FOREST COVER CHANGE DETECTION AND SPATIAL MODELLING FOR IDENTIFICATION OF EROSION PRONE AREAS IN KAPTAI RESERVOIR WATERSHED OF BANGLADESH

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Submitted by

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The thesis titled "Land Cover Change Detection and Spatial Modelling for Identification of Erosion Prone Areas in Kaptai Reservoir Watershed of Bangladesh", Submitted by Md. Aminul Islam, Roll no.: 100015024, Session: October 2000, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Urban and Regional Planning (MURP).

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Abstract

Erosion has become an important issue for Kaptai watershed, the largest man made freshwater body in Bangladesh which generates a significant share of Bangladesh's power supply by using hydro-power. It contributes significantly to the production of freshwater fish, flood control, tourism and agriculture. Over the past few decades forest depletion has become a main problem here because of human intervention, replacing the forest cover with shifting cultivation which eventually increasing soil erosion and thus contributing large amounts of sedimentation to the reservoir posing a serious threat to the power plant as well as navigability. Studies have been done to assess the sedimentation in Kaptai Lake have found that the expected life time of the lake has considerably reduced. This study is an effort to look into this fact and try to understand the spatial variation of erosion that leads to siltation.

The study has two major goals – first to monitor the change of vegetation and other major land covers over last two decades (1980-2000) and second to develop a simple spatial model to identify potential erosion prone areas in Kaptai watershed.

Land cover maps have been produced from satellite images of Landsat program. NDVI and bi-spectral plot techniques were used to identify land covers. Appropriate NDVI has been set chosen based on ground truth data, high resolution satellite image (IRS LISS III) and secondary land cover maps. Two land cover maps have been prepared for two nominal years (1980 and 2000). Finally maps have been compared with each other. It has been found that non-forest land has increased by 10.6% while low density forest area has decreased by 18.4% but high density forest has increased by around 7.9%. However overall forest coverage (low+high density) has decreased by 10.6% which is highly significant for 20 years time period (1980-2000).

A simple potential erosion model has been developed to assess the distribution of potential erosion prone areas in the watershed. This model emphasizes potential erosion because it does not estimate the actual erosion; rather it indicates areas that are potentially

erodable based on slope, soil, land cover and rainfall in the watershed. Modelling result shows that 45% of the area has low erosion risk while 17% has high erosion risk. The rest 36% falls into average erosion category. This is an indication of how much area is to be conserved for erosion management in Kaptai Watershed.

This study is a small preliminary effort to look into the erosion problem spatially. But this might be useful as a starting point for further in depth spatial study of this problem to figure out possible remedies.

Acknowledgement

First and foremost, I would like to express my debt of gratitude to my supervisor Professor K. M. Maniruzzaman, whose guidance, attention and encouragements has made this effort possible in spite of many limitations.

I also would like to thank to Mr. Emaduddin Ahmad, Executive Director; S. M. Mahabubur Rahman, Division Head; Md. Manirul Haque, Head GIS unit and Tanvir Hassan, GIS Specialist of Institute of Water Modelling (IWM) who extended their hands to help this study by providing necessary data and information.

I wish to thank the International Water Management Institute (IWMI), Sri Lanka, for providing me necessary data directly from their GIS server for Kaptai watershed area. A lot of thanks to Praveen Noojipady, Biradar Chandrashekhar and Van Straaten Oliver who helped a lot in expense of their valuable time when my hard drive crashed.

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Abbreviations & Acronyms

BFDC: Bangladesh Fish Development Corporation
BWDB: Bangladesh Water Development Board
BBS: Bangladesh Bureau of statistics
CHT: Chittagong Hill Tracts
CRU: Climatic Research Unit
DEM: Digital Elevation Model
EGIS: Environment of Geographic Information Service
ERTS: Earth Resource Technology Satellite
ETM: Enhanced Thematic Mapper
FAO: Food and Agriculture Organization
FAP: Flood Action Plan
FCC: False Color Composite
GIS: Geographic Information System
GLCF: Global Land Cover Facility
GPS: Global Positioning System
GT: Ground Truth
MSS: Multispectral Scanner
NASA: National Aeronautics and Space Administration
NDVI: Normalized Difference Vegetation Index
NIR: Near Infrared
SRTM: Shuttle Radar Topographic Mission
TCC: True Color Composite
TM: Thematic Mapper
USGS: United States Geological Survey
UNEP: United Nations Environmental Program
UNPO: Unrepresented Nations and Peoples Organization
UTM: Universal Transverse Mercator
WGS: World Geodetic System

Units
deg = Degree
ha = Hectare
km = Kilometer
m = Meter
mm = Millimeter
sqkm = Square Kilometer
MW = Mega Watt

Chapter One

Introduction

Chapter One

Introduction

1.1 Introduction

Kaptai reservoir, the largest man-made freshwater body in Bangladesh with an installed capacity of 230 MW. It is the only hydropower source in Bangladesh; about 5% of the electricity consumed in the country is produced there (Praveen et. al, 2002). It was created in 1964 at Kaptai village in Rangamati District of Chittagong Hill Tracts (CHT) with the help of USAID, the reservoir covers an area of about 58,300 ha and has a mean depth of 46 meters (BWDB, 2000). The Kaptai lake has a catchment area of 1103 square kilometers. Forest depletion and reservoir sedimentation has already become a serious problem for Kaptai lake (Chowdhury, 1992). The life of the Kaptai Reservoir was estimated to be 300 years in 1957. Thirty years after its commissioning, the calculated life has become 180 years, a reduction of 120 years from the original estimate (Mirza, 1998; BWDB, 2000). Bangladesh Water Development Board carried out a sedimentation survey at 67 sections in Kaptai lake for three years – 1983, 1986 and 2000. They have found that siltation of 30959.61 sq.m took place from 1983 to 2000 in 67 sections. The difference in cross sectional area through the three study years indicates a process of siltation (BWDB, 2000).

Although primarily created for hydro-electric power generation, the Kaptai Reservoir contributes significantly to the production of freshwater fish, flood control, tourism and agriculture. Over the last few decades forest depletion has become a main problem here as human intervention is replacing the forest cover with shifting cultivation, increasing soil erosion which is eventually contributing large amounts of sedimentation to the reservoir posing a serious threat to the power plant as well as navigability (UNEP, 2002). There are 73 species of fish in the lake. According to the Bangladesh Fish Development Corporation (BFDC) the catch of carp has decreased to 220 tonnes from as high as 972 tonnes in 1964. The traditional *jhum* cultivation practiced by the indigenous people and recently by the Bengalis is the main reason for soil erosion. The eroded soil finds its way into the lake and fills it up. The hydro-electric project located on the lake is under threat due to siltation.

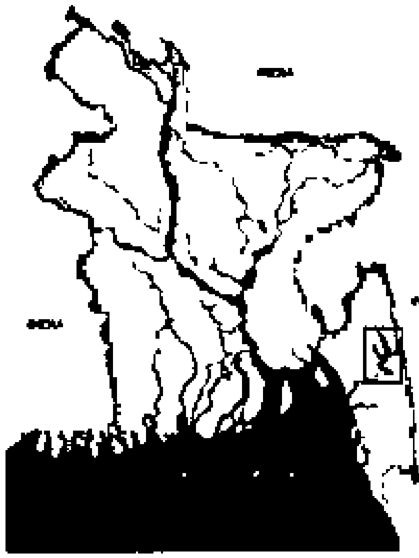

Figure 1.1: Bangladesh and location of Kaptai Lake

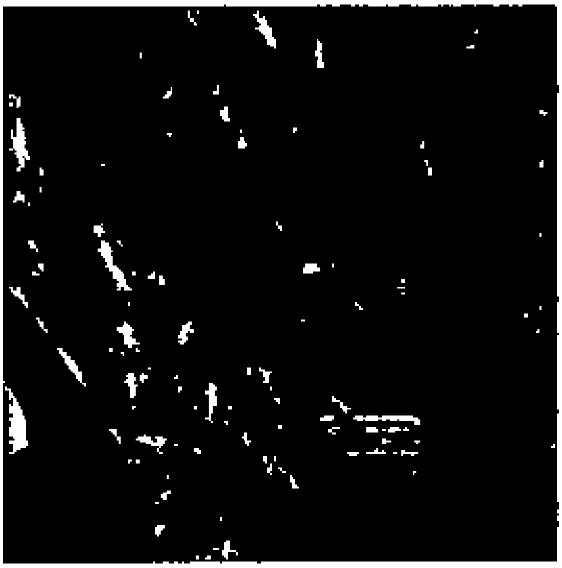

Figure 1.2: Kaptai lake and its surroundings in Landsat Geocover Image. Band B:6, G:4, R:2

Siltation also makes navigation difficult from Rangamati to Longodu, Barkal, Gurachhari and Baghaichhari during December to May. About 100 launches and 2,000 motorboats ply on these routes around the year (Pinaki et.al., 2003). Proper management of the watershed areas can mitigate these problems.

It is a general impression that vegetation in CHT has decreased substantially (Pinaki et.al., 2003). To look into this issue it is necessary to map the trend of vegetation cover in the watershed. It is important to see if vegetation has increased over time, since vegetation cover has direct relationship with erosion (FEWSNET, n.d.). If vegetation has decreased then it would be easy to conclude that vegetation depletion is the factor for increased erosion in Kaptai watershed. Also it is necessary to identify erosion prone areas to take proper physical or policy measures. As forest depletion and erosion have become major concerns here, the proposed study is aimed at assessing the land cover changes over two decades (1980-2000), looking at the vegetation cover change and finding out the erosion prone areas in the catchments of Kaptai Lake by using GIS based modelling and remote sensing techniques. The study will help the policy makers considerably to take necessary alternative steps on hot spots to reduce forest depletion and erosion.

1.2 Hypothesis:

Vegetation cover has depleted in Kaptai watershed over the 1980-2000 time period.

1.3 Objectives:

The main objectives of the study are

1. to assess the changes in vegetative cover from 1980 to 2000 and
2. to develop a spatial model to identify the erosion prone areas for the year 2000 within the catchment area of Kaptai lake.

