CREATION OF DIGITAL ATLAS FOR LANDSLIDE HAZARD

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

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in

DISASTER MITIGATION AND MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the work carried out in this dissertation report entitled, "**CREATION OF DIGITAL ATLAS FOR LANDSLIDE HAZARD**" is presented on behalf of partial fulfillment of the requirements for the award of degreeof**"Masters of Technology"**submitted in **Centre of Excellence in Disaster Mitigation and Management,** Indian Institute of Technology Roorkee, under the supervision of **Prof. P.K. Garg**, Professor, Department of Civil Engineering, IIT Roorkee.

The matter presented in this dissertation has not been submitted by me for the award of any other degree or diploma of this or other Institute.

Date: 19/5/2015

Place: DEHRADUN

(Vipin Chanalia)

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

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Date: 19/5/2015

(Vipin Chanalia)

ABSTRACT

The assessment of landslide hazard manually is a challenging task. With the evolution of geospatial technologies like remote sensing and Geographic Information System (GIS), the estimation of the hazard has become effective and convenient. Landslide Hazard Zonation (LHZ) mapping constitutes an integral part of landslide mitigation. In order to accomplish the objectives of LHZ mapping, various parameters of considerable importance are taken into account and each parameter serves as a thematic layer. Eventually, these layers are then integrated to produce a LHZ map. For future assistance, there is a need to organize the thematic layers and LHZ maps. The best way to do so is assembling them in the form of a book, better known as an 'atlas'. But there are various limitations bound to paper atlas like, their cost of reproduction, non-customizability, fixed frame of maps, etc. To overcome these limitations, electronic adaptation in the form of digital atlas has come to the rescue. A digital atlas is the most interactive and user-friendly form of representation till now which can carry various tools and functions like- customizability, zooming, panning, better visualization, easy navigation, etc. The digital atlas thus stands as a ready-to-help source which may assist planners and decision makers in mitigating disasters like landslide.

Keywords: Landslide, landslide hazard zonation mapping, geospatial technology, digital atlas.

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CHAPTER 1
INTRODUCTION

1.1 General

Every year thousands of people all over the world are killed and lakhs of people become homeless in natural disasters like earthquake, landslide, and flood. Also, the economic damage by these disasters is increasing every year turning from millions to billions. Hence, for mitigating these unwilling impacts of natural disasters, it becomes primarily important to promote and accelerate various risk mitigating efforts and to have an effective technique which can serve for the purpose of planning, mitigation and management. Of these catastrophic events, landslide is a serious threat in many parts of the world (Sassa et al, 2007). India is also a victim of landslides. About 15% of the total area of India is susceptible to landslides. This 15% of total area of India majorly includes the Himalayan region (north and north-east), the Eastern Ghats, Western Ghats and hills of the southern middle parts of India. All these landslide susceptible regions are characterized by dynamic geological and geographical conditions. The Uttarakhand state falls in the northern Himalayan region of India and it too has very dynamic geological conditions as it comes in a region of orogeny where the mountain building processes are still running.

1.2 Preamble

The term "landslide" comprises variety of mass movements influenced by the gravitational force. It is downward and outward movement of the material on the steep and unstable slopes which includes the materials like broken rock fragments, blocks, boulders, loose soil debris or a complex combination of these. The movement of the material can be in the form of- topple, fall, slide, flow or spread. The rate of the movement varies from very slow (mm to cm per year) to very rapid and sudden movement (meters per second).

The landslide studies can be categorized as pre- and post-disaster studies. The pre-disaster studies include landslide hazard zonation mapping at different scales to identify the areas/locales susceptible to landslide hazard. The landslide hazard zonation maps, thus developed, provide an assessment of the safety of existing habitations and infrastructural elements, and help plan further developmental activities in mountainous regions. The post-disaster studies include development of inventory data bases of existing landslides, assessment of landslide incidences occurring in the region as a part of quick response to landslide occurrence, detailed studies of selected landslides and studies of landslides with an effort to stabilize them.

Now-a-days, geospatial technologies like remote sensing, Geographic Information Systems (GIS) and navigation technique like GPS can be effectively used to map and monitor landslides and landslide prone areas with greater accuracy than could be accomplished previously with field reconnaissance alone which is a costly and time consuming method. These technologies also provide opportunity to map the associated features which could be used in overlay analysis method or modelling approach to generate Landslide Hazard Zonation (LHZ) maps.

With the advancement of technologies and taking the help of a boon in technical field named as- "computer", a digital atlas containing such thematic maps along with the landslide hazard zonation maps, important in landslide studies can be made. This digital atlas will be very useful for the purpose of planning and mitigation as it will be interactive with the user and facilitate the user with the functionalities like- zooming, panning, easy navigation etc.

1.3 Landslides, its types and its causative factors:

Landslide is defined as the downward and outward movement of slope forming materials under the influence of gravity (Fig.1.2.1).

Figure 1.2.1: Landslide in a hilly region

Varnes (1978) classified slope movement as (Tab.1.3):

Table 1.3: Schematic landslide classification by Varnes (1978)

Type of movement			Type of material		
			Bedrock	Engineering soils	
				Predominantly fine	Predominantly coarse
Falls			Rock fall	Earth fall	Debris fall
Topples			Rock topple	Earth topple	Debris topple
Slides	Rotational		Rock slump	Earth slump	Debris slump
	Translational	Few units	Rock block slide	Earth block slide	Debris block slide
		Many units	Rock slide	Earth slide	Debris slide
Lateral spreads			Rock spread	Earth spread	Debris spread
Flows			Rock flow	Earth flow	Debris flow
			Rock avalanche		Debris avalanche
			(Deep creep)	(Soil creep)	
Complex and compound			Combination in time and/or space of two or more principal types of movement		

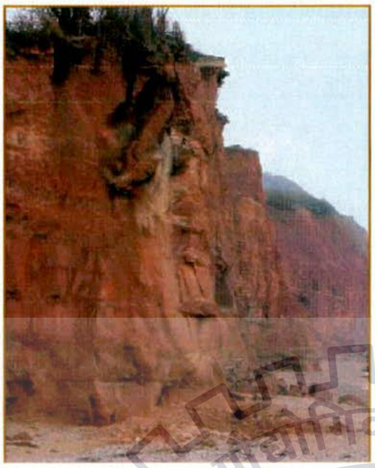
Fall- A fall is the detachment of rock mass from a steep slope along a surface on which little or no shear displacement takes place (Fig. 1.2.2).

Topple- A topple is the forward rotation, out of the slope, of a mass of soil or rock about a point or axis below the center of gravity of the displaced mass (Fig. 1.2.3).

Slide- A slide is a down slope movement of a soil or rock mass occurring dominantly on surfaces of rupture or relatively thin zones of intense shear strain (Fig. 1.2.4).

Spread- A spread is an extension of a cohesive soil or rock mass combined with a general subsidence of the fractured mass of cohesive material into softer underlying material. The rupture surface is not a surface of intense shear. Spreads may result from liquefaction of flow of the softer material (Fig. 1.2.6).

Flow- A flow is a spatially continuous movement in which surfaces of shear are short lived, closely spaced and usually preserved (Fig. 1.2.5).



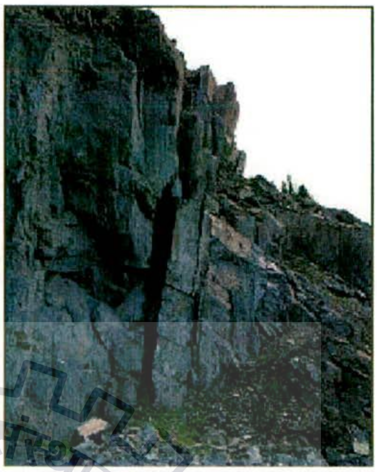


Figure 1.2.2: Fall

Figure 1.2.3: Topple

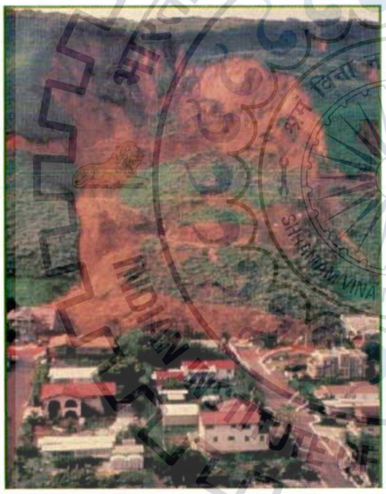


Figure 1.2.4: Slide

Figure 1.2.5: Flow

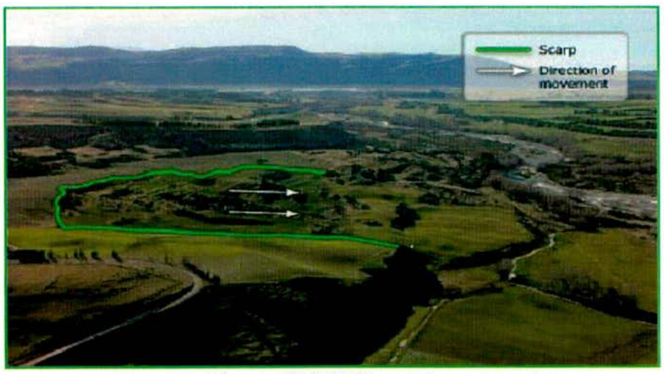


Figure 1.2.6: Spread

There are several factors responsible for landslide occurrence. Some of the important parameters are discussed below along with their relationship with landslides:

Slope- Slope is the most significant parameter in causing the instability of a surface. Steeper the slope more is the chance of instability (Lee & Min, 2001).

Aspect- After slope, aspect is another parameter that drives the instability of a surface. It is basically the direction of sunshine, rainfall, etc., that affects a surface's stability (Van Westen & Bonilla, 1990).

Lithology- Lithology deals with the study of rock-formation. Type of rock formation therefore has a great role in initiating landslides. Rocks that are composed of minerals like clay, gypsum, mica, etc., are prone to landslides (Carrara et al. 1991; Anbalagan 1992).

Ground water- Water being a universal solvent tends to dissolve or decompose minerals and that comes its way, therefore, leaching of the rock takes place that eventually makes the rock weak and with low strength.

Rainfall- Just like ground water, rainwater penetrates the joints and fractures present in a rock and make the surface slippery and weak that results in the slippage of overburden in a downward and outward direction.

Geology- Geological structures like faults, joints, fractures, etc., are the plane of weaknesses along which a mass of rock may slide down leading to a landslide.

Human Influence- Deforestation, construction of roads, tunnels, rail tracks, etc., are some of the human activities that directly or indirectly have a great role in disturbing the stability of rocks.

Seismicity- An earthquake release vibrations that are enough for causing instability in a rock by adding the released energy to the shear stress in a slope, thus making it weak and instable.

Distance from Rivers- The degree of saturation of the slope material also controls the stability of a rock mass. Closer the slope to drainage systems, lesser will be its stability (Gokceoglu and Aksoy 1996).

Distances from Roads- Slopes nearer to the roads are less stable because of the reduction in the load of a slope, due to which the stress in the back of the slope increases and results in land sliding (Pachauri and Pant 1992).

1.4 Need of the study

Landslide is one of the most devastating natural disasters, particularly in the mountainous terrains. India is having about 15 to 20 per cent of its total area in mountainous terrain. About 15 per cent of the total area of India is susceptible to landslides. This 15 per cent of total area of India majorly includes the Himalayan region (north and north-east), the Eastern Ghats, Western Ghats and hills of southern middle parts of India. The Fig. 1.3 shown below represents the landslide hazard zonation of India by Survey of India in 2001 on map with scale of 1:15000000.

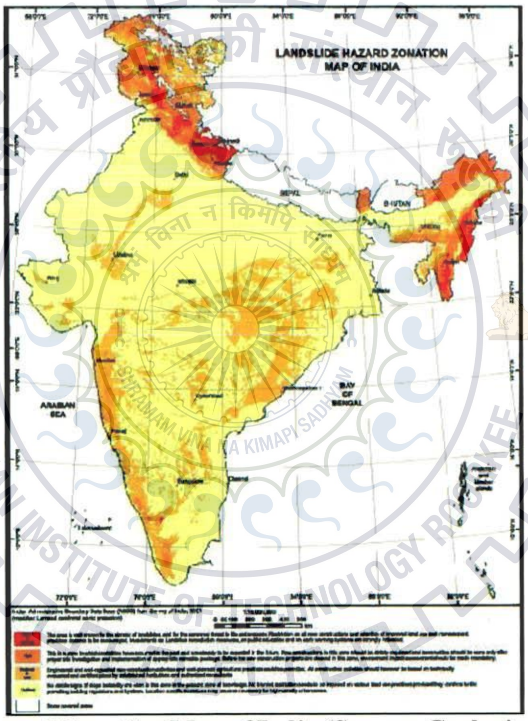


Figure 1.3: Landslide Hazard Zonation Map of India (Source: Geological Survey of India, 2001).

The map is clearly showing that the northern frontier and the north eastern part of India come under the zones of sever to very high susceptibility to landslide.

So, it becomes essentially important to have easily accessible and well assorted data about such vulnerable areas. Therefore, the main motto is to collect the data using geospatial techniques, and to make such data easily understandable, interpretable & usable for planning, mitigation and management.

1.5 Objectives

The objectives of my research work are:

(i) To incorporate, digitize and generate the various thematic maps to derive the landslide hazard zonation maps using the geospatial technologies like remote sensing and GIS softwares.

(ii) To develop a digital flipbook with the help of different programming languages to represent the various thematic maps and the landslide hazard zonation map digitally in the form of a digital atlas so that they can be understood, interpreted and used properly to serve the purpose of mitigation and planning.

CHAPTER 2

LITERATURE REVIEW

2.1 Landslide Hazard Zonation (LHZ)

Anbalagan, et al, (2015) carried out study in Lachung Valley (Sikkim Himalaya) and successfully identified landslide hazard zones using fuzzy logic and frequency ration approach. In addition to the landslide inventory, temporal data of remote sensing was considered to mark important landslide inducing parameters. In order to integrate the parameters with the prevalence of landslides, fuzzy logic approach was applied. The frequency ratio values of landslide asserted the significance of classes in land sliding. Total five LHZ maps were produced, each constituting five zones viz. very low to very high hazard zones.

Landslide is a manifold geological, geomorphologic or meteorological mechanism governed by a number of parameters that are also responsible for the complexity of the assortment of current landslides and forecasting of the future ones. According to Carrara and Guzzetti (1995), the foremost step for the assessment of landslide susceptibility in a GIS environment is the collection and sorting of actual data related to the manifestation of landslides. For their study, they considered various important parameters like, slope, aspect, geology, land use land cover, soil depth, flow accumulation, soil classification, texture class, and distance from road.

Borga, et al. (1998) reported a range of advances used in the assessment of landslide hazards are: investigation of scars and deposits of landslides to trace probable hazardous sites; diversified analysis of parameters marking examined sites of slope instability; and rating of stability establishing geological and structural traits. Lately, GIS has proved to be an efficient technique in the landslide hazard zonation by organising spatial data digitally and by assessing correlations among various data types and extracting admissible topographic information.

