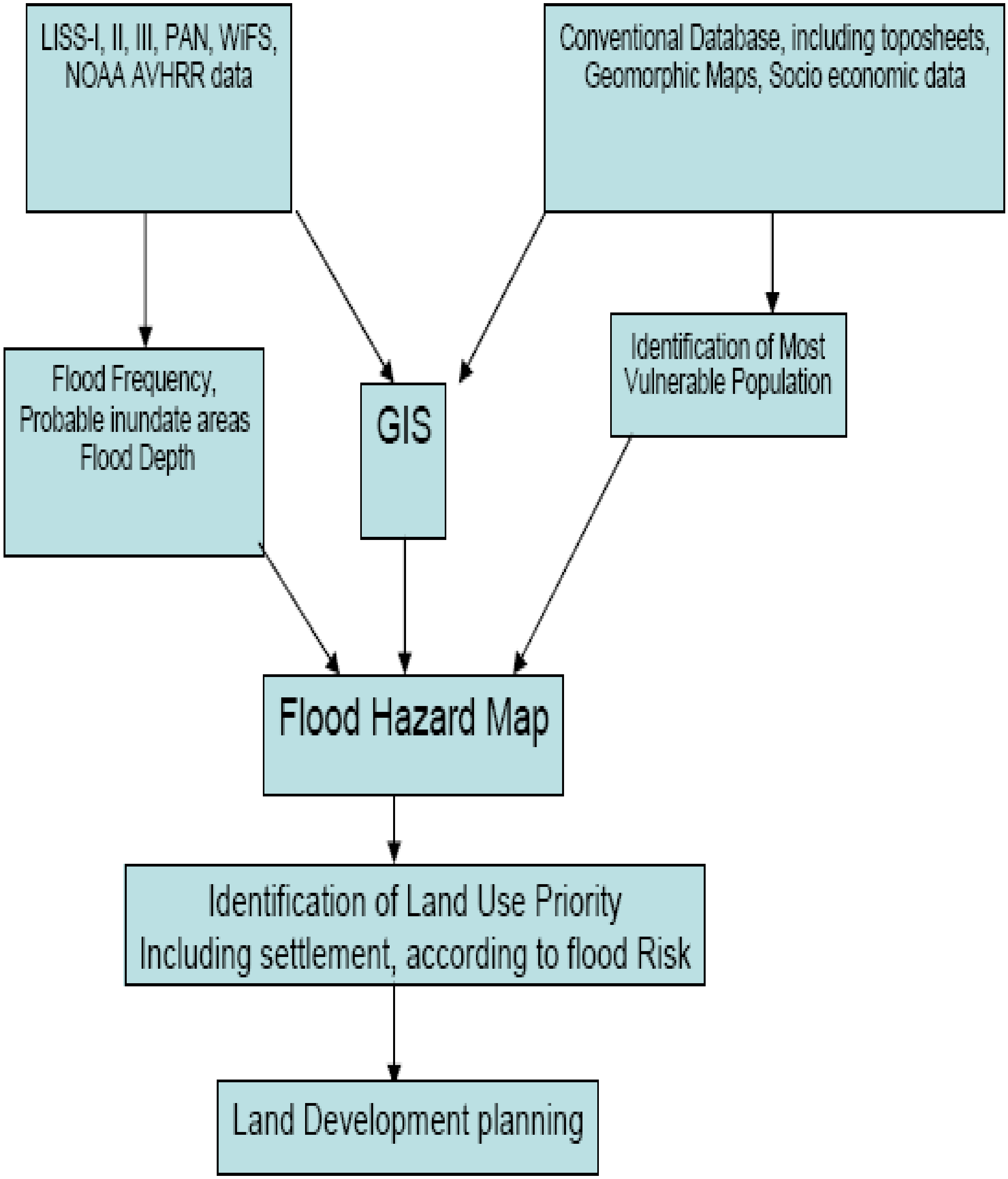

Figure: - 2. Land Use Planning in Flood Plain (www.mapindia.org)

6. Constraints of the Case Studies: -

Though GIS provides a suitable platform for data integration and it is appropriate for planning purpose, there are some requirement and constraints, while using GIS for flood mitigation planning in North Indian Plains. These Constraints were found to be common for the both the case studies as they are in the same region and are taken care by the same: -

1. Lack of Suitable Equipments- There is lack of economic resources in North Indian plain resulting in limited resources. Computers are not available; even in some district head quarters hence Computer based mapping is not feasible in such a condition.