1.4 Limitations of the study

Every study has some kinds of limitations like time, budget, restrictions etc. In the case of this study budget was a limitation for purchasing time series satellite data which could be more useful to classify land cover into more detail level. Due to this limitation it was not possible to map agricultural land use. GT survey in the study area was difficult as it was very risky to carry GPS in military controlled area of Kaptai Lake. A few control points were taken on land, other points were taken in or at the edge of the lake, and land cover descriptions were written as precisely as possible including direction. Extensive GT survey was not possible for the whole watershed because it would have been very expensive and time consuming. Moreover GT survey in Indian territory was not possible. Considering all these limitations land cover classes were limited to only broad classes, mainly vegetated/forest and non vegetated/non-woody/non forest classes.

It is always a challenge to map agricultural area from a single date image because it does not reflect the seasonal variation of the crops and has very high probability to mix with other land covers like bare land or forest cover. Only very high resolution data like IKONOS, QuickBird or IRS can give such detail shape and pattern of the field which helps lot to interpret images visually Having intermediate resolution of 28.5m or more, Landsat is not able to show up to that level. In this circumstance another way is to analyze time series data which reflects the changes in agricultural land over time, which eventually helps to identify it precisely including the crop type if cropping pattern is known. But no free time series data at Landsat resolution level for last 2 decades was found. Considering these realities agricultural land class was discarded from the land cover classification of this study.

Chapter Two

Literature Review

Chapter Two

Literature Review

As this study concentrated on remote sensing based mapping, literatures were chosen which describe the methods and techniques to map land cover by using remote sensing tools. There is no study found that worked on land cover or erosion mapping from satellite imagery at high resolution in Kaptai watershed but study at low resolution exist. United Nations Environment Program (UNEP) has studied the forest cover change for 1985-86 to 1992-93 period for Bangladesh based on NOAA AVHRR (10 km resolution) dataset. During this period a significant portion of evergreen forest was found to be converted either into degraded forest or agricultural land in Chittagong hill tracts. The underlying reason for the transformation, as gleaned from the analysis, is primarily due to the shifting cultivation and partly because of the conversion of forest cover and/or shifting cultivated areas to permanent agricultural land. (UNEP, 2002)

In many ways the present study is very unique for Kaptai watershed because it has a high mapping scale at 30m resolution and covered the real watershed area extending beyond international territory. Also this study has produced three land cover (broad) maps those indicate the changes in area of land covers over two decades. Finally this study aimed at developing a simple erosion model to see the spatial distribution of potential erosion. Interesting part here is that all these works were done by using GIS technique, which made it possible to compute, analyze and process data very efficiently and quickly.

Several studies have described the Normalized Difference Vegetation Index (NDVI), derived from red and near infra-red bands, as the means to map general land covers (e.g., Uchida, 2001; Daniel et al., 2000). Many natural surfaces are about equally as bright in the red and near-infrared part of the spectrum with the notable exception of green vegetation. Red light is strongly absorbed by photosynthetic pigments (such as chlorophyll a) found in green leaves, while near-infrared light either passes through or is reflected by live leaf tissues, regardless of their color. "This means that areas of bare soil having little or no green plant material will appear similar in both the red and near-infrared wavelengths, while areas with much green vegetation will be very bright in the near-infrared and very dark in the red part of the spectrum" (US Water Conservation Laboratory, n.d.). This proven principle leads all modern scientists to use NDVI for mapping broad land cover ranges from bare to forest areas.

NDVI works also as a means to measure vegetation density. It is found that NDVI has a positive correlation with the density of vegetative cover (Jensen, 2000). This proven principle has led to mapping vegetation density qualitatively.

A number of studies used different erosion models like Universal Soil Loss Equation (USLE) and Morgan approach. These two models are now widely used all over the world. USLE, developed by Wischmeier and Smith in 1978, or the Revised USLE (RUSLE), is often used to predict rainfall erosion in landscapes using GIS. Using GRID cell representation of landscapes and the assumption that the area within each cell is normally uniform with respect to rainfall, soil, crop, aspect and slope gradient, enables to calculate the average annual soil erosion for any given cell. By using the following equation.

$$A = R*K*L*S*C*P \qquad (2.1)$$

Where R is the long term annual average of the product of event rainfall kinetic energy (E) and the maximum rainfall intensity in 30 minutes (I30), K is the soil erodibility factor, L is the slope length factor, S is the slope gradient factor, C is crop management factor and P is the conservation support practice factor. But this popular model has some limitations.

a. The model applies only to sheet erosion since the source of energy is rain; so it never applies to linear or mass erosion.
b. The type of country side: The model has been tested and verified in plain and hilly country with 1-20% slopes and excludes young mountains especially slopes steeper than 40% where runoff is a greater source of energy than rain and where there are significant mass movements on earth.

c. Type of rainfall: the relations between kinetic energy and rainfall intensity generally used in this model apply only to the American Great Plains and not to mountainous regions although different sub models can be developed for the index of rainfall erosivity.

d. The model applies only for average data over 20 years and is not valid for individual storms.

e. Lastly a major limitation of the model is that it neglects certain interactions between factors in order to distinguish more easily the individual effect each. For example it does not take into account the effect on erosion of slope combined with plant cover, nor the effect of soil type on the effect of slope (FAO, n.d.).

So the main difficulties of USLE model are many input parameters that are not available for all locations in the world. Nobody has developed such factors particularly for Bangladesh as no reference was found over internet and Meteorological Department of Bangladesh does not have such data.

Another popular model is called Morgan's erosion model which requires rainfall detachment index, soil detachability index, annual kinetic energy, interception etc. (ITC, n.d.). But none of them are available for Bangladesh.

Chapter Three

Methodology

Chapter Three

Methodology

The study was carried out following several steps as follows. A simple diagram of the methodology is presented in Figure 3.13 at the end of this chapter.

3.1 Problem identification

First, the problem was identified based on several source as mentioned in 'Introduction' section of this chapter. Problem identification helped to move further to set up the goals and objectives for this study

3.2 Identification of study objectives

Objectives were set to conduct the study in a guided way. Two objectives were set to assess the changes in forest cover from 1980 to 2000 and to develop a spatial model to identify erosion prone areas.

3.3 Literature review

The literature had been extensively reviewed to learn about similar studies done in different parts of the world. Different techniques and approaches of land cover mapping and erosion modeling were also learnt through literature review.

3.4 Base data preparation

Real work started with developing the base datasets. The base datasets range from simple international boundary to land cover classified from satellite imagery. The process includes

a. collection of data
b. digitization/rasterization (if not in available in GIS format)
c. projection / transformation into common coordinate system
d. Data processing (Digital Elevation Model (DEM), satellite imagery, soil map,

precipitation)

e. Derived products (Normalized Difference Vegetation Index (NDVI), slope, watershed,) generation by using topographic functions, flow functions, classification, interpolation etc.

All these efforts made it possible to bring all spatial and attribute data into GIS format. ERDAS Imagine 8.6, ArcView 3.2 and ArcGIS 9 softwares were used for processing and analysis. A list of datasets is given in Table 3.1

3.4.1 Choosing available appropriate data

Efforts were made to choose datasets which have proximity to the scale or resolution of Landsat data because this is the common dataset used to accomplish both objectives Bangladesh has a national level DEM which is 300m in resolution but it was too crude to measure slope and very inconsistent with 30m resolution Landsat imagery. Another DEM is Global SRTM* DEM* which is 90m in resolution, but the problem with this is it has a +/- 15m error in vertical measurement. But so far it has been observed during the processing that it has greater consistency with Landsat image in hilly areas. National level DEM does not have those fine qualities because of low resolution. So finally SRTM DEM was chosen for this study to maintain accuracy and consistency with other GIS layers.

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* SRTM: The Shuttle Radar Topography Mission (SRTM) is a joint project between the National Imagery and Mapping Agency (NIMA) and the National Aeronautics and Space Administration (NASA). The objective of this project is to produce digital topographic data for 80% of the Earth's land surface (all land areas between 60° north and 56° south latitude), with data points located every 1-arc-second (approximately 30 meters) on a latitude/longitude grid. The absolute vertical accuracy of the elevation data is 16 meters (at 90% confidence). This radar system gathers data that results in the most accurate and complete topographic map of the Earth's surface that has ever been assembled.

* DEM: Computer generated Digital Elevation Model that represent the topography of the earth surface. This raster based model also is different than Digital Terrain Model (DTM) which represents the earth terrain surface, not the elevation of the objects on the earth.

Table 3.1: Different datasets used in this study

Data type	Data name	Source	Year	Data model	Data depth (raster)	Resolution / RF Scale
Digital Elevation Model (DEM)	SRTM	NASA	1999	Raster	Signed 16 bit	90m
Slope	SRTM Slope	Generated from SRTM DEM	2005	Raster	Unsigned 16 bit	90m
Flow direction	Flow direction	Generated from SRTM DEM	2005	Vector	-	90m
Flow accumulation	Flow accumulation	Generated from SRTM DEM	2005	Vector	-	90m
Watershed boundary	Watershed	Generated from SRTM DEM	2005	Vector	-	90m
Stream network	Stream	Generated from SRTM DEM	2005	Vector	-	90m
Forest cover map	Forest cover map of Bangladesh	Forest Department	2000	Vector	-	1:250000
Secondary land cover maps	Global Land Cover	Global Land Cover Facility (GLCF)	2000	Raster	8 bit	1 km
Soil map	Bangladesh National Soil Map	CEGIS	1995	Vector	-	1:250000
Soil Map FAO	Soil Map FAO	Food and Agriculture Organization (FAO)	1995	Vector	-	1:250000
Precipitation data	CRU TS-2	Climatic Research Unit (CRU), UK	2000	Raster	16 bit	0.5 degree (55 km at equator)
Satellite imagery	Landsat ETM+ orthorectified	GLCF	Nominal 2000	Raster	8 bit	28.5m
	Landsat MSS orthorectified	GLCF	Nominal 1980	Raster	8 bit	57m
	IRS LISS III	IWM	13 March 2001	Raster	8 bit	5.8m to 14m
Land cover map	Land cover map for year 2000 & 1980	Mapped from Landsat imagery	Nominal 2000 & 1980	Raster	8 bit	28.5m
International boundary	International boundary	CEGIS	1995	Vector	-	1:250000
District boundary	District boundary	CEGIS	1995	Vector	-	1:250000

Forest cover map and Global secondary datasets were used to obtain an indication of dominant land cover type to set particular NDVI threshold for land cover mapping for this study. This Global secondary datasets are available for free.