According to Anabalagan (1992), landslide hazard zonation maps are of much importance to planners and developers for executing planning and developmental strategy in the mountainous terrains. Also these maps are indispensable for disaster mitigation and management associated people for taking relevant mitigation measures in sites vulnerable to landslide hazards and in order to adopt convenient precautionary measures. The LHZ map demarcates land in the form of various zones of varying degrees of susceptibility with the aid of parameters responsible for the instability based on their significance.

2.2 Digital Atlas

Atlas is a systematic and sequential arrangement of various maps having a specific theme to serve a specific purpose. These maps can be arranged systematically either in the form of a paper atlas or digitally with the help of electronic media. Thus, the collection of various thematic maps can be represented digitally with the help of computers and developed software in the form of a digital flipbook which is here termed as *"the digital/electronic atlas"*. The choice of digital representation instead of paper atlas is because of the various advantages of electronic atlas over a paper atlas. To overcome the limitations of paper atlas digital atlas provides various functionalities. A comparison was made by Kraak and Ormelling (1996) shown in the Tab 2.2.1 below whereas the Tab 2.2.2 shows the various advantages of digital representation.

Table 2.2.1: Differences between paper and digital atlases

Paper Atlas	Digital Alas
Static	Dynamic
Passive	Interactive
Maps only	Maps and multimedia
Limited/selective	Complete
Fixed map frames	Panning and zooming possible
Compromise for all types of use	Customized
Maps as final product	Maps as interface

Table 2.2.2: Advantages of Digital Atlas

Attribute	Description
Exploration	Exploration can be understood as the amount of freedom given to the user in order to explore the contents of the atlas. The use of GIS functionalities can be included in this concept. Interactivity is a key component in an exploratory atlas.
Dynamics/Animation	The use of animation and its new visual variables brings new forms of communicating spatial data.
Customisability	Once more the issue of interactivity is present, at this point the concept is to allow the user to customise the map as the interface of the information, by changing layers or visual variables for example, in order to attend individual requirements.
Integration with diverse media	It is possible to integrate the digital atlas with textbook, paper atlas, working sheet, wall map, and so on. In this way new didactic perspectives could be reached.
Current contents	A digital atlas can be easily updated; if the product is networked its contents are current and immediately available to the user.
Portability	The digital atlas is easier to transport when available in discrete media, moreover if it is available on the Internet portability is not an issue. However, the computers are still heavy.

Khosrowpanah and Wen (2005) created a digital atlas for the watershed of Southern Guam. The main tool used for the purpose was GIS. The steps taken to accomplish the objective are:
-to identify the map projection and a digital elevation model (DEM) that should be used for developing atlas,
-to generate watershed boundaries for all major basins in the area,
-to develop physical features for each watershed (soil type, rivers miles, vegetation and location of stream gauges).
Distinct layers were developed for each physical character. Also, digital elevation model (DEM) was developed for the area. Finally, all these layers were projected into a common projection system. For delineating the watershed boundaries, a digital elevation data having a horizontal spatial resolution of 10m was obtained from the United States Geological Survey (USGS). UTM map projections and the North American Datum 1983 (NAD83) was used for developing the atlas. For watershed delineation, hydrological functions in Spatial Analyst extension of Arc GIS 9X were used. The information about the slope and aspect was obtained from the digital elevation model. The DEM was also used to determine the watershed edges which were further referenced with previously determined Flood and Emergency Management Agency's (FEMA) watershed boundaries. The outcomes of their study are fourteen watershed delineations in the area which were depicted in a digital atlas.

Thomas, et al. (1999) discussed the South Carolina Atlas for Environmental Risks and Natural Hazards which was developed by the Hazard Research Lab, University of South Carolina. The atlas comprised of the informative maps about sixteen natural hazards including Hurricanes, Tornadoes, Thunderstorms, Flood, Drought, Earthquakes, Toxic spills, Forest Fires and Global Warming. The software used for this purpose are:

i. Adobe Exchange Software (to convert various type of documents into Portable Document Format)
ii. CorelDraw (to design the graphic layout)

Portable Document Format (PDF) are selected because they are compatible for all types of operating systems whether it Macintosh or Windows. The maps for each hazard section were prepared in GIS and then transferred into CorelDraw. The utility of CorelDraw is to design and prepare the graphic map layouts as the Adobe Exchange Software cannot prepare the graphic layouts. After preparing the graphic map layouts, these files are converted into PDF by using

Adobe Distiller a program of Adobe Exchange Software Package. At the same time sound effects including page narration were added in the form of WAV file format. Fig. 2.2 shows the various tool buttons and the section of Hurricanes respectively.

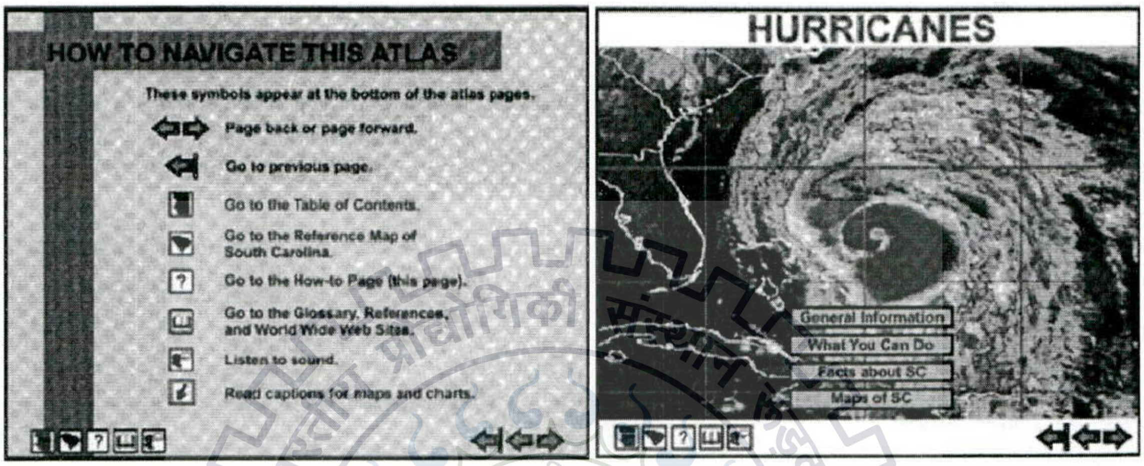


Figure 2.2: Various tool buttons and the section of South Carolina Atlas for Environmental Risks and Natural Hazards

CHAPTER 3

STUDY AREA

3.1 General

The study area for the research work is taken from the Uttarakhand state. The reason for choosing the study area from Uttarakhand is that the area lies in extra peninsular part of India which is characterized dynamic geological conditions which includes the processes of mountain building, intense folding and faulting. Every year the Uttarakhand state is stroked by a number of landslides occurring continuously (especially in rainy season). Every year huge loss to human lives and property occur.

3.2 The Study Area

The study area is along Tanakpur-Lohaghat-Pithoragarh-Malpa Route (Fig.3.2) which lies along the south-western border of Uttarakhand state (Kumaun Himalayas). The road stretch runs through the Udham Singh Nagar, Champawat and Pithoragarh districts of Uttarakhand state. The road has a national importance as it connects the important areas like- Chandari, Tanakpur, Champawat, Lohaghat, Barakot, Pithoragarh, Siroli, Dewal, Dharchula and Malpa. The last village is Garbayang. Almost 40% of the road length runs parallel to the India-Nepal border.

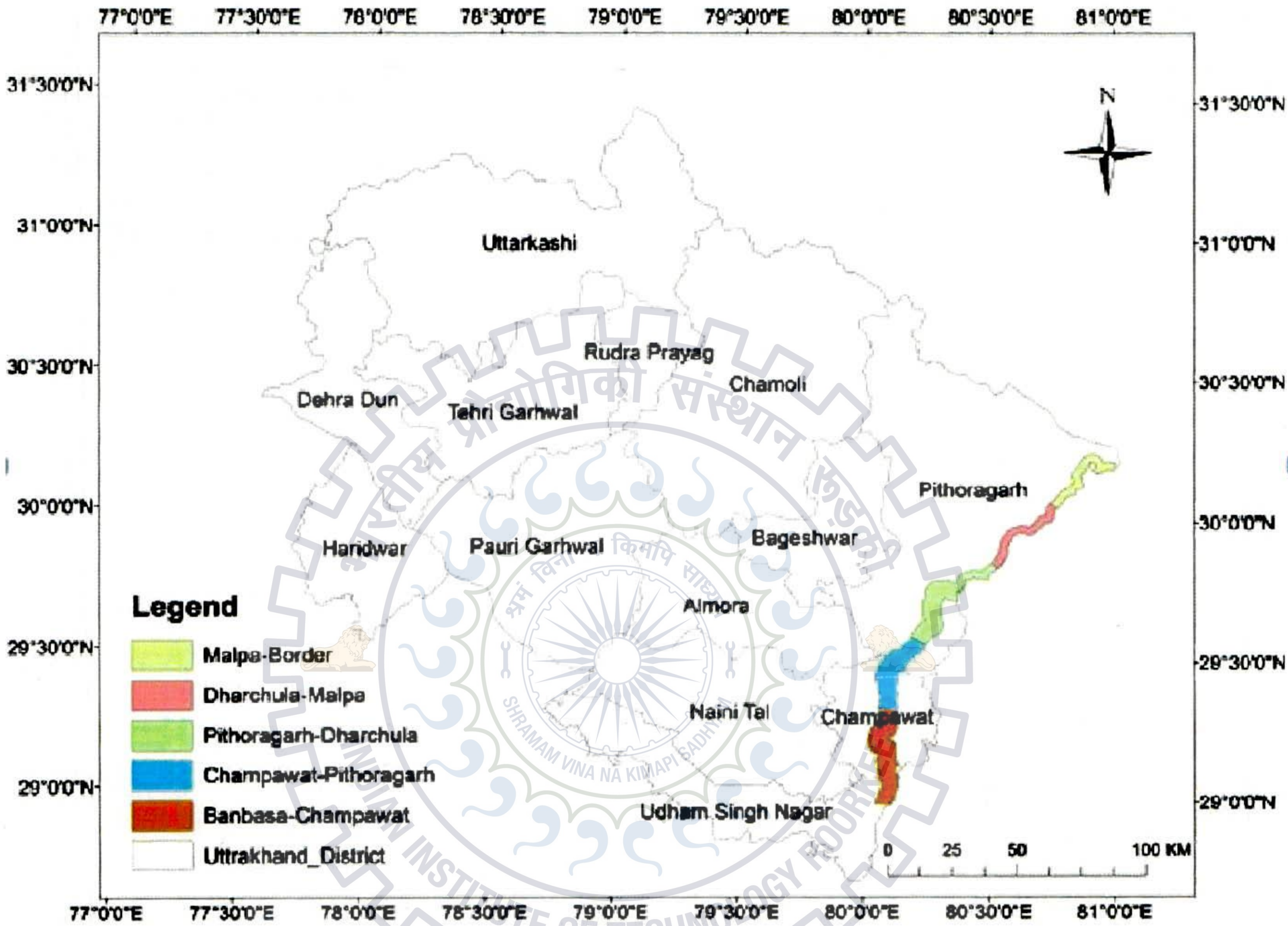


Figure 3.2: Map showing study area

CHAPTER 4

DATA AND SOFTWARES USED

Data used:

1) Toposheets (53O/13,14,15,16; 53N/16; 62C/1,2,3,4,5,6,7,8,9; 62B/4,8,12,16) were acquired from Survey of India, Dehradun.
2) Google Images.
3) Satellite Imageries (LISS III & Landsat).
4) SRTM DEM (slope and aspect were obtained from this).
5) Geological maps from Wadia Institute of Himalayan Geology (WIHG), Dehradun.
6) Soil data from National Bureau of Soil Survey (NBSS), Nagpur.
7) Annual temperature and rainfall record.
8) Hydrology (drainage, groundwater), Environmental Sensitive zone and Rainfall data from National Atlas and Thematic Mapping Organization (NATMO), Kolkata.

Softwares Used:

A. Software used for the image processing and generation of various thematic maps and landslide hazard zonation maps are:

(i) ArcGIS (Version 9.2)

(ii) ERDAS Imagine (Version 9.1)

B. Software used to design the digital atlas:

(i) Adobe Flash Player (Version CS5.5)

CHAPTER 5

MEDHODOLOGY

5.1 Overview

The main motto of the research is to prepare digital database about the landslide hazard of the area so that it can be presented in the digital atlas. These digital comprises of the various thematic layers (which will be exported as thematic maps with the help of ArcGIS) viz. the road map, rainfall map, geology map, lithology map, road buffer, fault map, geomorphology map etc. For this firstly the relevant data is acquired and then corrected, processed and transformed with the help of ArcGIS and ERDAS. Finally a digital atlas has been designed to which the prepared maps are imported and represented. This chapter mainly describes the work flow of how the landslide hazard zonation maps are prepared and the methodology of designing the digital atlas.

The work of the dissertation is divided into two steps-

1. Creation of various thematic maps and landslide hazard zonation maps.
2. Designing the digital atlas.

The flow chart (Fig.5.1) shown below represents how the work has been executed in different stages-

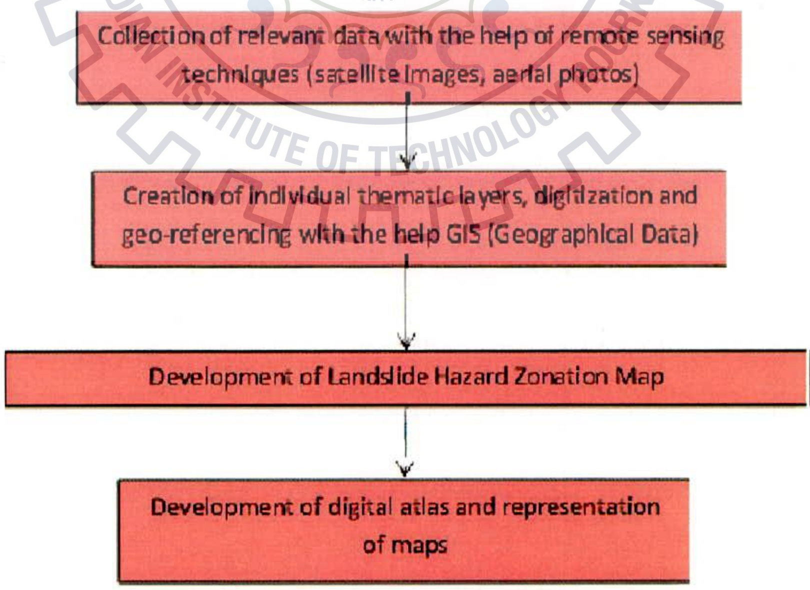


Figure 5.1: The different stages of the work flow

5.2 Preparation of thematic layers

Advancement of geospatial technology like remote sensing and GIS has made assessment of landslides convenient and effective. The technology helps in the capturing, storing, enhancement, analysis and management of data and eventually helps in producing an efficient outcome. Together remote sensing and GIS techniques has been used in the generation of thematic layers like, geology, geomorphology, lithology, lineament, annual temperature, environment sensitive zone, groundwater, irrigation, soil, soil depth, rainfall, drainage, drainage density, fault buffer, slope and aspect.