2. Data Collection and Data accuracy- The accuracy of data is required for proper spatial analysis. However, wrong data may produce wrong results. Many times the regional data is manipulated by administrators and even by state government to meet the financial aid. Apart from this the Data is not updated as required from a Flood hazard perspective.

3. Organization and coordination- A proper organization is required to design a long term plan. Coordination between various departments is essentially required including many Government departments which is a time consuming task and it can almost kill the project.

4. Political Will- The most important factor is political will, GIS researches are very rich in country, but due to lack of awareness at political level, plans are still plans.

7. Recommendations: -

The two case studies showed that in India the Flood Management is done on the basis of old methods and structural application more, where as the use of Modern day technology like GIS is not being used to the fullest. A new methodology is needed where the control of floods can be done in time and up to a certain level so that there should minimum loses of life and property. A plan is needed such that prior planning can be done so as to avoid the mass Destruction floods bring every year to the country.

I would like to propose a model, in which a warning system will be made such that it will alert before the floods come, will be active during the floods and will help in rescue and rehabilitation plus the assessment of destruction after the floods. This can be achieved by the use of GIS in the following steps:

A) Before flooding:

Before a flood, the system can be used to:

- ✓ Calculate the distribution of areas at high risk by comparing historical flood heights with digital elevation model data;
- ✓ Estimate social and economic losses under different alternatives for decision-making or flood routing based on social and economic databases and corresponding models;
- ✓ Suggest the best alternative for population withdrawal from areas at risk;
- ✓ Suggest the best alternative for storing and transporting flood-prevention materials.

This information is important for several reasons. If people are aware of the risks, they can make more informed personal decisions regarding the purchase of insurance and other mitigative and adaptive options. Government at various levels can devise better policy tools to deal with flood disaster, in terms of prevention, response, and recovery. Industries (e.g. insurance) can base their cost–benefit analyses on the best available data.

B) During flooding;

During a flood, GIS can be useful in the following areas:

- ✓ Dynamic monitoring of flooded areas;
- ✓ Estimating the expansion of flooded areas according to meteorological and hydrological forecasting; and
- ✓ Optimizing the transport of materials for disaster relief.

C) After flooding;

When a flood is over, the system can be used to calculate the actual flood losses in different administrative areas. Such information allows government agencies to determine relief funds and for insurance companies to calculate payments. By providing comprehensive spatial information, the system supports various efforts in rebuilding, such as planning water conservation facilities and selecting locations of new towns.

8. Conclusions: -

Proper planning can be done to eliminate the losses caused by catastrophic floods of North Indian plain. Land use plans need to be developed and implemented on the basis of knowledge regarding the special ecological, socio-economic and socio cultural conditions prevailing in the flood plain areas. Structural approach shouldn't be practiced any more, as it worsens the situation. The most difficult user requirement is information dissemination on near real-time basis, particularly for events such as floods, cyclones and earthquakes. It is here that remote sensing systems and GIS technology could serve as an efficient monitoring tool. The space, ground and user segments have to be oriented to use such tools for disaster management needs. The alterative plan is certainly based on the study of river hydrology and of human socio-economic behavior. This contrasted data integration can be easily done by using GIS techniques as GIS plays a very important role in flood control and disaster mitigation, especially in the serious floods of the Ganga and Brahmaputra Rivers. Further spatial and statistical analysis can suggest the appropriate land use in flood plains. The land use planning should be based on hazard maps and proper allocation of natural resources. While opting for GIS tools we should also ensure about its feasibility in existing socio economic conditions and administration behavior. The alternative plan requires paradigm shift in thinking of policy makers and a committed political will.

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