The Global Landsat Geocover datasets for three nominal years (1980, 1990 & 2000) are totally free too and advantage of this free dataset was taken to map land cover for two nominal years for Kaptai watershed.

Two kinds of soil map were available- national level soil map and Global FAO soil map. National level map is much detailed in classification scheme and scale, thus national level soil map was used for the Bangladesh part of Kaptai watershed. FAO soil map was used for Indian part of the watershed as Indian soil map was not available (Figure 3.1)

Two kinds of precipitation data were available for the study area- national rainfall measurement and Global precipitation data. National level rainfall data is always considered better than any global dataset, but only 2 rainfall stations were found in the Bangladesh part of Kaptai watershed which is not representative for the whole area and moreover it has no measurement for certain months. These two stations are around Kaptai Lake and more than 50km away from each other. Moreover rainfall data for the Indian part of the watershed was not available. Considering these limitations CRU precipitation dataset was used for this study which is 55km in resolution at the equator. This dataset is basically generated from national level rainfall datasets but processed through many techniques to correct the data gaps, elimination of abrupt values, taking into consideration the proximity of surrounding rainfall station measurements in Indian territory (CRU, 2001). This is a good dataset for such a big watershed like Kaptai and the only available gap filled, corrected and interpolated fine resolution rainfall dataset (Figure 3.2)

International boundary and district boundary data sets were taken from available national level database developed under Flood Action Plan (FAP) 19 project.

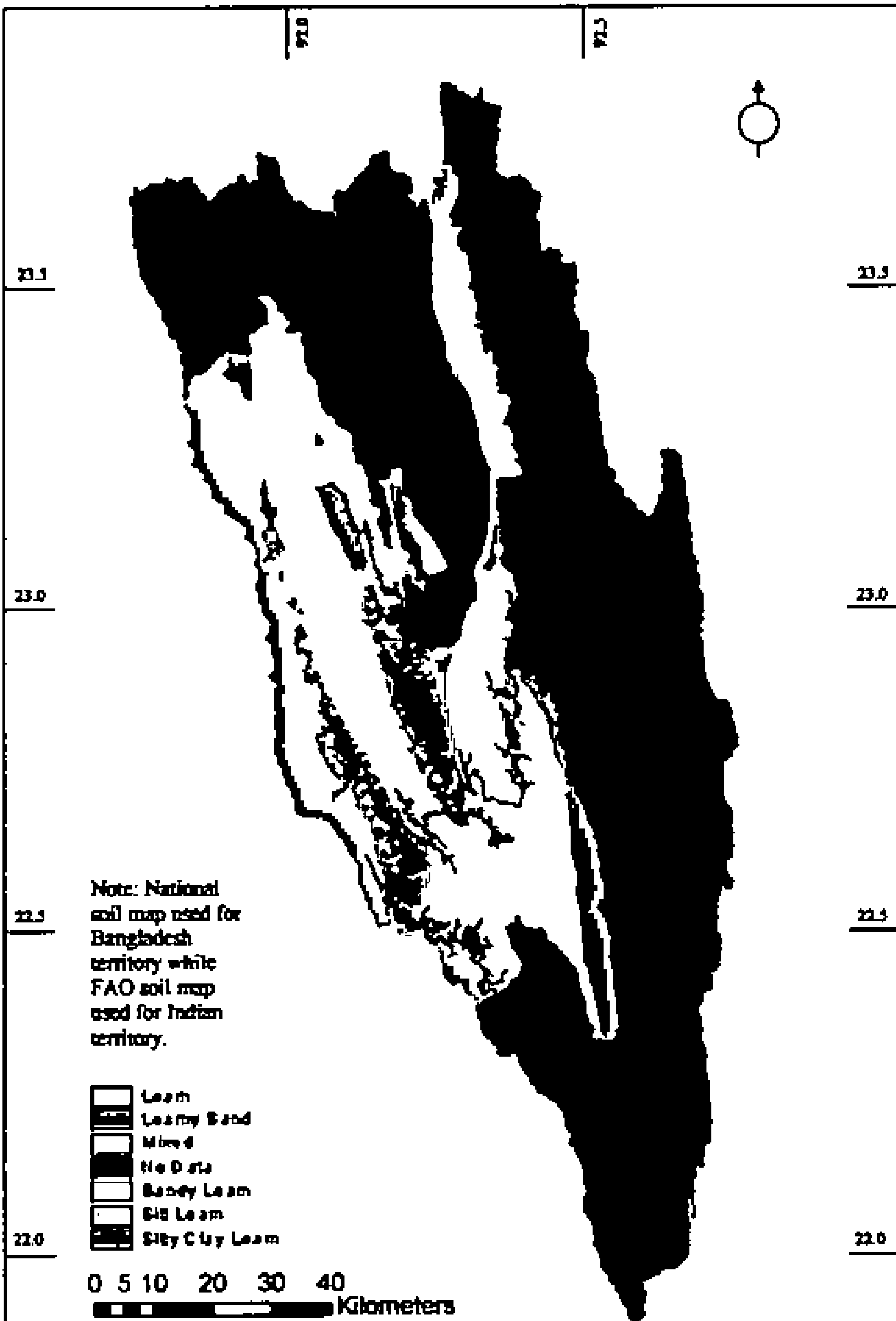


Figure 3.1: Soil map of Kaptai watershed

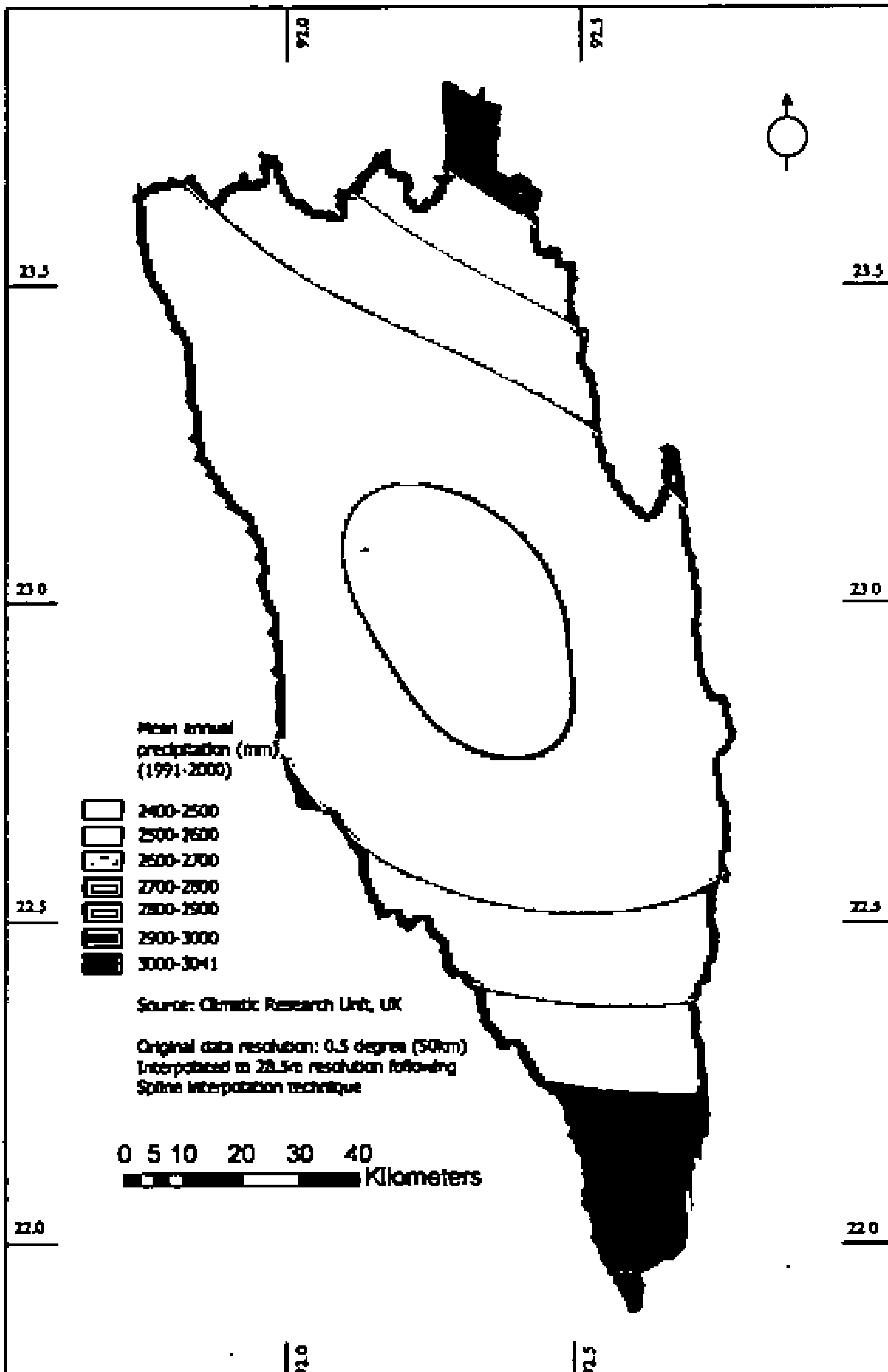


Figure 3.2: Annual rainfall map of Kaptai watershed

3.4.2 Processed / derived datasets

(a) Watershed boundary delineation

A watershed is an area that drains water and other substances to a common outlet as concentrated drainage. Other common terms for a watershed are: basin, catchment , or contributing area. This area is normally defined as the total area flowing to a given outlet, or pour point. These areas are the output of the Watershed function. The boundary between two watersheds is referred to as a watershed boundary or drainage divide.