The tiles were georeferenced with respect to Survey of India Toposheets. It was taken care that the RMSE (Root Mean Square Error) in each case was kept lower than 0.5. The mosaic subset was then used for the generation of various thematic layers. The layers were generated using the on screen digitization process: ERDAS Image processing software and ARC GIS software were used for this purpose. These layers were stored in the vector format and saved as shape files. The following flowchart (Fig.5.2) shows how the thematic layers are prepared.

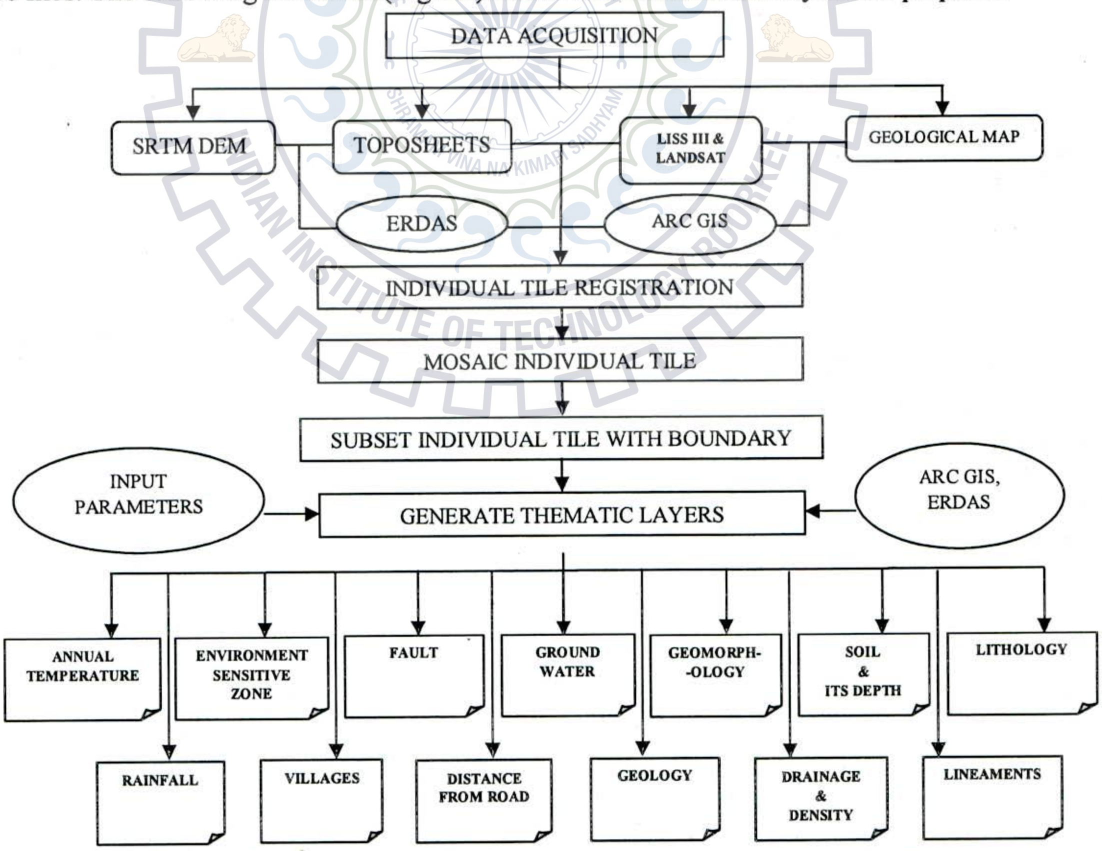


Figure 5.2: Flowchart for the Preparation of various thematic layers.

5.3 Generation of LHZ Map

Landslide hazard mapping was done by using weightage rating technique which depends on the relative significance of various causative parameters. These ratings of individual parameter were used for individual class of thematic layers (Fig.5.3). Each rating value corresponds to a particular class as an attribute value in GIS environment. Rating from 0-10 was done for each class. The weightage assigned to individual parameter depends upon the expected significance of the parameter. The zones for landslide hazard were obtained by multiplying the sum of attributes with the corresponding weights. On the basis of this, six hazard zones were identified having a range from very low hazard zone to severe hazard zone. These six zones are depicted on the landslide hazard zonation map produced as the outcome

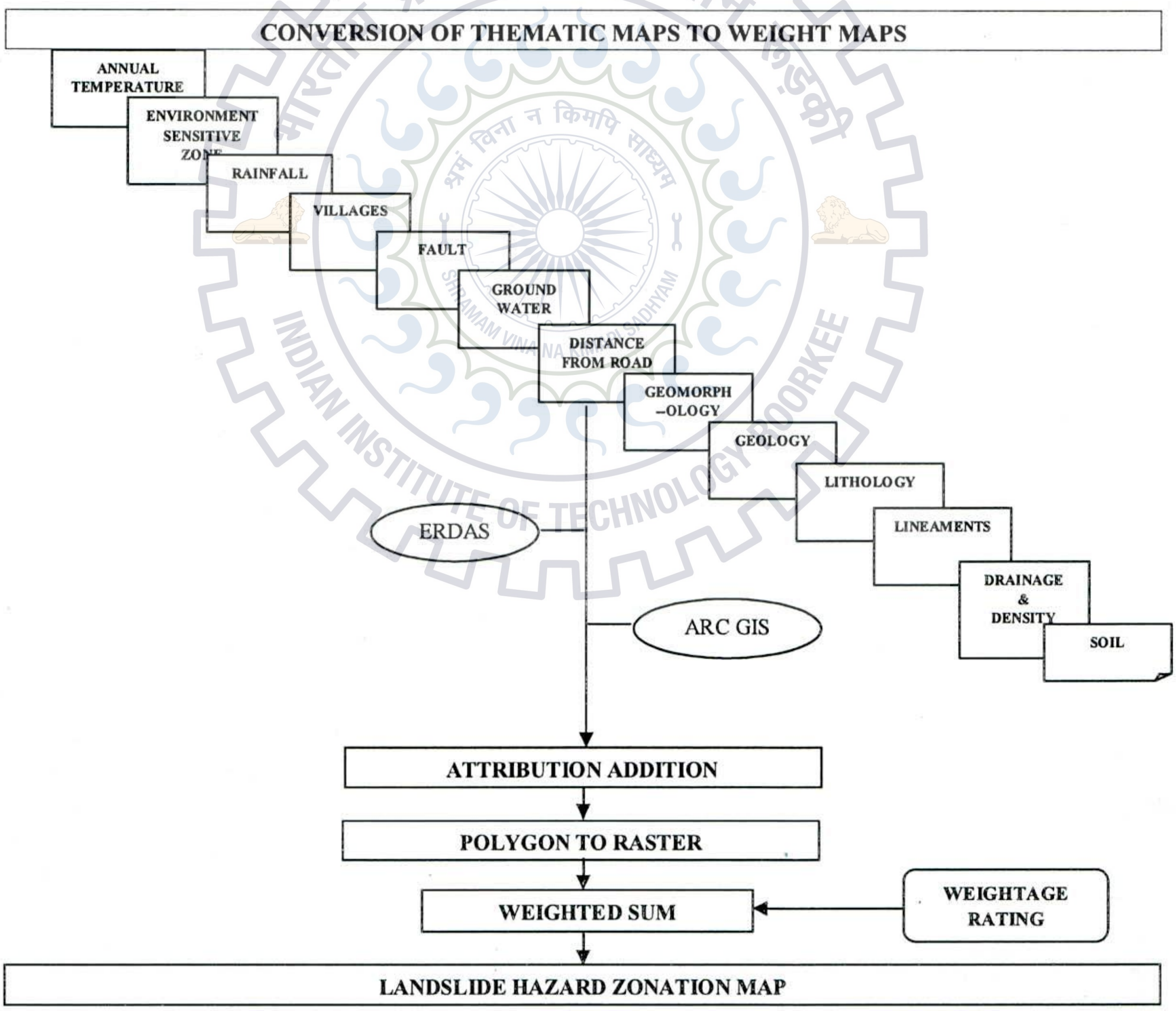


Figure 5.3: Flowchart for the Preparation of LHZ Map using various thematic layers.

Maps for various themes and the landslide hazard zonation maps as an outcome are exported in the form of JPG images. These maps are shown below Fig. (5.3.1 to 5.3.16) in a sequential manner:

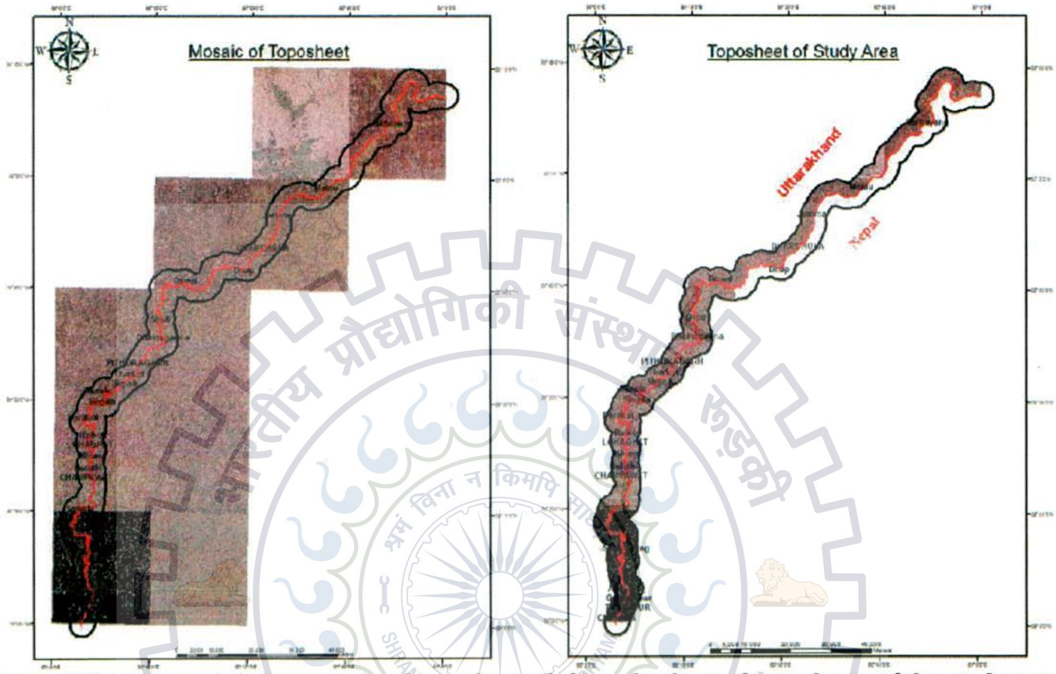


Figure 5.3.1: **Maps showing mosaic of toposheets (left) and subset of toposheets of the study area.**

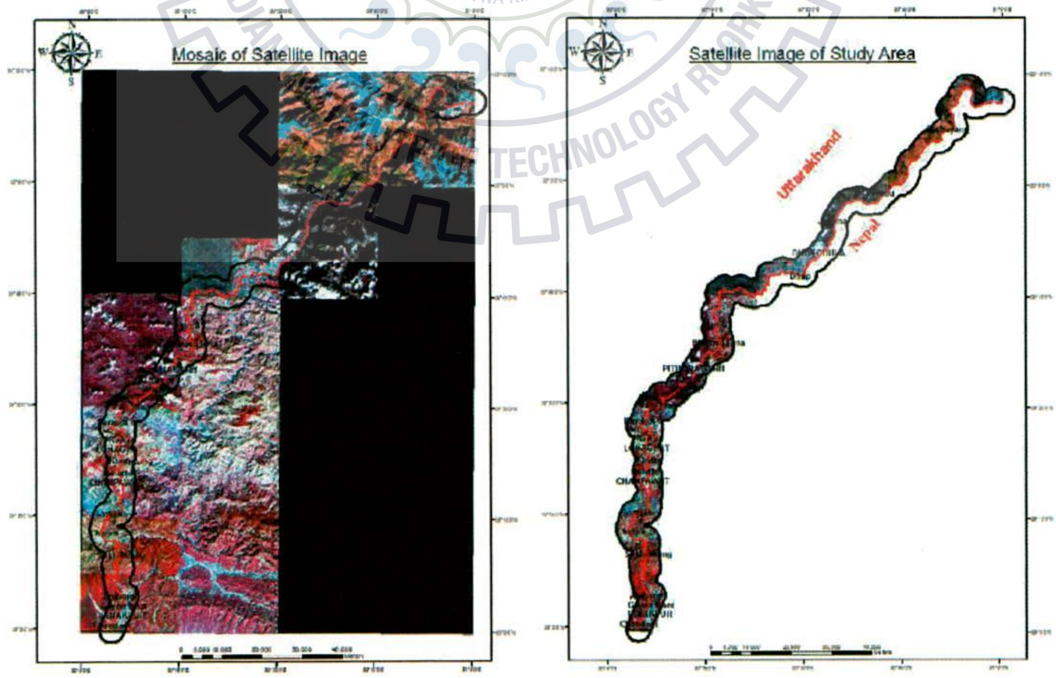


Figure 5.3.2: Maps showing mosaic of satellite images (left) and subset of satellite images of the study area.