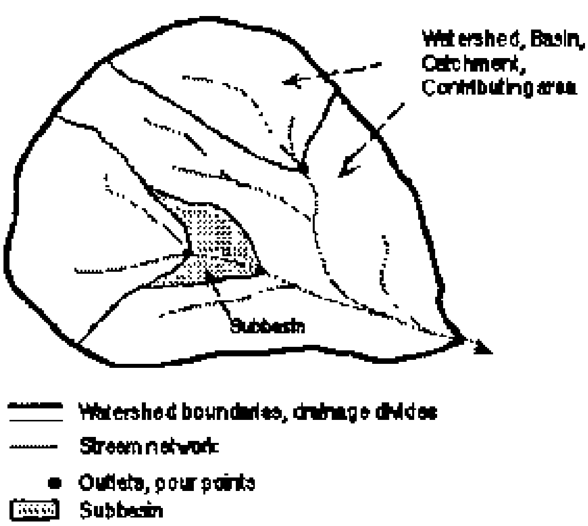


Figure 3.3: Diagram of a watershed

An outlet or pour point is the point at which water flows out of an area. This is the lowest point along the boundary of the watershed. In ArcInfo GRID module, the cells in the source Grid are used as pour points above which the contributing area is determined. Source cells may be features such as dams or stream gauges, for which a person wants to determine characteristics of the contributing area.

To derive the watershed SRTM DEM was further processed through several steps.

i) Filling the sinks in DEM
ii) Generation of Flow Direction GRID from DEM
iii) Generation of Flow Accumulation GRID from Flow Direction GRID
iv) Generation of Watershed based on minimum threshold area of watershed

One of the keys to deriving hydrologic characteristics about a surface is the ability to determine the direction of flow from every cell in the grid. This is done with the

FLOWDIRECTION function in ArcInfo workstation. This function takes a surface as input and outputs a grid showing the direction of flow out of each cell. There are eight valid output directions, relating to the eight adjacent cells into which flow could travel as shown in figure 3.4.

32	64	128
16		1
8	4	2

Figure 3.4: A raster neighborhood

The direction of flow is determined by finding the direction of steepest descent, or maximum drop, from each cell. This is calculated as

Maximum drop = change in z value / distance (4.1)

The distance is determined between cell centre. Therefore if the cell size is 1, the distance between two orthogonal cells is 1 and the distance between two diagonal cells is 1.414216, the square root of 2. If the descent to all adjacent cells is the same, the neighbourhood is enlarged until the steepest descent is found.

2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

Flow direction

Figure 3.5: Flow direction

When a direction of steepest descent is found, the output cell is coded with the value representing that direction. If all neighbours are higher than the processing cell, the processing cell is a sink, and has an undefined flow direction. If two cells flow to each other, they are sinks, and have an undefined flow direction. If a cell has the same change in z value in multiple directions it is also a sink and has an undefined flow direction.

For cells that have an undefined flow direction, the value for that cell in the output flow direction grid will be the sum of those directions. For example, if the change in z value is the same to the right (flow direction = 1) and down (flow direction = 4), the flow direction for that cell will be 1 + 4 = 5. To obtain an accurate representation of flow direction across a surface, the sinks should be filled.

This flow direction GRID was used to produce Flow Accumulation GRID. The Flow Accumulation function creates a Grid of accumulated flow to each cell, by accumulating the weight for all cells that flow into each down slope cell.

Cells of undefined flow direction will only receive flow, they will not contribute to any downstream flow. A cell is considered to have an undefined flow direction if its value in the flow direction Grid is anything other than 1, 2, 4, 8, 16, 32, 64, or 128. The accumulated flow is based upon the number of cells flowing into each cell in the output Grid. The current processing cell is not considered in this accumulation. Output cells with a high flow accumulation are areas of concentrated flow and may be used to identify stream channels.

The following graphic shows the results of the default usage of the FlowAccumulation function in a GIS.

2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

flowGrid

=

0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	2

accumGrid

Figure 3.6: Flow accumulation from flow direction

This flow accumulation product along with flow direction were used to derive watershed boundary at 50000 cells thereshold (minimum number of cells/ minimum size to be considered as watershed). The whole process has been presented with figures (Figure 3.7 to 3.10).

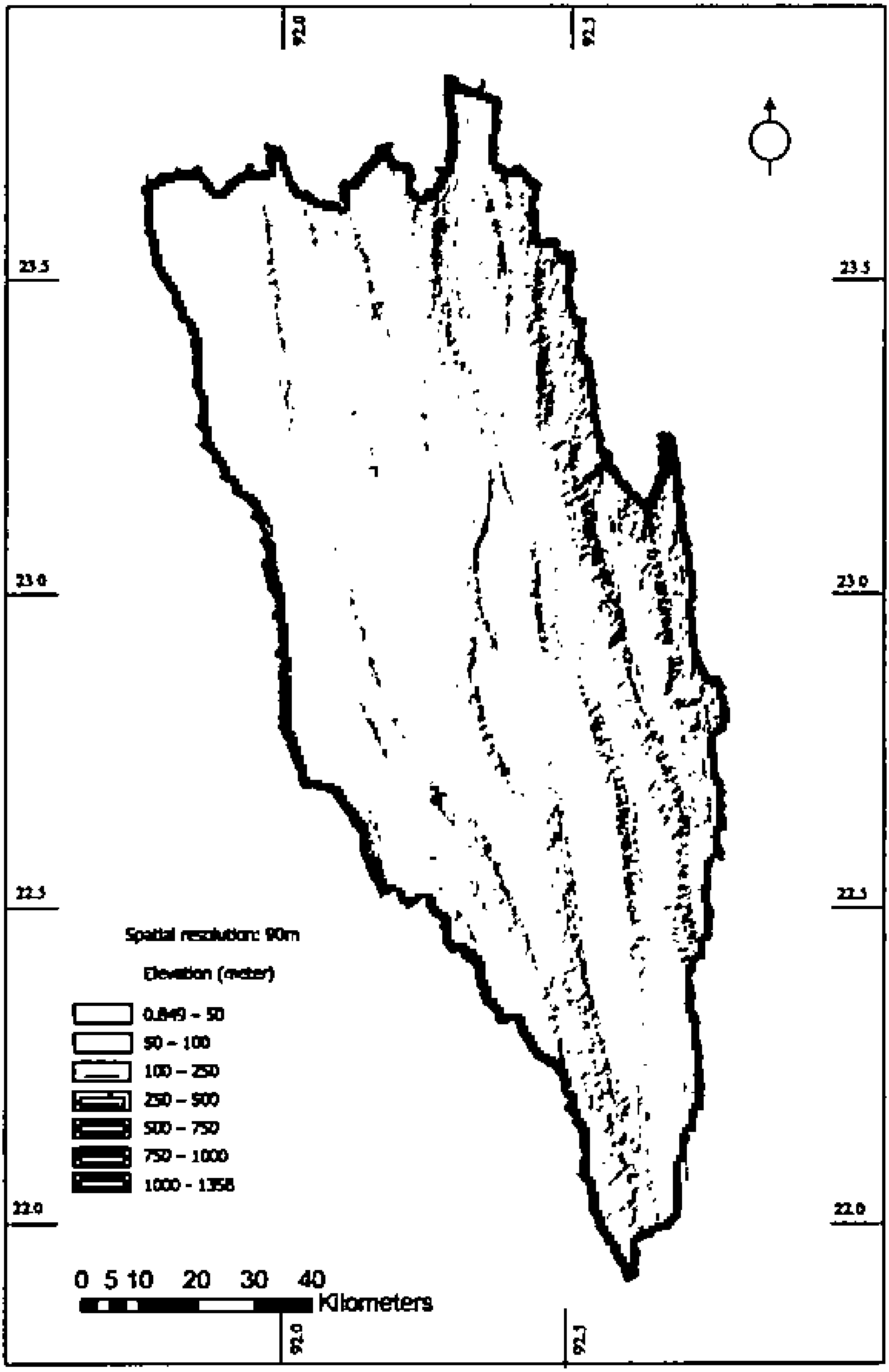


Figure 3.7: Digital Elevation Map (DEM) of Kaptai watershed

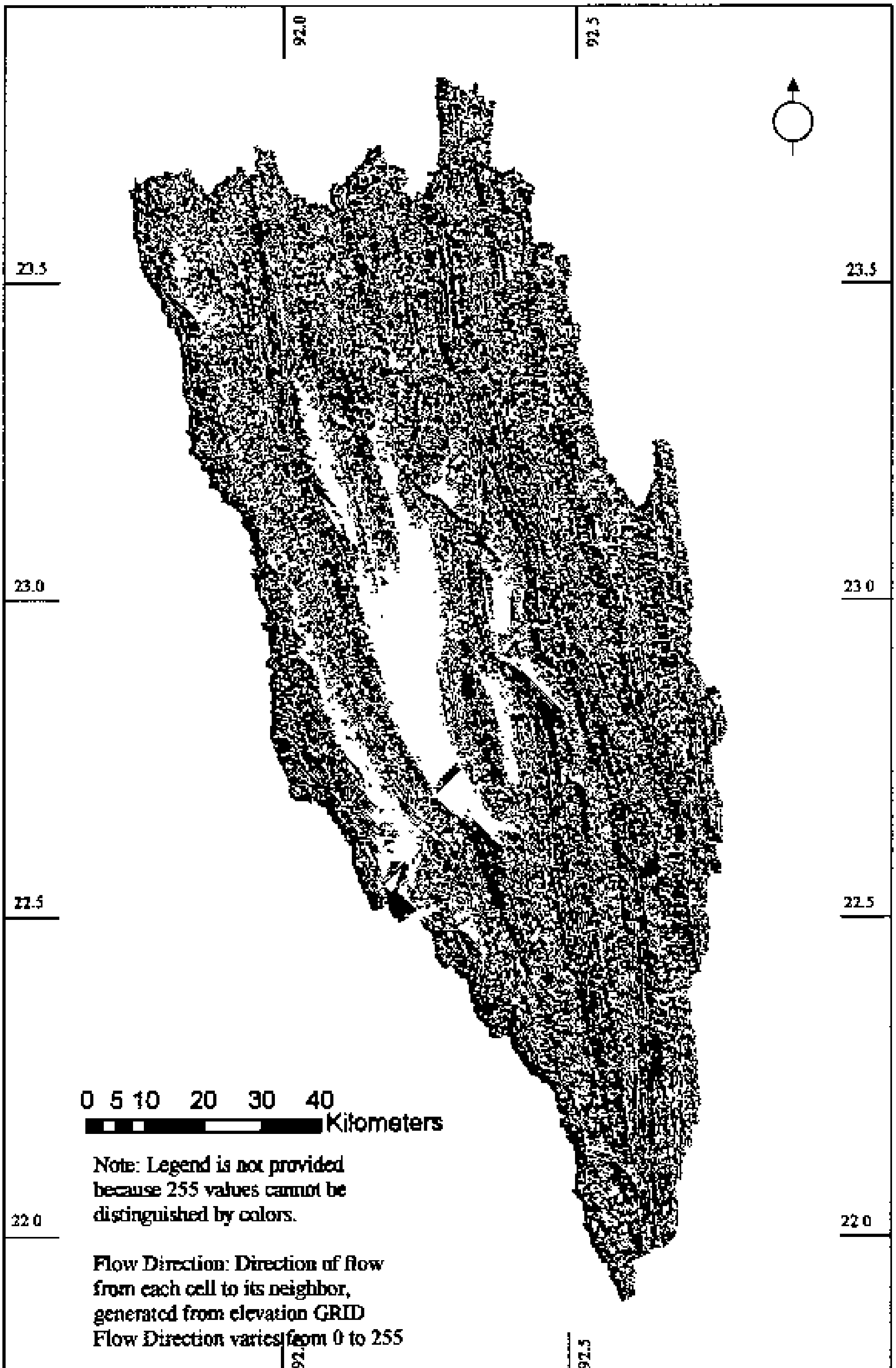


Figure 3.8: Flow direction map of Kaptai watershed

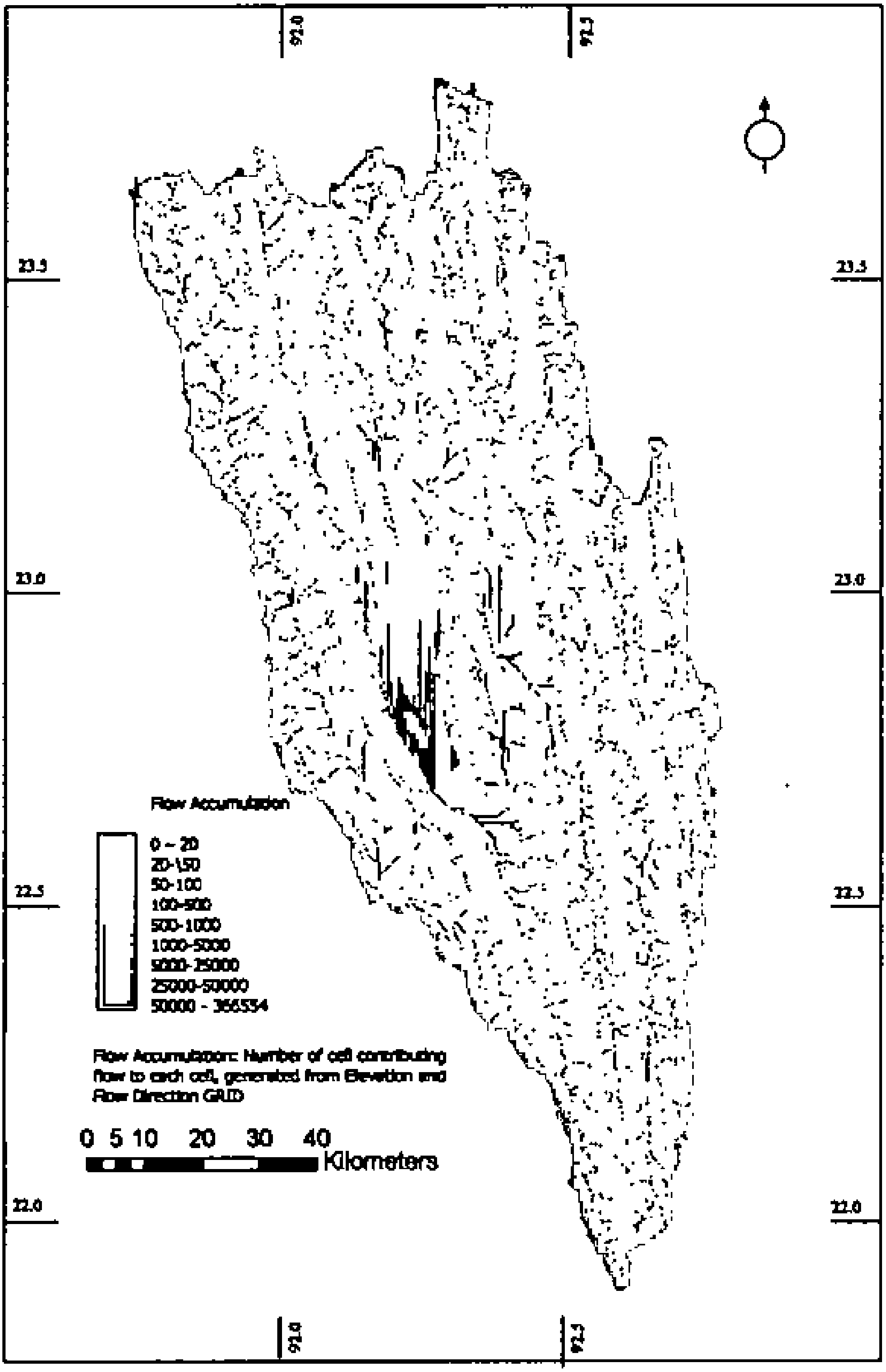
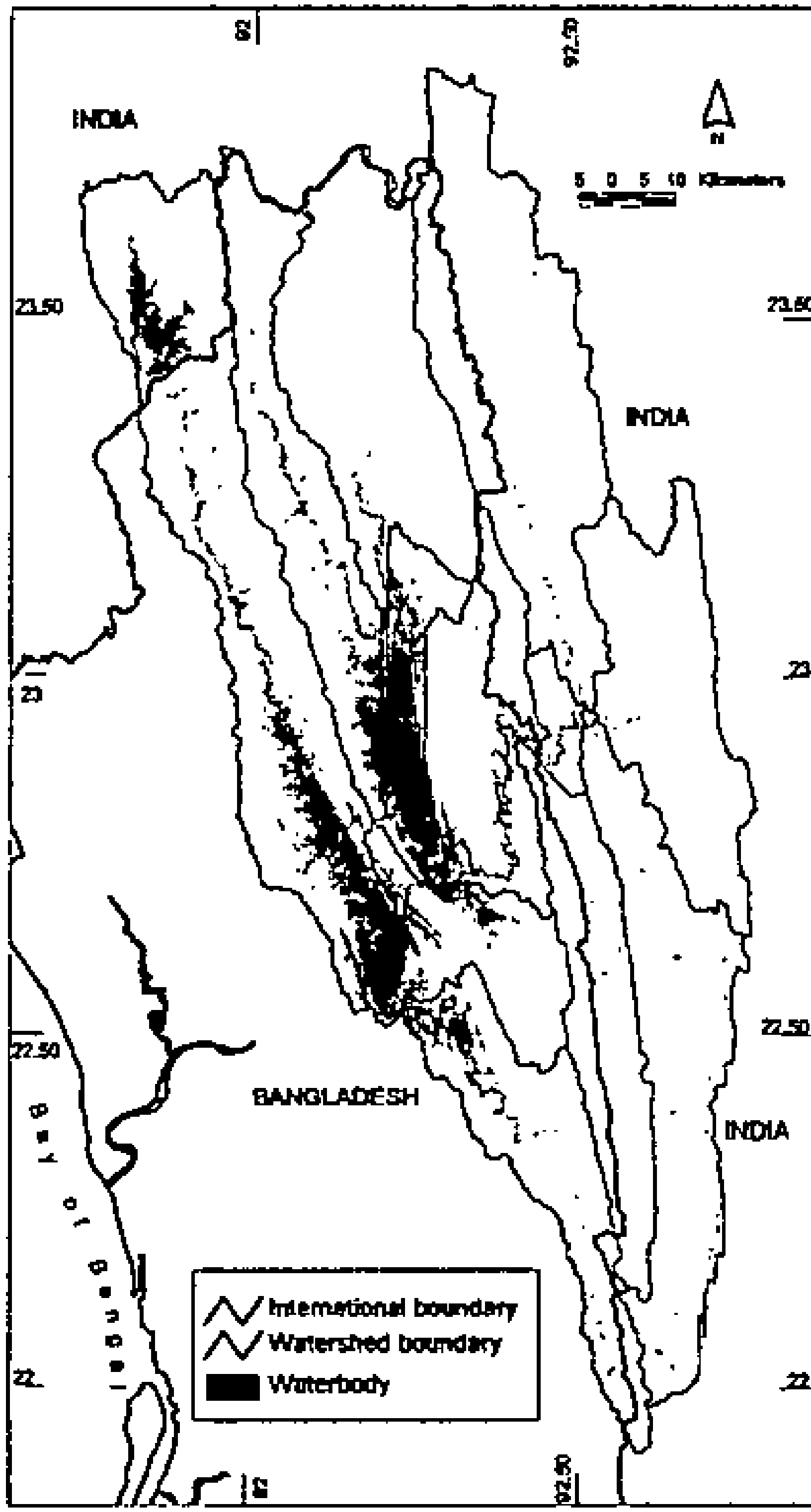


Figure 3.9: Flow accumulation map of Kaptai watershed



Note: Watershed GRID for 50000 threshold generated from Flow Direction and Accumulation GRIDs

Figure 3.10: Watershed boundaries generated from SRTM DEM

(b) Slope Map generation

Another derived dataset is the slope map (Figure 3.12), which was derived from SRTM DEM. Slope identifies the maximum rate of change in value from each cell to its neighbors. People sometimes confuse between slope measurements expressed in degrees and as a percentage. Consider triangle B where the angle of the slope is 45 degree. The rise is equal to the run. Expressed as percentage, the angle is 100%. Note that as the slope angle approaches vertical (90 degrees), the percentage slope approaches infinity.