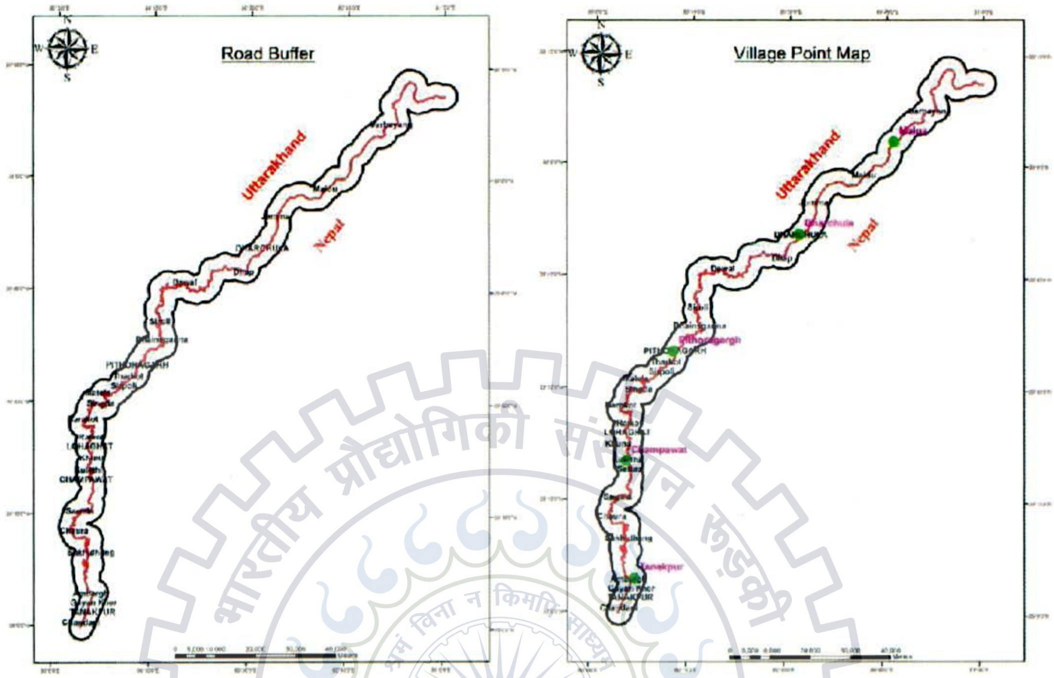


Figure 5.3.3: Maps showing road buffer (left) and Village points

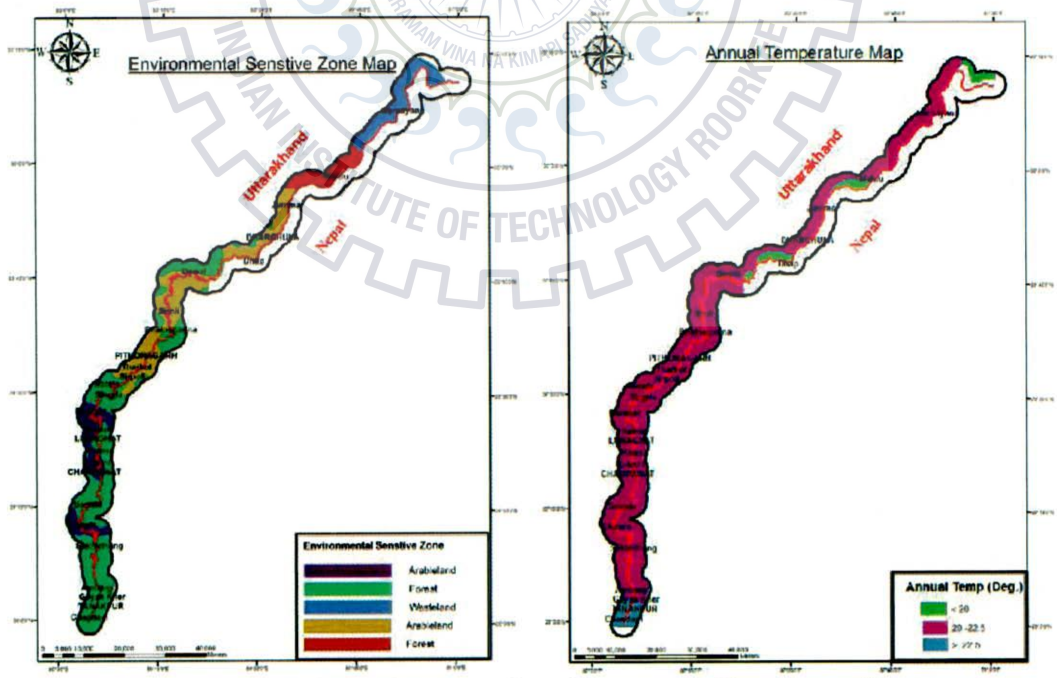


Figure 5.3.4: Maps showing environmental sensitive zone (left) and annual temperature.

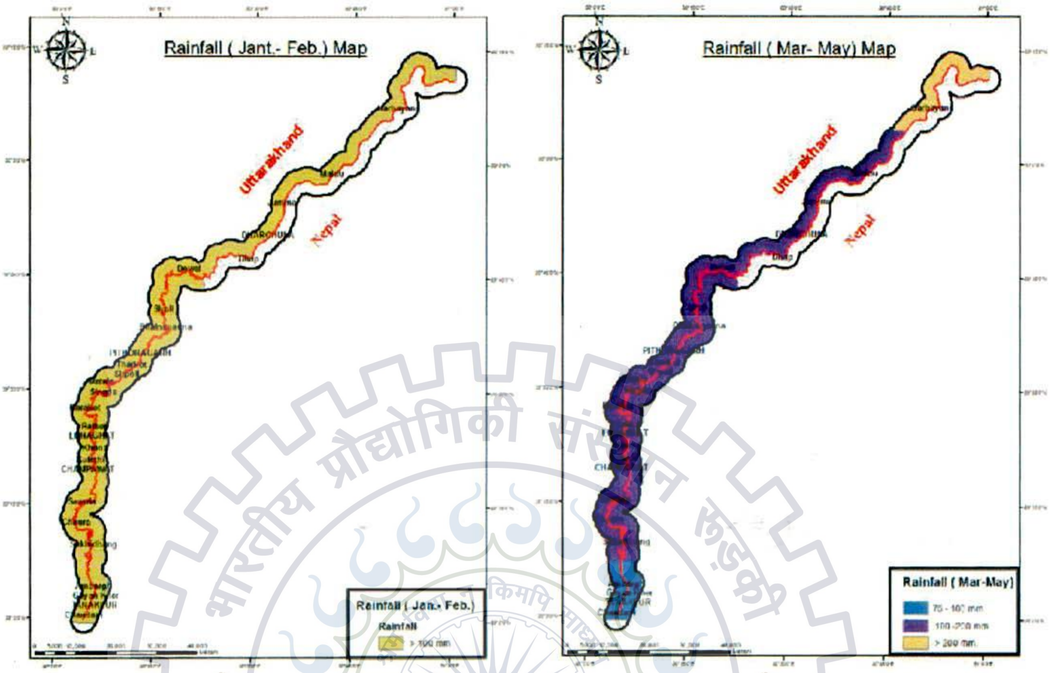


Figure 5.3.5: Maps showing rainfall (Jan-Feb) (left) and rainfall (Mar-May).

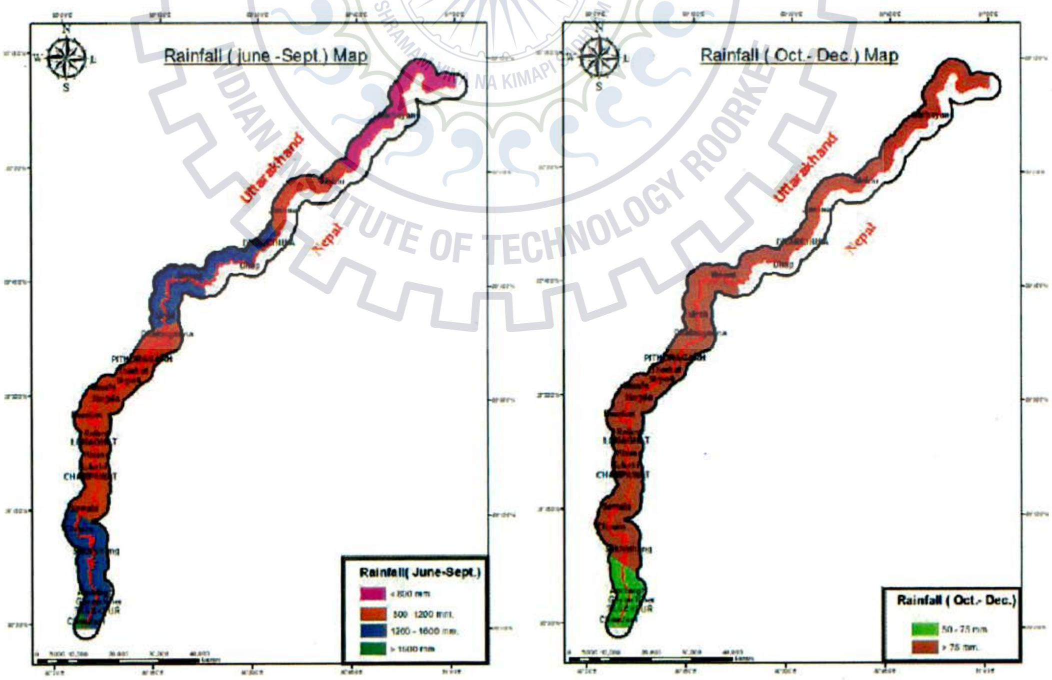


Figure 5.3.6: Maps showing rainfall (June-Sep) (left) and rainfall (Oct-Dec).

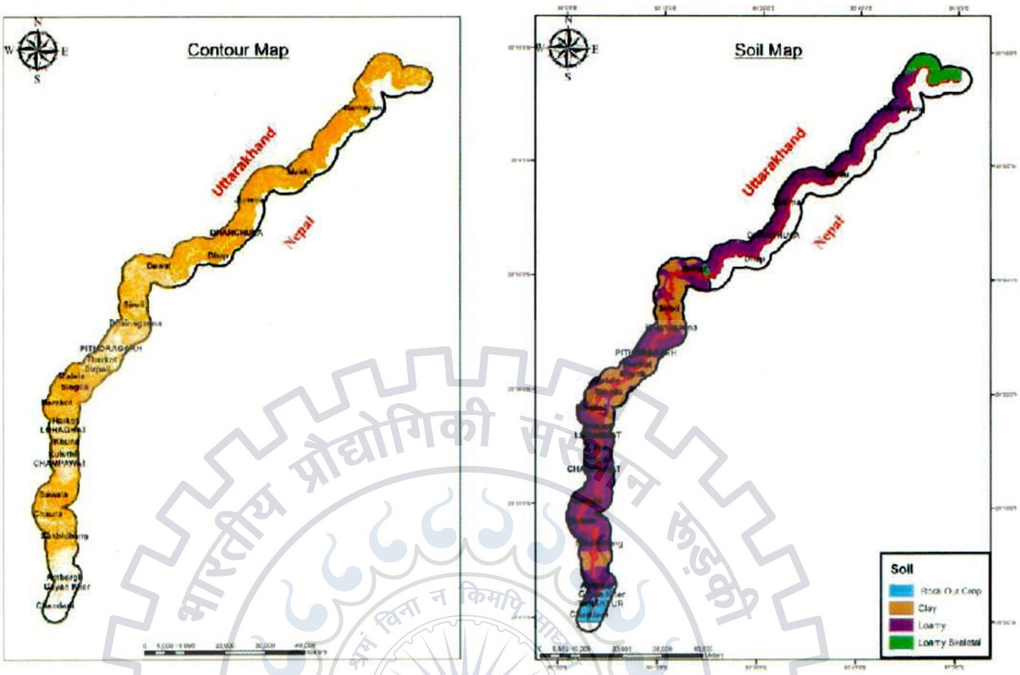


Figure 5.3.7: Maps showing contour (left) and soil.

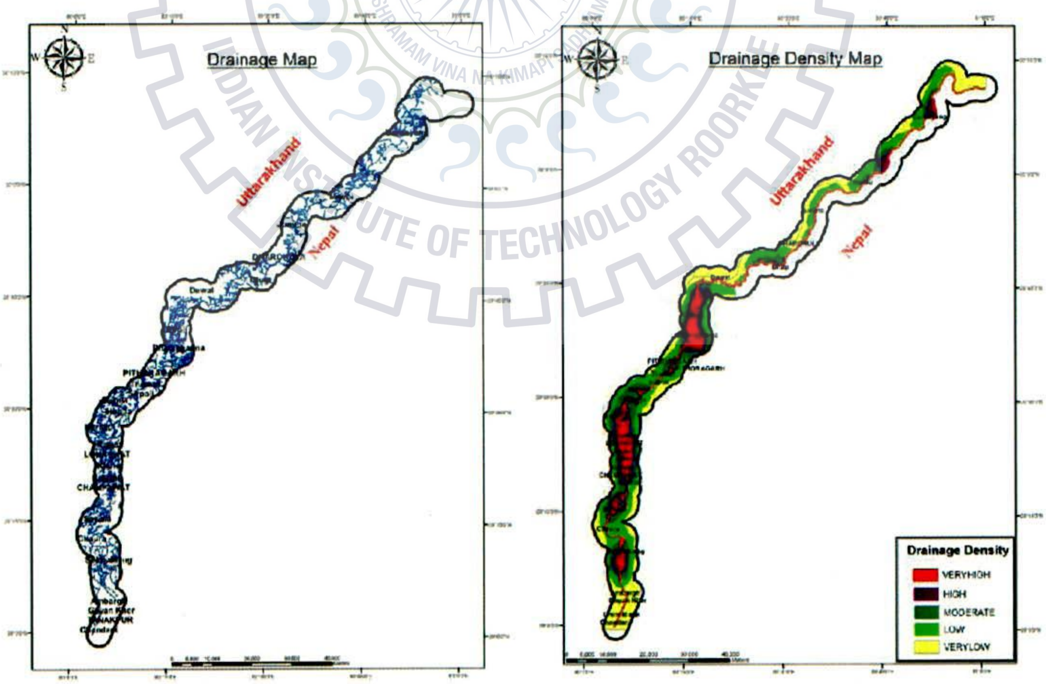


Figure 5.3.8: Maps showing drainage (left) and drainage density.

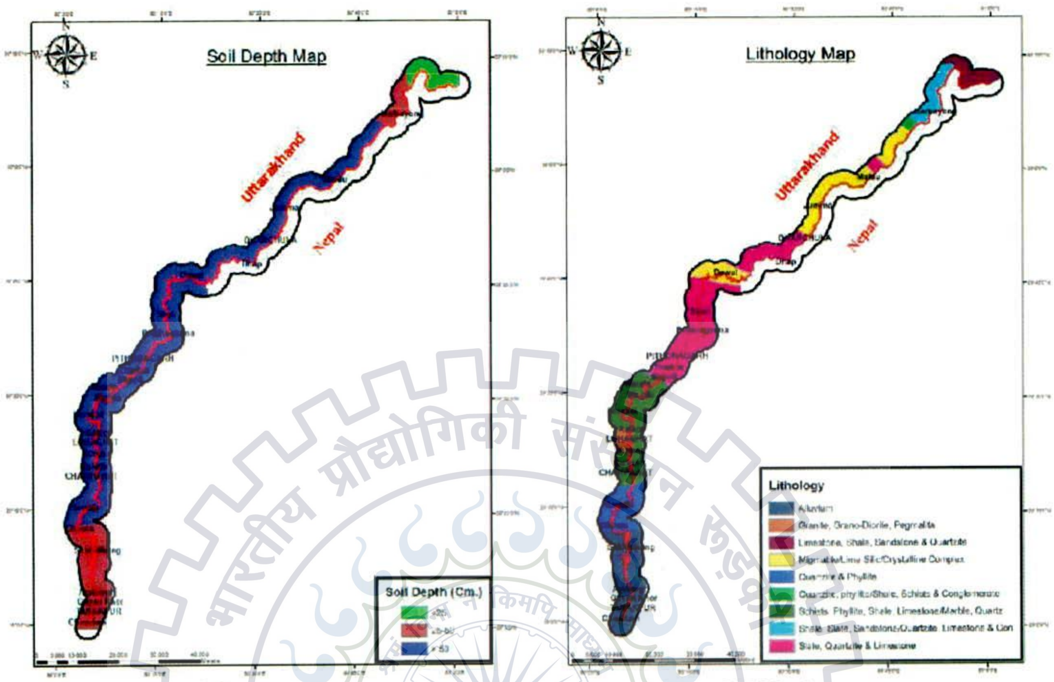


Figure 5.3.9: Maps showing soil depth (left) and Lithology.