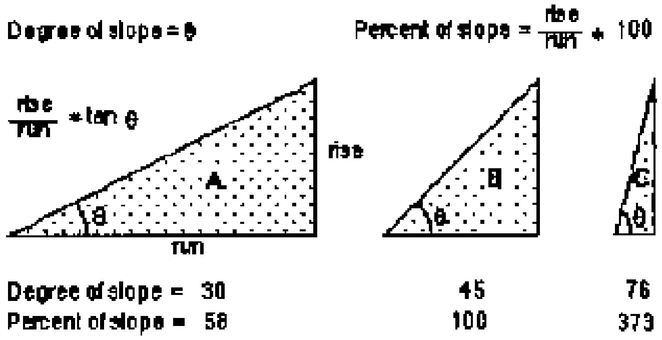


Figure 3.11: Degree and percent of slope.

3.5 Ground Truth (GT) survey

Prior to land cover classification a Ground Truth (GT) survey (collecting GPS location with description of surrounding land cover) was conducted during April 2005. Only 23 GT points had been collected in and around Kaptai Lake due to restriction imposed by the Bangladesh Army. It was not possible to do the same in Indian territory because of time and budget constraints.

3.6 Land cover classification

Mapping always has a relationship with the scale at which experts want to map it. One is spatial scale (e.g. 1:50000 scale) and another is non-spatial scale (e.g. number of mapping classes) both of which describe the level of detail of the map. As this study concentrated on remote sensing based mapping, literature was chosen which describe the methods and techniques to map land cover by using remote sensing tools.

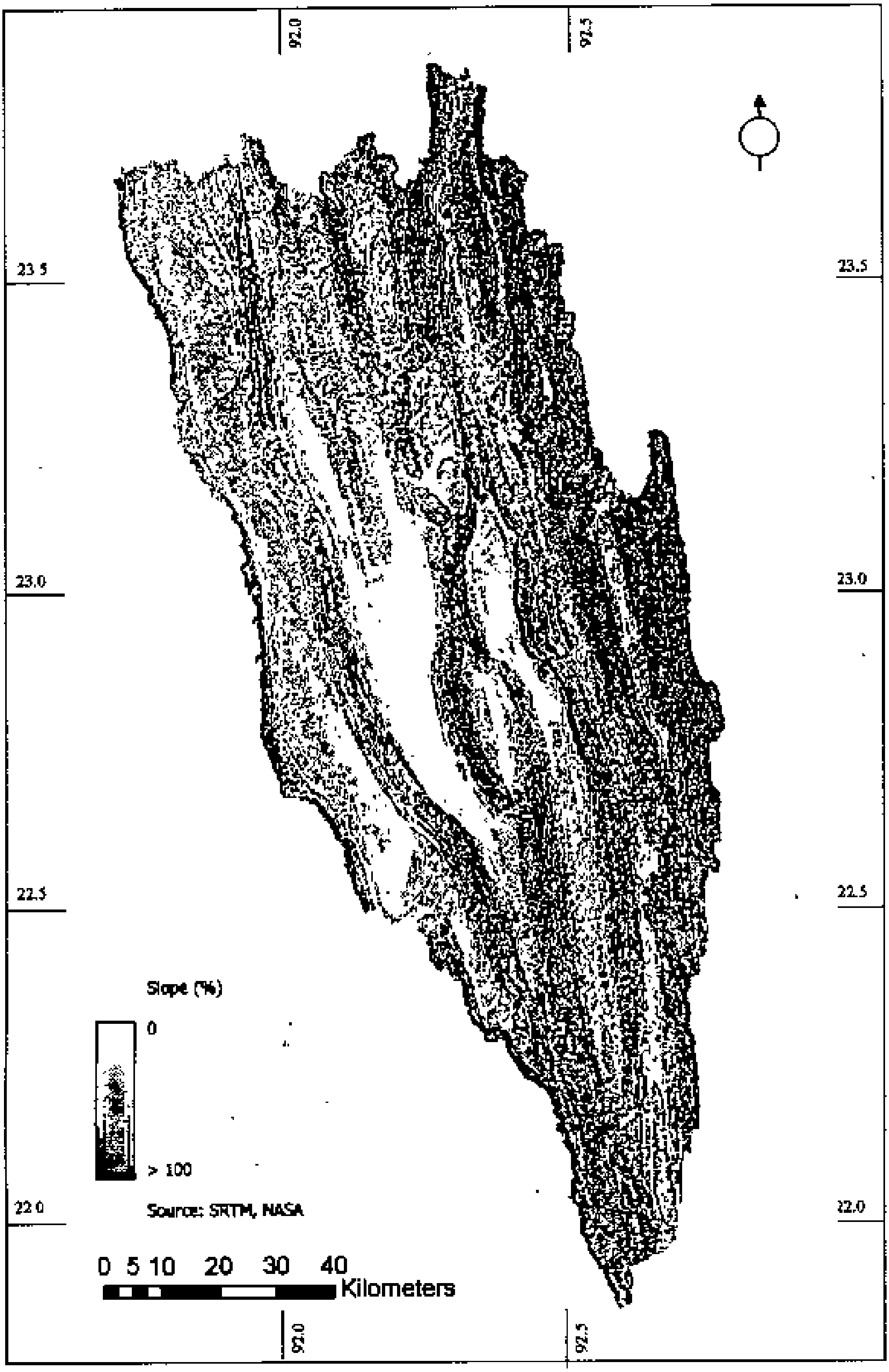


Figure 3.12: Slope map of Kaptai watershed

Some literature have described the NDVI (which is an index derived from red and near infra-red bands) as the means to map general land covers like water body, vegetation density and bare land (e.g., Uchida, 2001; Daniel et al., 2000). As the study aimed at identifying the changes in land cover which is particularly responsible for erosion, and also as there was not enough ground truth points to make the map more detailed, NDVI approach was mainly taken in consideration to map broad land cover classes in Kaptai watershed. No particular map/study was found on remote sensing based land cover mapping on Kaptai watershed.

For this study Landsat orthorectified images at 28.5m (for 2000s) and 57m (for 1980s) resolution were used to assess the forest cover changes over two decades. Visual interpretation, Ground Truth Global Positioning System (GPS) data as well as secondary coarse resolution land cover map were the main keys for setting up appropriate NDVI thresholds to classify land cover. The detail is discussed in Land Cover Mapping chapter.

Resolution of the map was set based on the availability of free Landsat Geocover series and resolution proximity to the resolutions of other datasets for erosion modeling. Second closest free time series data was from MODIS but it commenced very late, in 1999.

It is always a challenge to map agricultural area from a single date image because it does not reflect the seasonal variation of the crops and has very high probability to mix with other land covers like bare land or forest cover. Only very high resolution data like IKONOS, QuickBird or IRS can give such detail shape and pattern of the field which helps a lot to interprete images visually. Having mid-resolution of 28.5m or more Landsat is not able to show up to that level. In this circumstance another way is to analyze time series data which reflect the changes in agricultural lands over time and then relating this change with cropping pattern. But no free time series data at Landsat resolution level for last two decades was found. Considering these reality agricultural land class was discarded from the land cover classification of this study.

3.7 Change detection approach

Change detection approach has always been very effective to identify the change over time and space. Two nominal year's land cover maps were superimposed on each other and then changes were identified using GIS overlay procedures.

3.8 Spatial modelling of erosion for the year 2000

Some literature reports the use of different erosion models like Universal Soil Loss Equation (USLE) and Morgan approach. These two models are now widely used all over the world. The main difficulties of these models are many input parameters that are not available for all locations. For example Morgan approach requires rainfall detachment, soil detachability index, annual kinetic energy, interception etc. (ITC, n.d.). But none of them are available for Bangladesh. For USLE, it requires rainfall erosivity, soil erodibility, topographical factor, plant cover factor etc. (Bancy Mati et al., 2000). But nobody has developed such factors particularly for Bangladesh. Moreover there are some limitations like USLE was tested for <9% slope and only for 49 sq. km. area. This model has uncertainty to produce good result for hilly, large watershed of Kaptai lake. So because of the unavailability of necessary input data and uncertainty of these popular models, it was decided to develop a simpler model based on available data to have a rough look of the erosion distribution in Kaptai watershed though no attempt was made to validate the model due to time and resource limitations However this effort might be a starting point to look into this matter for further study in future.

The erosion model of this study is to identify erosion prone areas and the level of erosion over space. Basic inputs and their sources are as follows:

- Soil (National soil coverage)
- Rainfall (Climatic Research Unit (CRU) data)
- Land cover map (from Landsat orthorectified image for the year 2000)
- Slope map (SRTM)