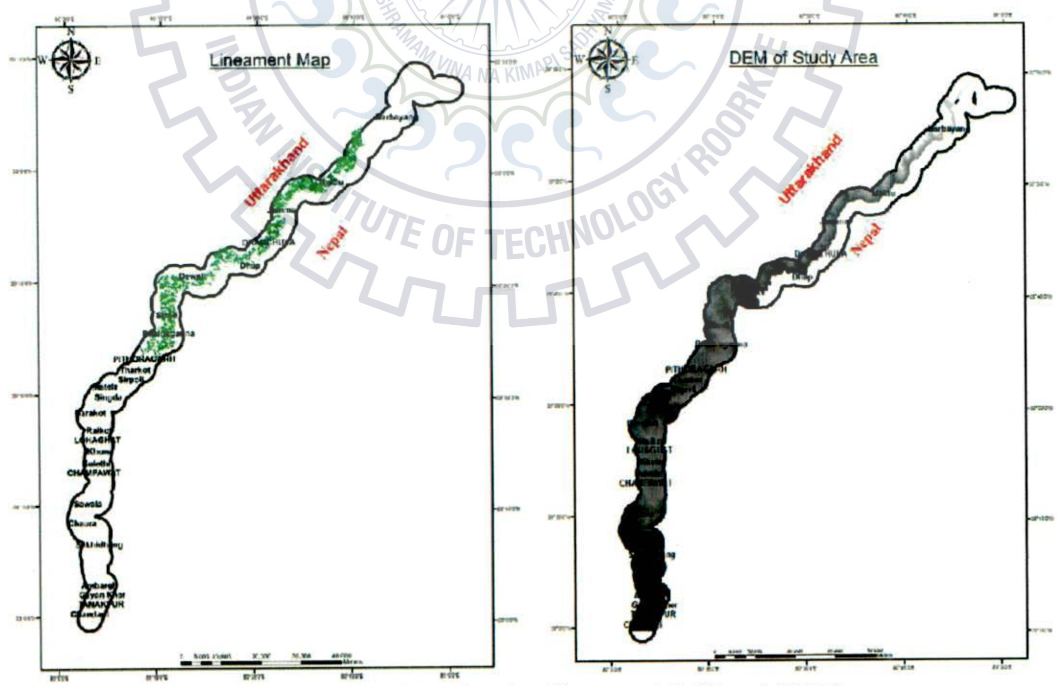


Figure 5.3.10: Maps showing lineament (left) and DEM.

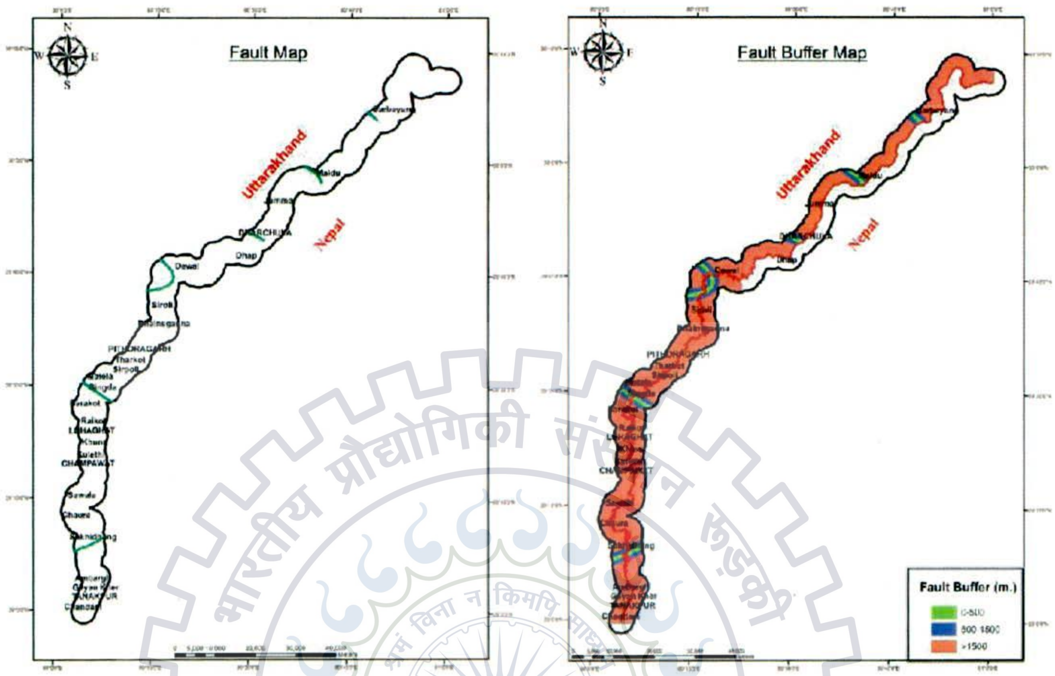


Figure 5.3.11: Maps showing fault (left) and fault buffer.

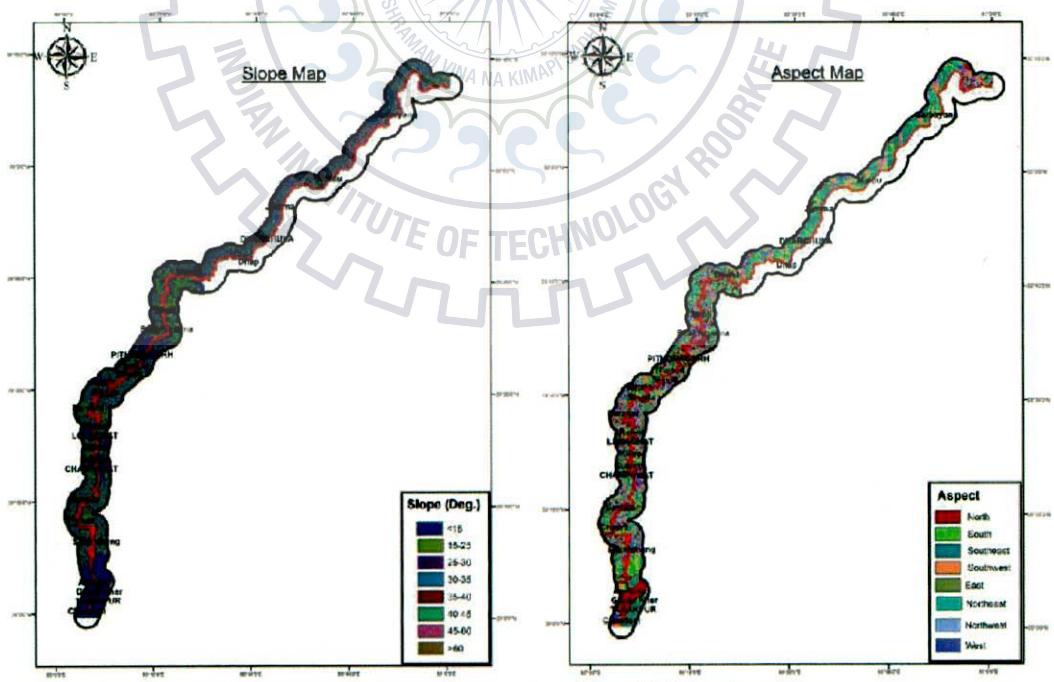


Figure 5.3.12: Maps showing slope (left) and aspect.

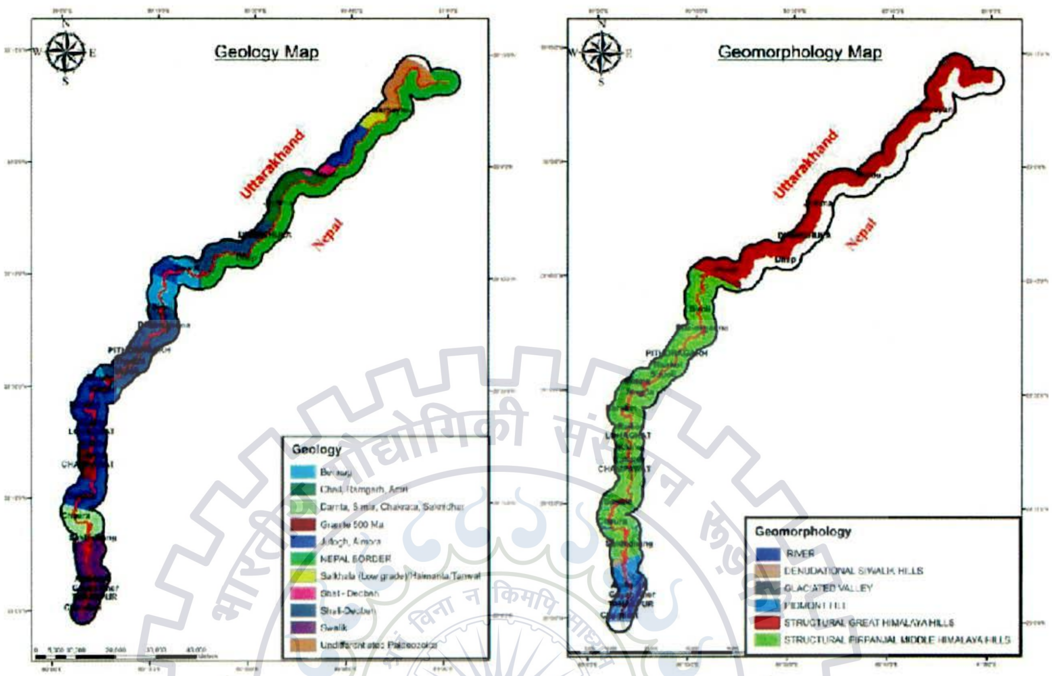


Figure 5.3.13: Maps showing geology (left) and geomorphology.

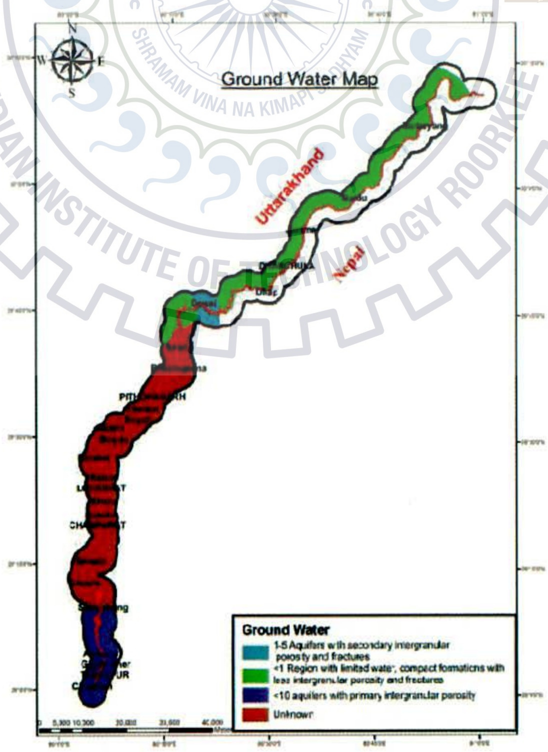


Figure 5.3.14: Map showing ground water of the study area.

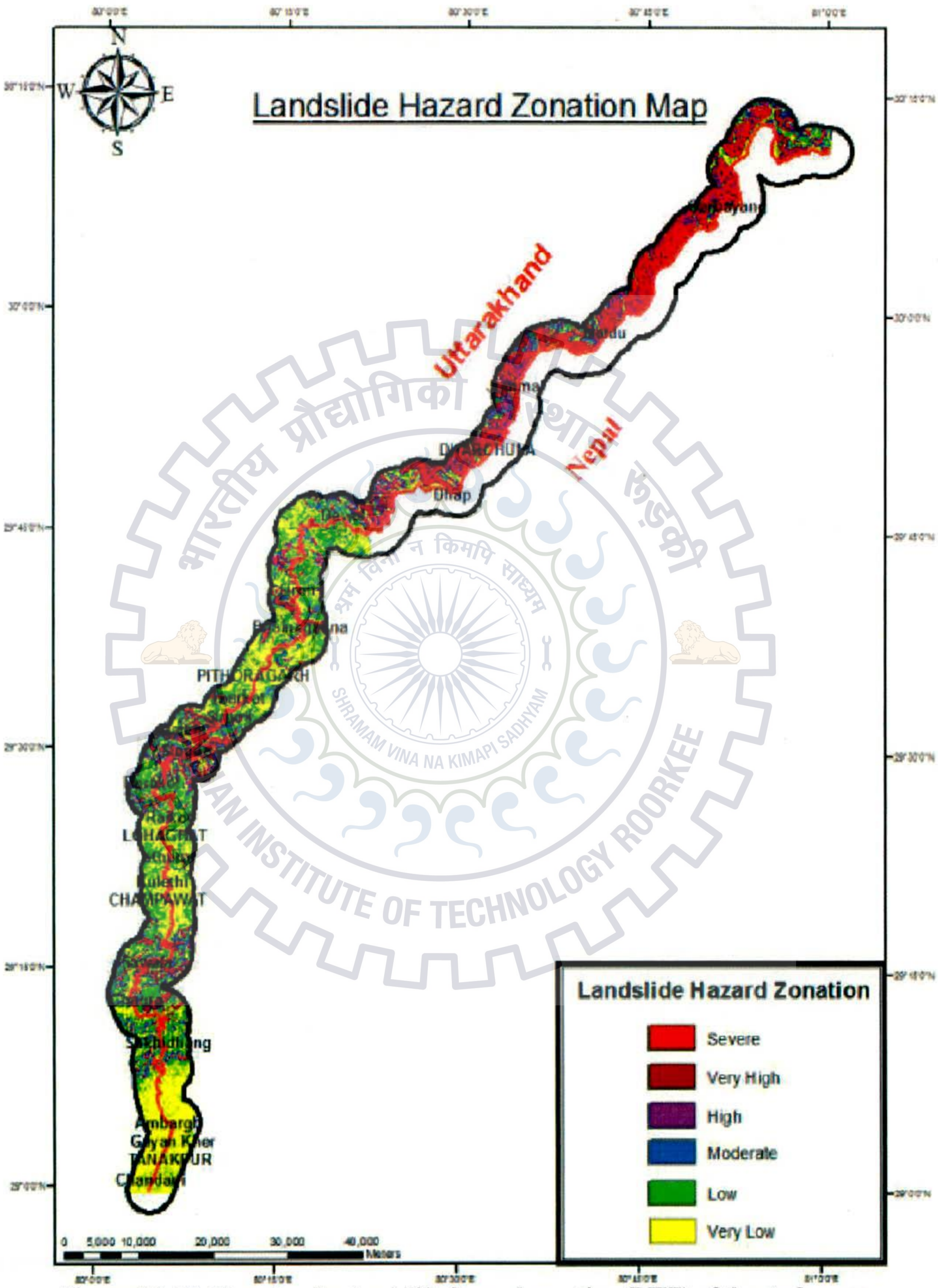


Figure 5.3.15: Map showing landslide hazard zonation (LHZ) of the study area.