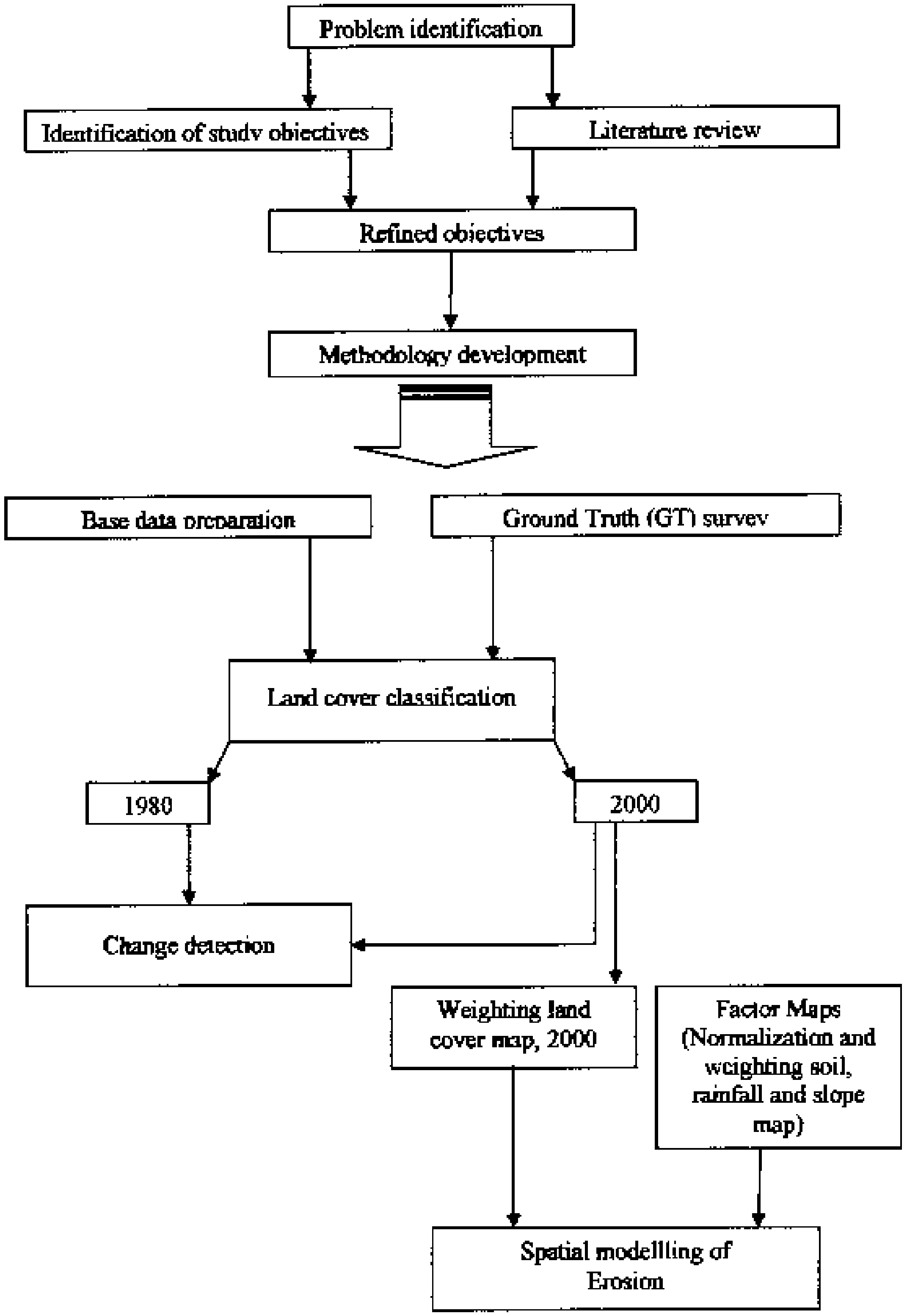


Figure 3.13: Flow diagram of the methodology adopted in this study.

All those themes were classified based on their contribution to erosion and specific weights were given to each class. Finally the model calculated the erosion level over space based on those weights and the results were classified into three categories namely Highly Erodable, Moderately Erodable, Low Erodable area. A simple diagram of the model is shown in Figure 6.5 for better clarification.

Chapter Four

Study Area

Chapter Four

Study Area

4.1 Introduction

Kaptai watershed for the purpose of this study is considered to be bounded within a rectangle with its upper left corner at 91 degree 30 min E longitude and 24 degree N latitude and the lower right corner at 93 degree E longitude and 21.5 degree N latitude. The watershed boundary was delineated following some GIS based topographical functions, which is explained in detail in Chapter three. Watersheds comprised the study area covers most of the Chittagong Hill Tracts (CHT) (mainly Khagrachhari and Rangamati districts) and extends further beyond the international boundary of Bangladesh covering large part of India. Figure 4.1 shows the location of Kaptai lake and its watersheds. Table 4.1 shows the area statistics of Kaptai watersheds for Bangladesh and India.

Table 4.1: Area statistics for Kaptai watersheds in Bangladesh and India.

Watershed	Bangladesh		India		Total	
	Area (Sqkm.)	%	Area (Sqkm.)	%	Area (Sqkm.)	%
Total	6819.84	60.10	4526.85	39.90	11346.91	100.00

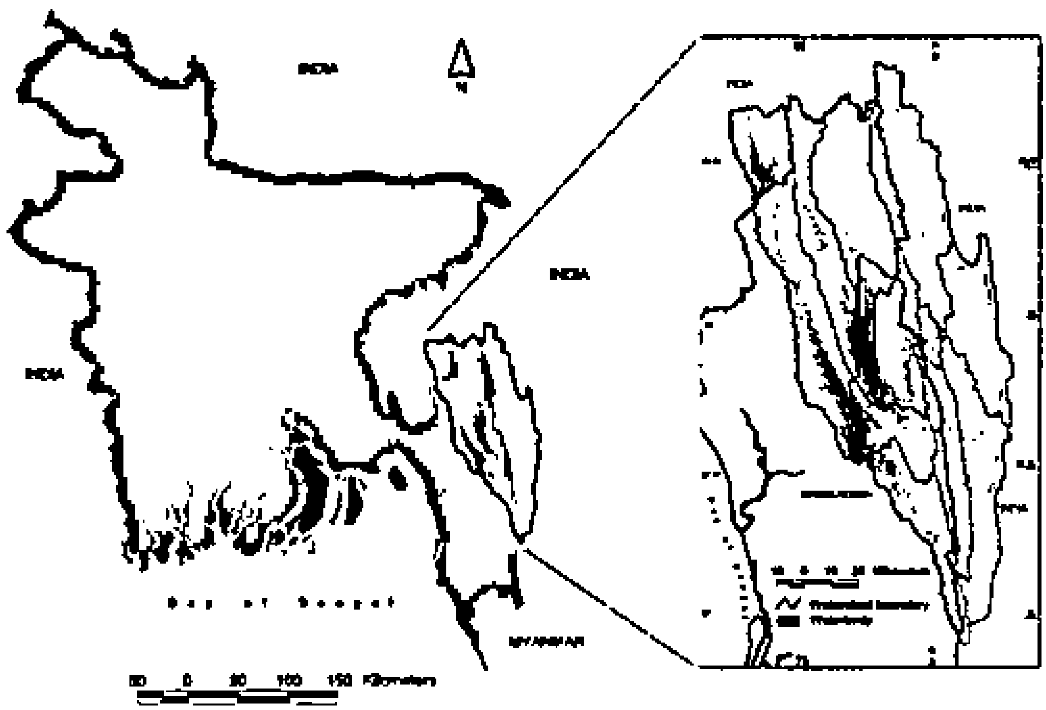


Figure 4.1: Location of Kaptai reservoir and its watersheds in Bangladesh and India

4.2 Topography & Landscape:

Elevation in the study area ranges from 42m to 1363m with a mean of 194m and the slope varies from 0 degree to 82.67 degrees with a mean of 8.63 degrees. The whole watershed is mainly covered by trees and shrubs. There is considerable intensity of shifting cultivation, mainly of banana, rice and vegetables.

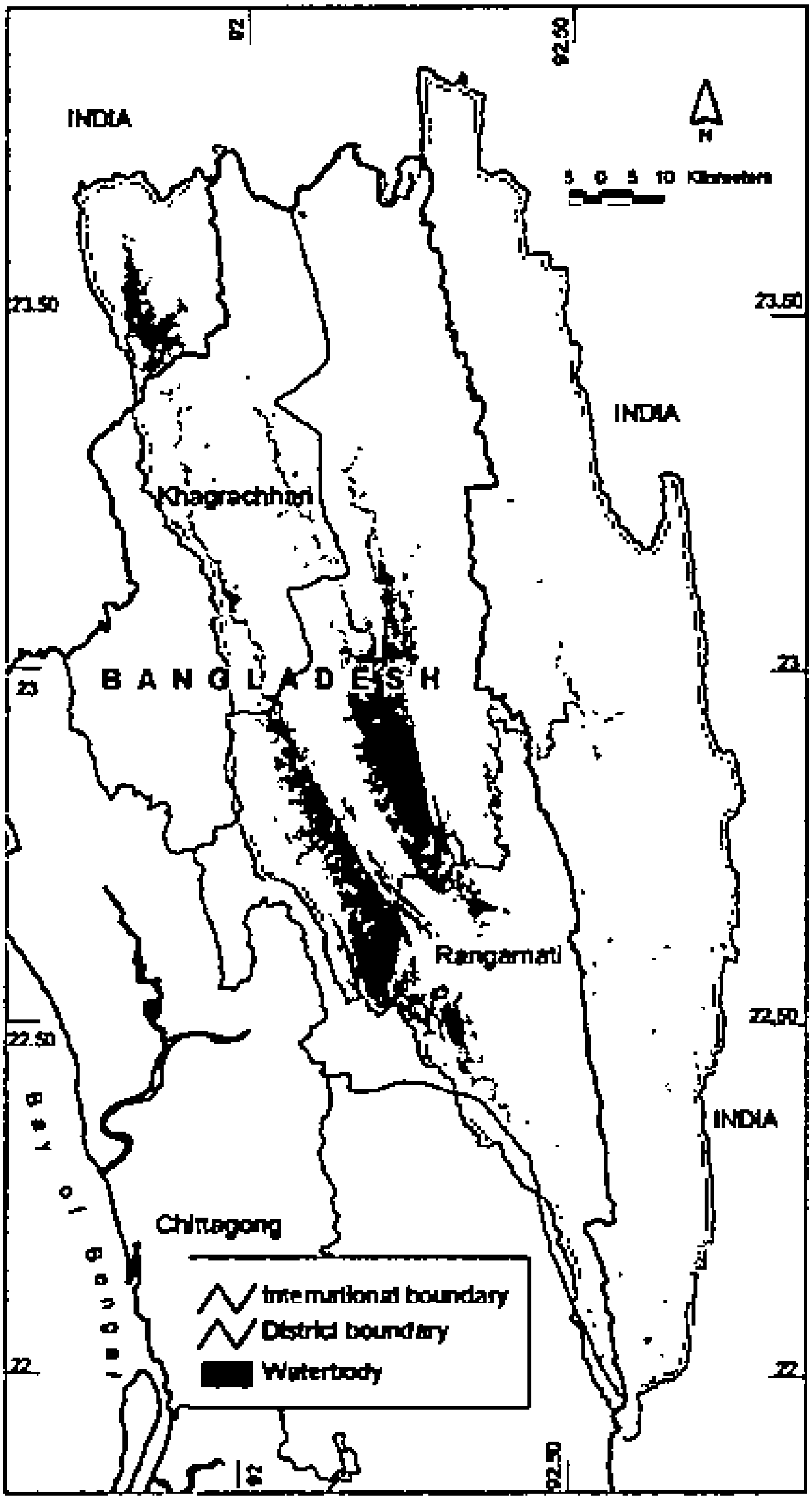


Figure 4.2: Districts of Bangladesh in watersheds.