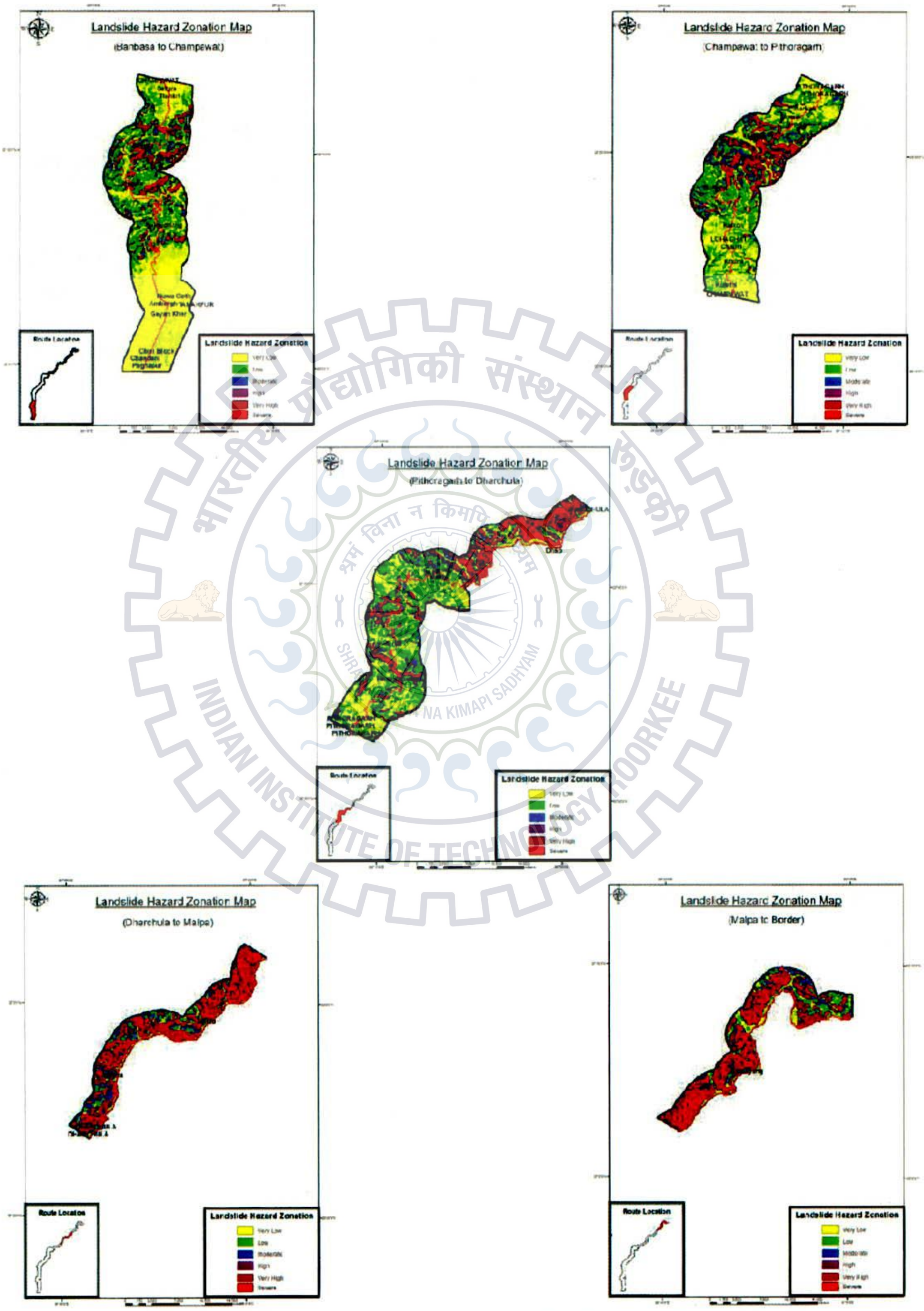


Figure 5.3.16: Maps showing LHZ in segments of the study area

5.4 Designing of atlas

This Digital Atlas is deployed using Adobe flash player (software version: CS5.5), and have many functionalities. These functionalities enable us to perform various tasks such as viewing different maps to analyze and to summarize the results. A Graphic User Interface has been designed in Adobe flash player (software version: CS5.5) by developing a bespoken application using Flash's Action Script AS2. AS2 is a scripting language of Flash that is used to make our application more interactive. Its operation is similar to that of JavaScript in developing Java Applications. This Atlas have been developed keeping in mind that its maps can undergo several operations like Zooming, Slideshow with certain delay and showcasing maps in Tile format. Another option is available for thumbnails and bookmark and notes. In addition, tools for navigational search, page view, contents, magnifying glass, page search, and print and help menu are introduced in the design of this Atlas. This Atlas is controlled using either the toolbar or by clicking on the pages of the publication.

The flow chart shown below (Fig. 5.4.1) shows the algorithm of developing digital Atlas that has been done for the compilation of this thesis. In this flow chart, various elements of flash environment are discussed such as:

(a) Flash document .fla file
(b) Media Library(to store symbols and imported image files)
(c) Special Characters and symbols
(d) Imported Raster Images or Bitmap
(e) Static Images or Rasters
(f) Event Handler
(g) Animation
(h) Clip
(i) Event
(j) Time Controller
(k) Time Controller Header
(l) Current frame indicator
(m) Center frame button
(n) Frames

Taking the above shown elements as base the flash documents contains individual scenes having keyframes which describes the changes in the stage. The flash documents are very efficient in sharing the libraries and loading the files (images or other flash files) using scripting methods.

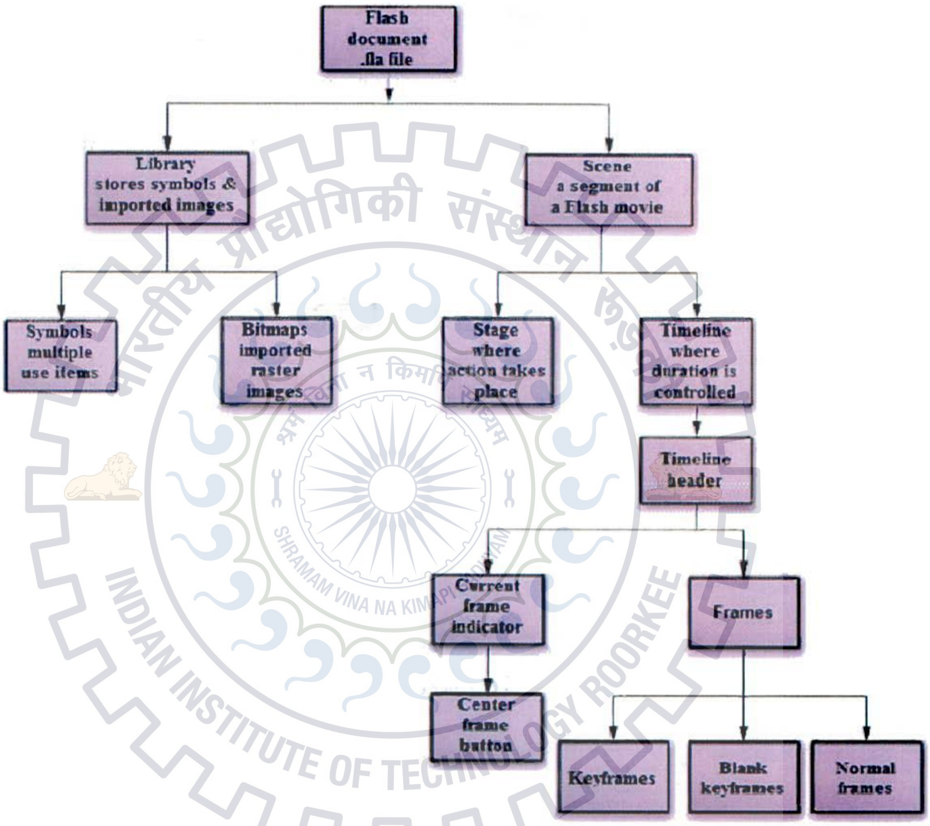


Figure 5.4.1: Flow chart showing the development of Digital Atlas.

(a) Flash documents: Having the extension type .fla.

(b) Media Library: To display the listed media elements present in the flash document.

(c) Special Characters & Symbol: Special Characters or Symbols are the graphical button developed by using the classes. The objects converted into symbols appear in the library and can be reused by dragging it out throughout the document.

(d) Imported Raster Images or Bitmap: Bitmaps describe the image as grid of coloured pixels and store colour of every individual pixel in the image.

(e) **Scene (segment of flash movie):** It is a multiframe timeline independent of main movie timeline. These are movie clips in the form of mini-timelines having interactive tools and sound effects, nested in the main timeline.

(f) **Stage:** It is the platform where all the graphics, animations, videos, buttons and tools appears during platform.

(g) **Timeline:** The timeline defines the ordering of the various graphic layers on the stage. The graphics appears on the stage in accordance to the timeline.

(h) **Timeline header:** The timeline header appearing at the top is to indicate the layer number.

(i) **Center Frame button:** The utility of this button is to center the timeline on the current frame.

(j) **Frames:** The contents of the document are controlled and organized by frames. The frames are designed to move at a certain rate (frames per second) when the animation starts.

(k) **Keyframe:** The keyframe have the ActionScript code and where the new symbol instances appear in the timeline.

(l) **Blank keyframes:** It holds the symbols in the timeline.

(m) **Normal frames:** The ActionScript codes are kept in the Normal frames.

Shock wave flash (.swf) format

The following flow (Fig.5.4.2) chart explains about the generated SWF files to publish a FLA file in Adobe Flash Player Professional. SWF files may have animation effects, graphics and movies. The generated SWF files are usually played back in the Flash Player as a browser plug-in but sometimes it can also be played back as a Standalone Player. The publishing operations also generate HTML files which include the embedded parameters which are to be added with SWF files to ensure the proper appearance in browser window.

In order to export the smallest possible SWF file the information content is refined and optimized and any surplus unused information content is not exported in the Flash Movie.

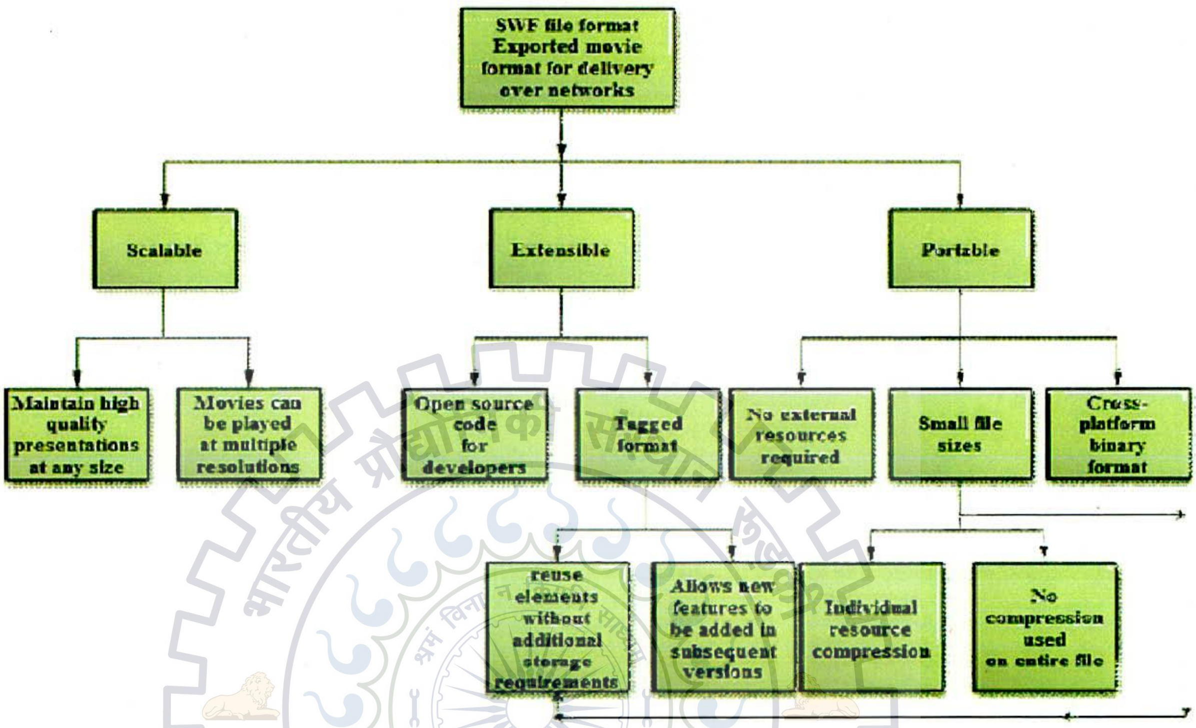


Figure 5.4.2 Outline of the shock wave flash (.swf) format

CHAPTER 6

RESULTS & DISCUSSIONS

6.1 Results

This dissertation produces an innovative and much helpful output in the form a multimedia atlas which will assist planners, developers, environmentalists and disaster mitigation and management associated people. The GIS outputs were in the JPG image formats which were finally introduced in the designed digital atlas. Landslide Hazard is a matter of major concern in the mountainous terrains of India. Facilitating the user with the numerous tools such as zoom, thumbnails, notes, bookmarks, effects, search, contents, print, help, etc. (Fig. 6.1.1 to 6.1.12), the digital atlas makes itself more user-friendly and interactive.

The digital atlas developed has various significant and user-friendly features which will be beneficial for making decision support systems, for searching appropriate sites for installation of early warning systems for landslides, earthquakes, etc., for planners and managers to carry out developmental activities in mountainous terrains, etc.

The different tools buttons provided in the atlas are shown in the following screenshots:

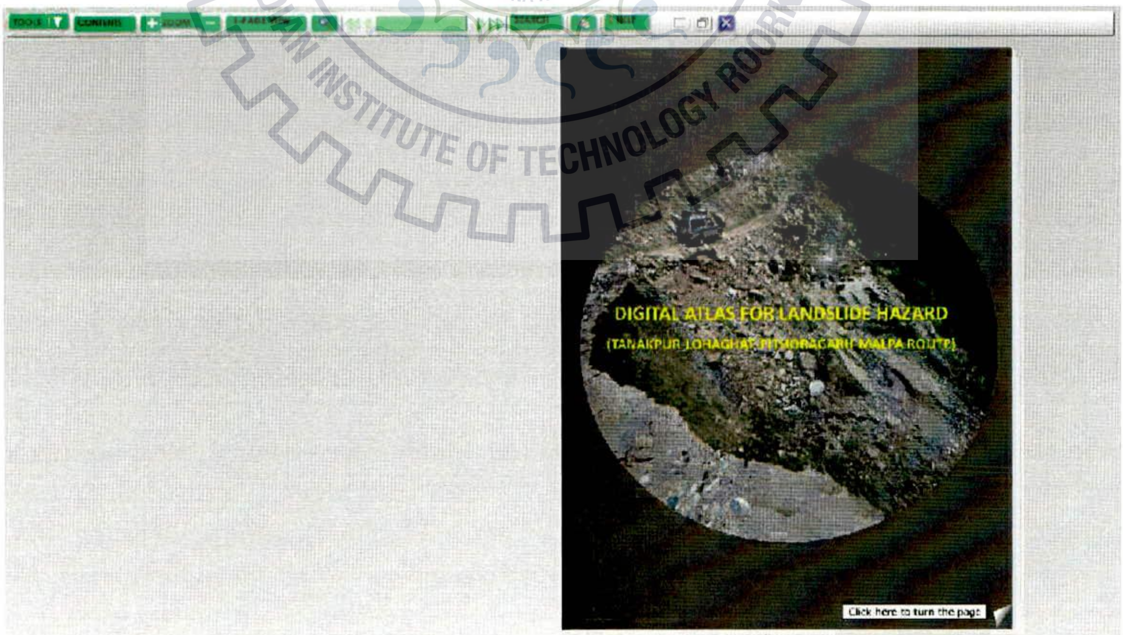


Figure 6.1.1: Screenshot of the main page/cover page of the digital atlas for landslide hazard.

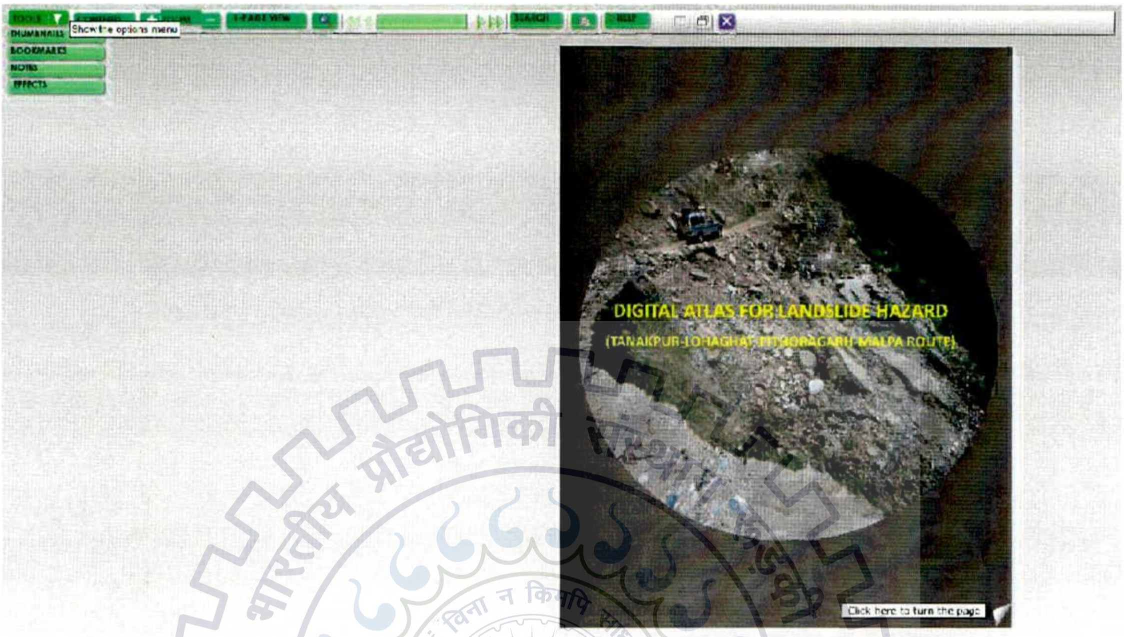


Figure 6.1.2: Screenshot showing tools such as thumbnails, bookmarks, notes and effects.

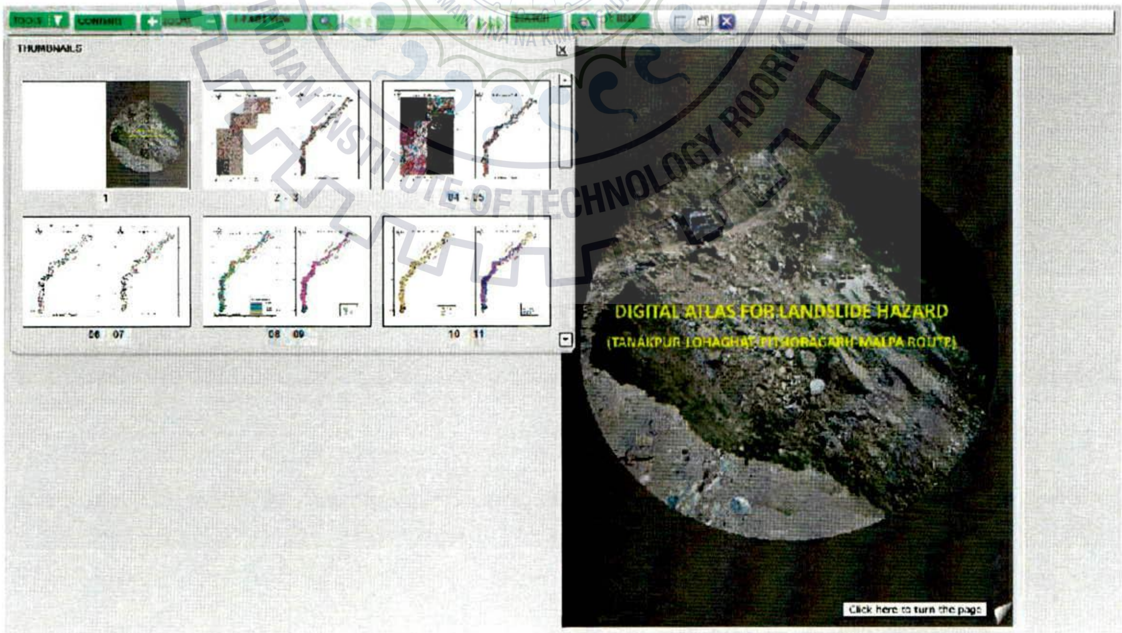


Figure 6.1.3: Screenshot showing thumbnail tool.

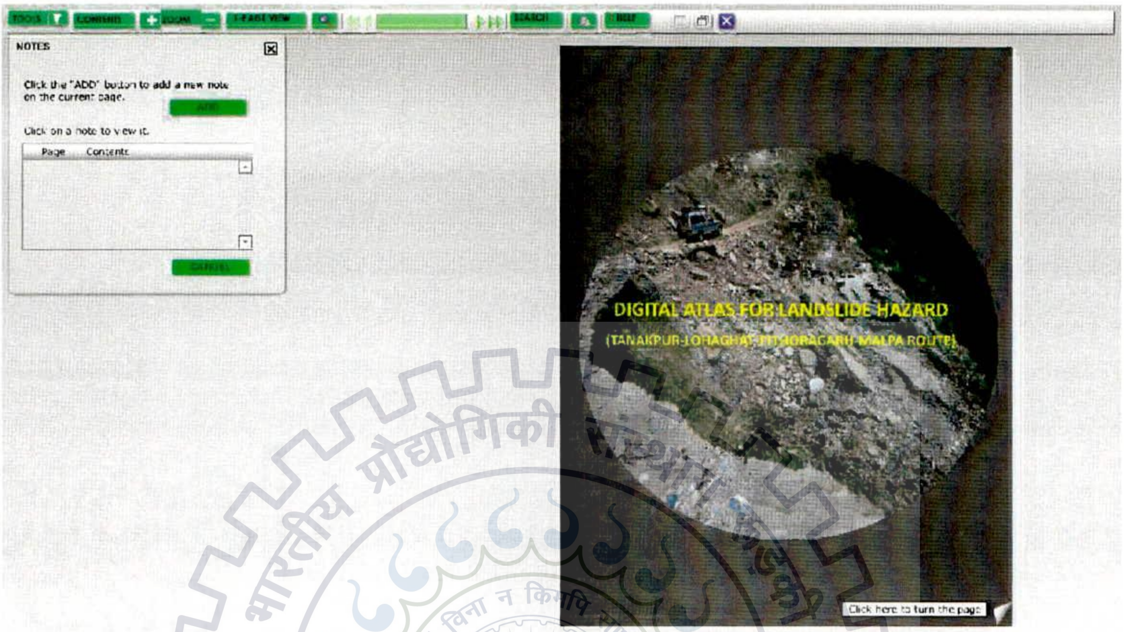


Figure 6.1.4: Screenshot showing notes tool.

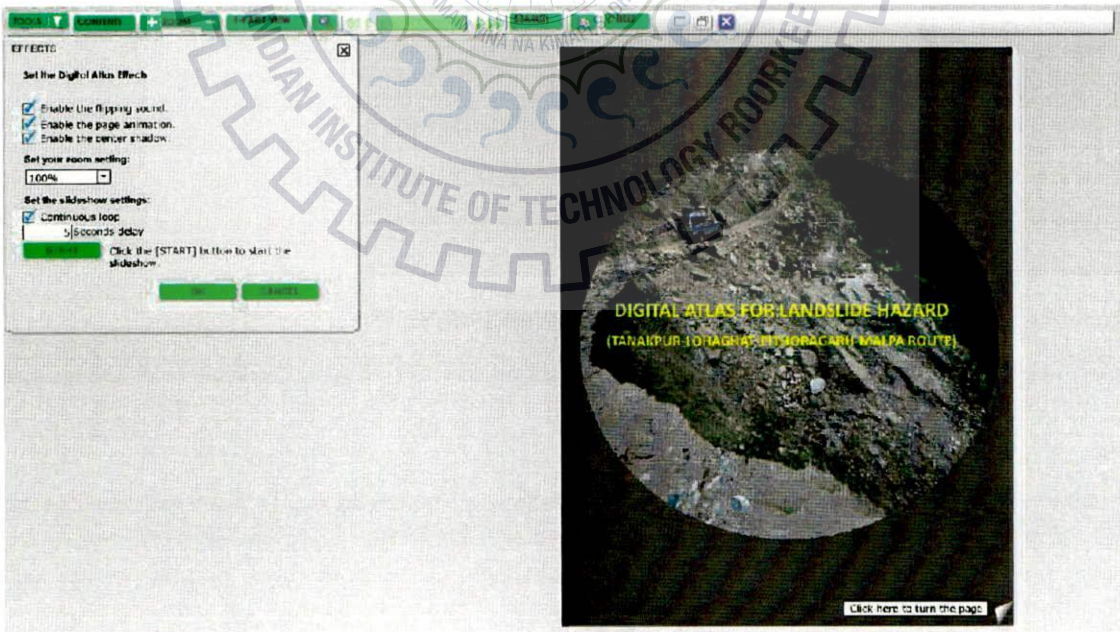


Figure 6.1.5: Screenshot showing effects tool.

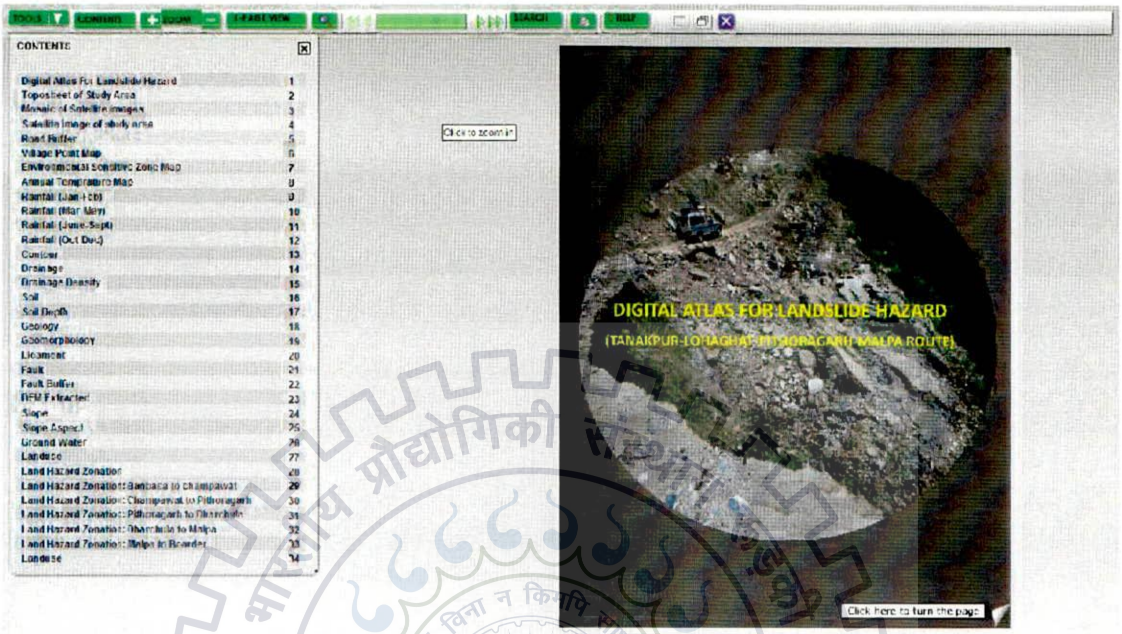


Figure 6.1.6: Screenshot showing contents of the digital atlas.

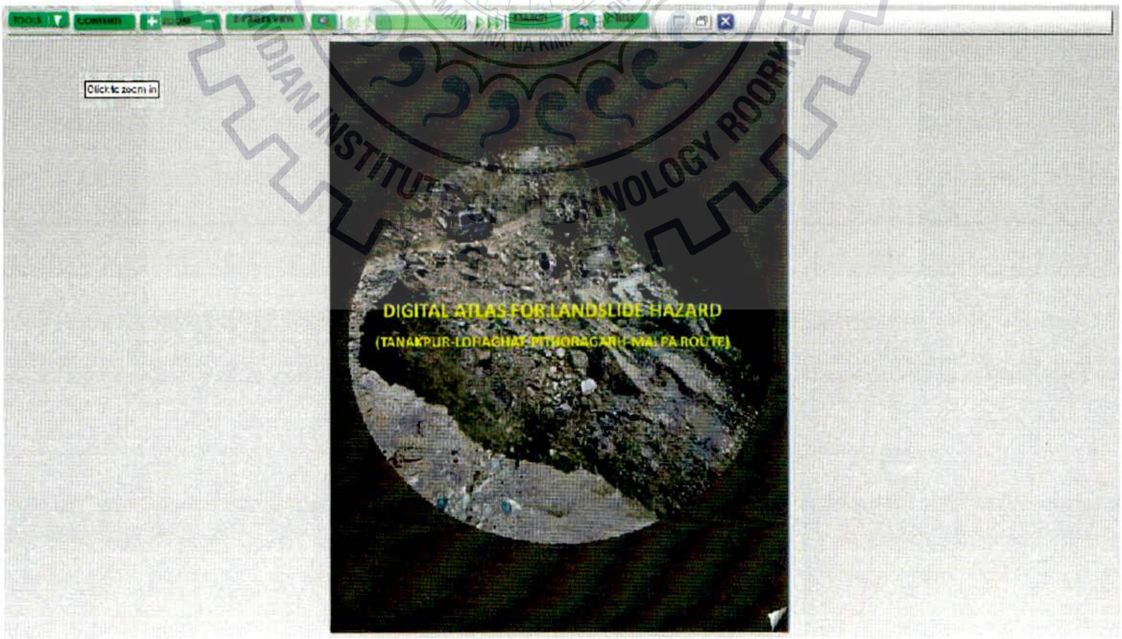


Figure 6.1.7: Screenshot showing zoom in-out tool.

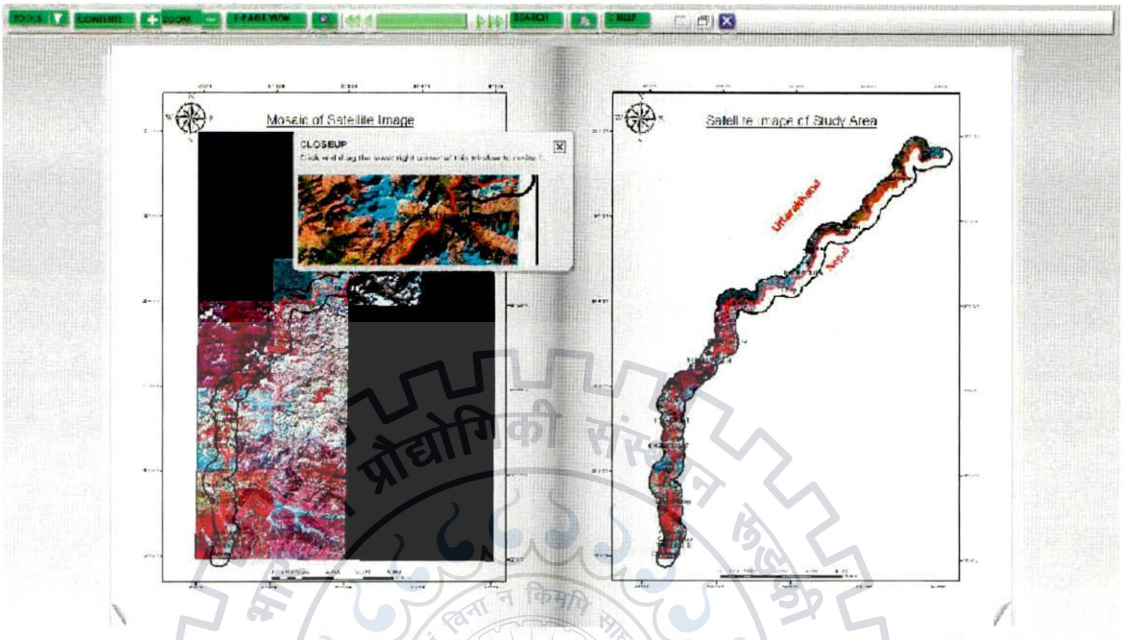


Figure 6.1.8: Screenshot showing close up window on one of the digital atlas pages.

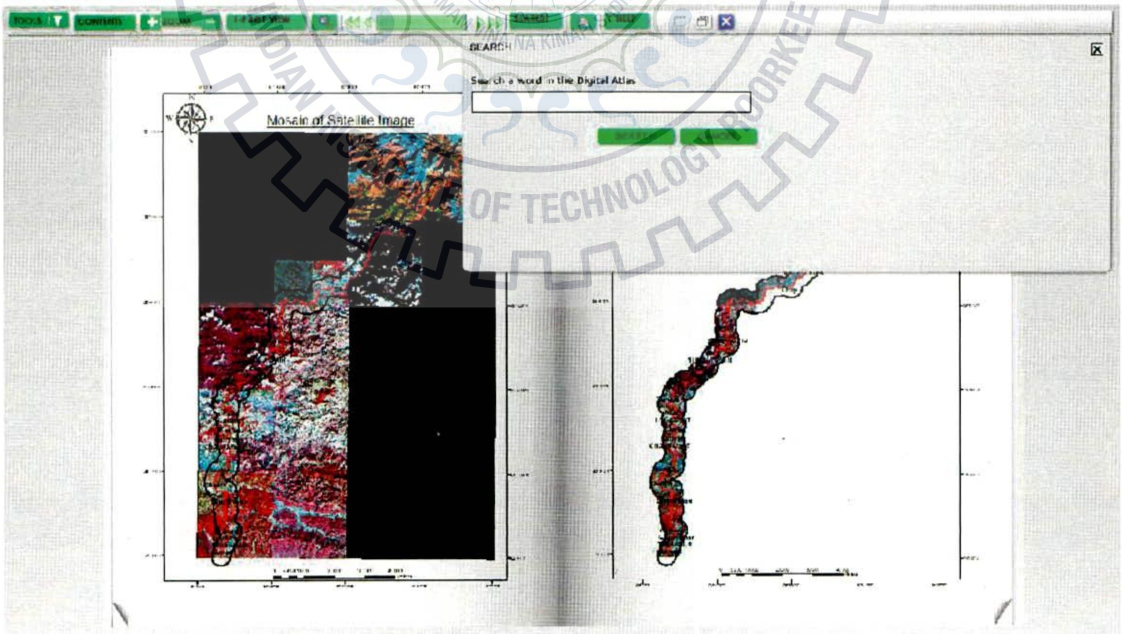


Figure 6.1.9: Screenshot showing search window on one of the digital atlas pages.

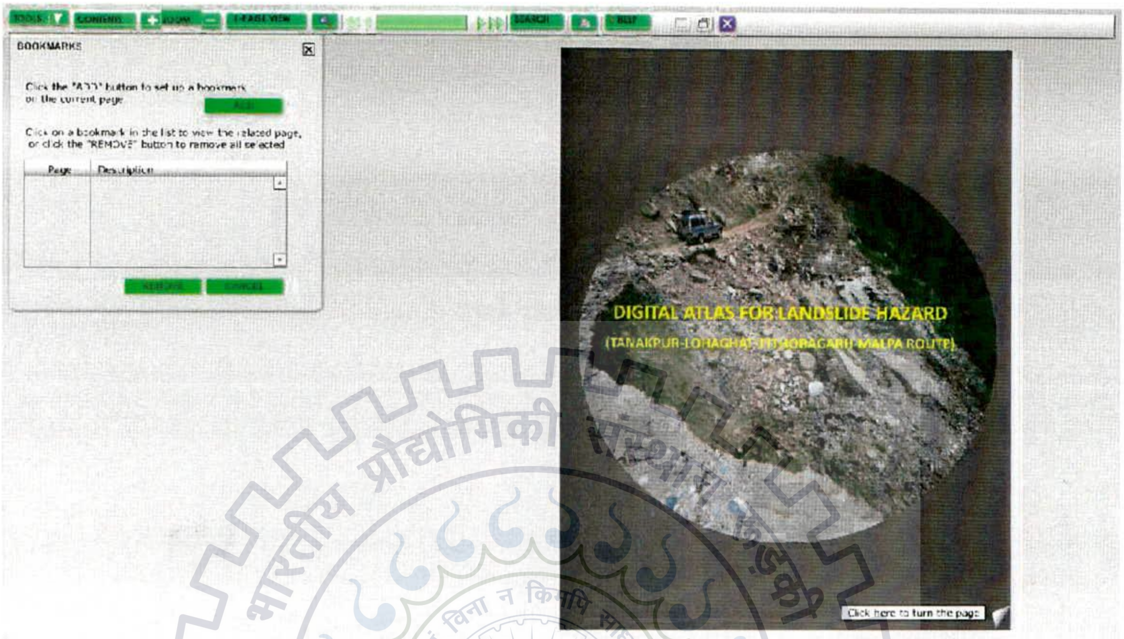


Figure 6.1.10: Screenshot showing bookmarks tool.

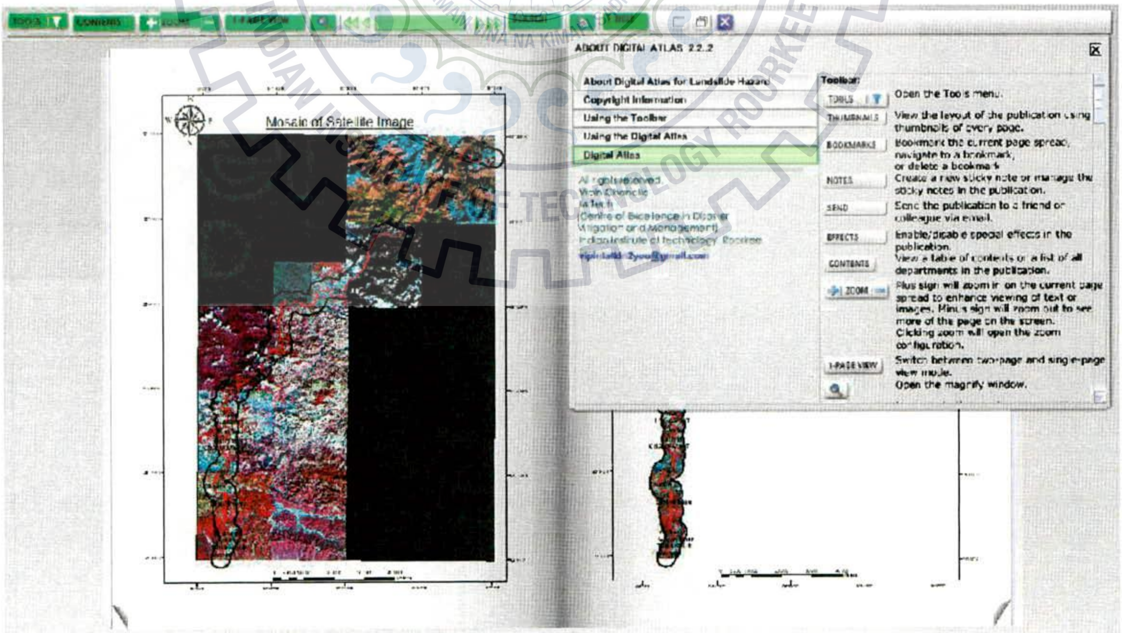


Figure 6.1.11: Screenshot showing help window containing details about the digital atlas.

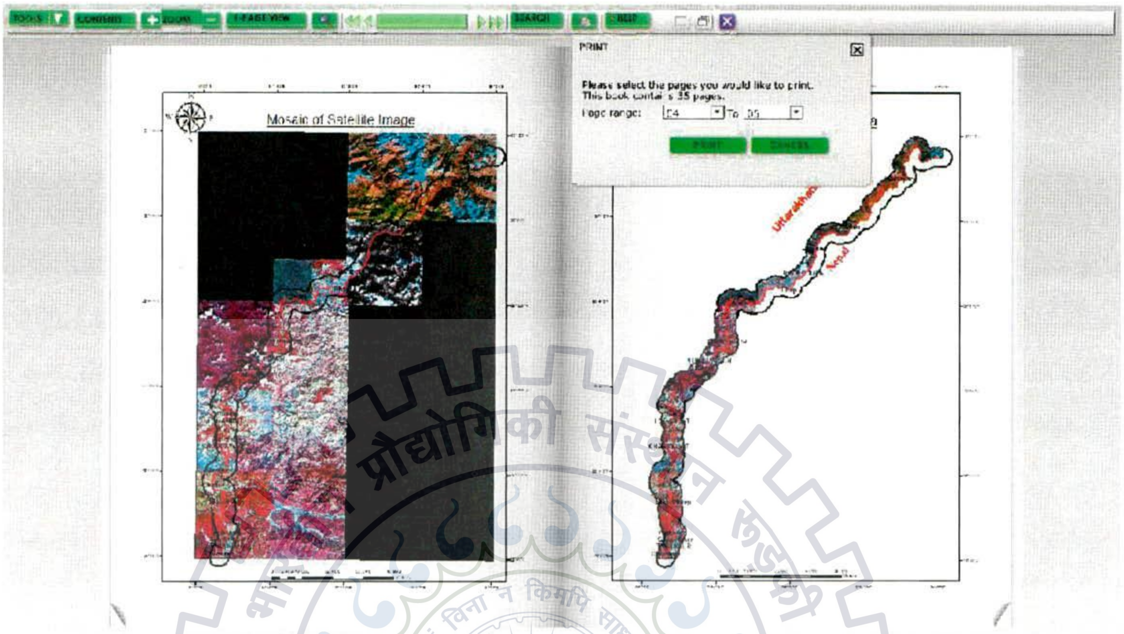


Figure 6.1.12: Screenshot showing print tool window with page range option.

6.2 Discussions

The landslide hazard atlas presented in this dissertation is probably an innovative step to keep the data in good and well assorted form so that it can easily be available to planners and managers. Any non-GIS background person can also use it very easily. Today, in the field of disaster mitigation and management the most primary and important thing is to have past records and data about any area which is under investigation. This kind of digital atlas can effectively serve the purpose. Not only landslide, the country like India having a wide variety of geology, geomorphology and climatic conditions, suffer many other natural hazards every year. The major ones are landslide, drought, flood, earthquake and cyclones. Keeping a digital collection of data about such hazards can be very helpful in understanding the pattern, nature, probability and damageability of such hazards.

However such digital atlas cannot be the replacement of the source data or the field data. This atlas importantly focuses on the better visualization and interpretation of data with the aid of graphics, animation and audio effect. The output of data processing softwares like- ArcGIS, ERDAS and ENVY are the input of this kind of digital atlas. Hence this atlas cannot replace these GIS and data processing softwares.

CHAPTER 7

CONCLUSION & FUTURE SCOPE

7.1 Conclusion

The Digital Atlas for Landslide Hazard Zonation is meant not only to disaster mitigation and management associated people, but also to planners and managers to carry out developmental activities in the fragile terrains like Himalayas. This can also be used by environmentalists as it will help them in focusing the environment sensitive regions and to conserve the natural resources. The atlas comprises of various maps on different themes like the annual temperature of the area, the annual rainfall, the ground water conditions, the soil and rock types, geology and geomorphology, environment sensitive zone and settlements, etc. The atlas enables its users to carry out analysis of the layers. With the magnifying tool provided in the atlas, one can have a better visualization of the maps like settlements, landslide spots, road, etc. which is not possible with the paper atlas. Search tool of this atlas allows its users to jump directly to the page of their interest. With the help of content tool one can go through the entire list of the matter present in the atlas. The print tool of this atlas allows taking out the prints of the desired page of the atlas.

The digital atlas shown in this research work can be a valuable tool not only in the field of planning, management and mitigation but also in the domain of education even at school level. Now a day, the availability of data to proceed any research is a great concern. The importance of this concern increases when it comes to natural hazards. The data available in paper form is very susceptible to get damaged with time. Moreover, it is very difficult to keep the paper data like maps in well assorted form. The kind of atlas shown in this research work is capable of keeping maps and other important data in a proper well assorted form. In addition to this, various tools provided in the atlas enable users to interact with the data and to understand & interpret easily so that they can effectively extract information out of it. Also, one does not have to be an expert of GIS and all to use this digital atlas as software.

7.2 Future Scope

Depending upon the analytical capabilities, digital atlas can be developed for more advanced interactions. The present landslide hazard digital atlas uses static JPG image format (.jpg) maps as input in which we cannot create more interactive tools like measuring the lengths and area accurately. A digital atlas on a GIS platform can be created using the shapefiles (.shp), which are editable and contains attributes like measurement of different geometries. Using shapefiles, dynamic maps can be created which can make the digitals atlases as interactive as the GIS software.

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Urvashi Meena, Vipin Chanalia, Pradeep Kumar Garg. (2015). Integrating geospatial technology with models and warning systems for landslide mitigation: a review. *Jounal of Emerging Technology in Mechanical Science and Engineering*. Vol. 5(1). Feb 2015, pp. 28-33. ISSN No. : 0976-2558.

Conference

Urvashi Meena, Vipin Chanalia and Pradeep Kumar Garg. (2014). Towards a better understanding of disasters and technologies. *4th International Conference on Climate Change and Sustainable Management of Natural Resources.* ITM University, Gwalior, M.P. 12-14 February, 2014.