4.3 Livelihood:

People living in the study area are mainly dependent on shifting cultivation (of mainly banana, rice and vegetables). Apart from that, people are also very much dependent on fishing from the lake. Tourism is not much developed here. Areas around Kaptai lake are controlled by the Army and movement for civilians, especially foreigners, is severely restricted. Felling of trees in low density forests (except in areas controlled by the Forest Department) is a very common phenomena driven by the need for fire wood (Tripura et.al, 2003). Rangamati is the major centre in the area with links to Chittagong. As road and tele-communication links are not much developed, people still live in a mainly rural environment. No effective initiatives have been taken by the government to uplift their quality of life.

4.4 Rainfall Pattern:

Rainfall pattern of Kaptai is depicted in Figure 4.3 which is generated from monthly time series rainfall data of Climatic Research Unit (CRU), UK. Rainfall is very low during

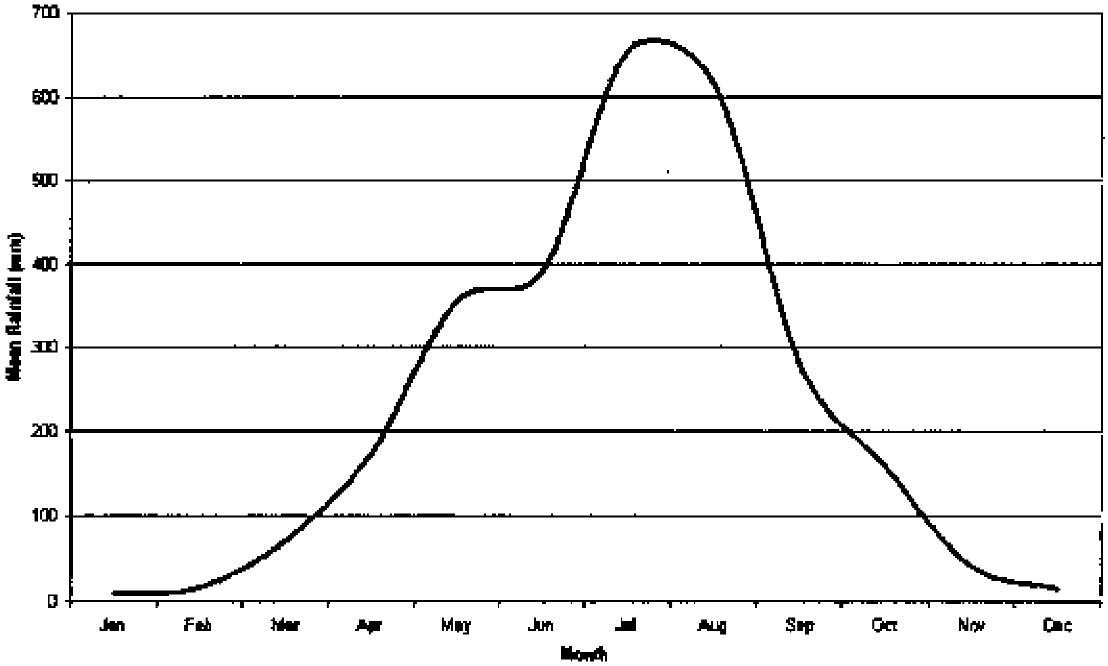


Figure 4.3: Mean monthly rainfall (1961-2000) in Kaptai watershed

October to March (winter season) while very high during March to September (summer season).

There is considerable rainfall in May and June (> 300 mm) which rises even further from June to July up to August (around 650 mm) and then starts to fall again. Mean monthly rainfall varies from 9 mm (January) to 650 mm (July). The mean annual precipitation varies from 2481 mm to 3041 mm with an average of 2599 mm.

4.5 Forest types in Chittagong hill tracts

Tropical evergreen and semi evergreen forests extends over Chittagong, Cox's Bazar, Chittagong Hill Tracts and Sylhet totaling an area of 6,70,000 hectare which is 4.54% of total the landmass of the country and 44% of national forest land. Depending on topography, soil and climate these area are categorized as i) Tropical wet evergreen forests and ii) Tropical semi-evergreen forests.

The hill forests are abundant with numerous plant as well as animal species. Some important flora are Garjan (*Dipterocarpus spp.*), Chapalish (*Artocarpus chaplasha*), Telsur (*Hopea odorata*), Tali (*Palaquium polyanthrum*), Kamdeb (*Callophyllum polyanthum*), Uriam (*Mangifera sylvatica*), Jarul (*Legarstromia speciosa*), Civit (*Swintonia floribunda*), Toon (*Cedrela toona*), Bandorhola (*Duabanga grandiflora*) etc. Moreover there are bamboo, cane, climbers and fern etc. in these forests.

These forests have been brought under plantation programme since 1871. At present, plantation activities are being conducted under development projects. Some valuable plantation species are Teak (*Tectona grandis*), Gamar (*Gmelina arborea*), Mehogani (*Swietenia spp*), Chapalish (*Artocarpus chaplasha*), Jarul (*Legarstromio speciosa*), Koroi (*Albizzia spp*), Chikrassi (*Chikrassia tabularis*), Pynkado (*Xylia dolabriformis*), Kadam (*Anthocephalus cadamba*), Telsur (*Hopea odorata*) etc.

The latest forest inventory shows that a total of 23,93 million cubic meter forest produces are available there

Bangladesh is one of the signatories of the Convention on Biological Diversity. Nevertheless, the three types of forests existing in the country -- the evergreen and semi-evergreen rainforests in the eastern region and the Chittagong Hill Tracts region, the moist and dry deciduous forests, known as "sal" forests, situated in the central plains and the northeast region, and the tidal mangrove forests along the coast -- are under threat, and little is being done to save them. In the meantime, the annual deforestation rate has reached 3.3 per cent.

The Chittagong Hill Tracts comprise 14,000 square kilometers, which represent about 10 per cent of the country's area. Some of the major species in these forests grow to gigantic heights and diameters. **The tallest part of the canopy is generally formed by deciduous and semi-deciduous trees while the under storey is of evergreen type.** Bamboo formations and savannah are also present. Several important species of mammals inhabit the area: e.g. elephants, bisons, deers, leopards, etc. Birds like the imperial pigeon, the green pigeon, and the white winged wood duck are also present. Commercial tree plantations, illegal logging, dam mega-projects, and forced displacement are responsible for the accelerated destruction of those precious ecosystems, which means the destruction of their biodiversity. Rubber, teak and eucalyptus monocultures for export have provoked negative ecological effects by the substitution of part of the forest, as well as conflicts between local communities belonging to the 13 ethnic groups that inhabit the region and the Forest Department (UNPO, n.d.)

(Chowdhury, 1992)

4.6 Visual survey of Kaptai lake and the surrounding areas

The following photographs (Photo 4 1-4.4) were taken in and around Kaptai lake in April 2005, during the Ground Truth survey.

Photo 4.1: Market, uncovered land around Kaptai watershed during dry season

Photo 4.2: Kaptai fringe, uncovered lands are flooded seasonally

Photo 4.3: Part of Kaptai lake from birds eye view

Photo 4.4: Part of Kaptai lake from hill top

Chapter Five

Land Cover Mapping and Change Detection (1980-2000)

Chapter Five

Land Cover Mapping and Change Detection (1980-2000)

Changes have been identified by classifying Landsat orthorectified images for nominal years 1980 and 2000 to see if there is any depletion of vegetation cover in the Kaptai watershed, which might have fostered the siltation process in Kaptai reservoir. Data were downloaded from Global Land Cover Facility (GLCF) site, which is freely downloadable. ERDAS Imagine 8.6, ArcView 3.2 and ArcGIS 9 software were used for data processing, classification and mapping. Here hypothesis is "vegetation cover has been depleted over the period 1980-2000".

5.1 Land cover classification

Classification was done based on Landsat satellite data for two nominal years at 20 years range. To understand the classification, accuracy and scale, it is important to know about the Landsat program and data properties.

"In 1967, the National Aeronautics and Space Administration (NASA), encouraged by the US Department of Interior, initiated the Earth Resource Technology Satellite (ERTS) program. This program resulted in the deployment of five satellites carrying a variety of remote sensing systems designed primarily to acquire earth resource information. The most noteworthy sensors were the Landsat Multi-spectral Scanner (MSS) and Landsat Thematic Mapper (TM)" (Jensen, 2000). Landsat 7 Enhanced Thematic Mapper Plus (ETM+) is under NASA's Earth Observing System (EOS). The Landsat program has launched seven satellites so far but several of them have already expired and three are still operational except Landsat 6, which failed to reach the orbit. A detailed description of different Landsat satellite's launch and retirement dates have been given in table Table 5.1

Table 5.1: Landsat satellites launch and retirement dates

Landsat	Launch date	Retirement date
Landsat1	July 23, 1972	January 6, 1978
Landsat2	January 22, 1975	July 27, 1983
Landsat3	March 5, 1978	September 7, 1983
Landsat4	July 16, 1982	Operational
Landsat5	March 1, 1984	Operational
Landsat6	October 5, 1993	Failed to achieve orbit
Landsat7	April 15, 1999	Operational

(Jensen, 2000)

Landsat MSS covers Landsat 1, 2 and 3; Landsat TM covers Landsat 4 and 5. The Enhanced Thematic Mapper plus is Landsat 7 (ETM+). All these sensors and their different characteristics are important while doing temporal change detection especially for last 20 years or more. Landsat sensor characteristics have been given in Table 5.2. The present study has long time duration to see the changes in land cover for nominal 1980s, 1990s and 2000. Data were downloaded from Global Land Cover Facility web site (http://glcf.umiacs.umd.edu/data/guide/technical/geocover.shtml). Landsat MSS, TM and ETM+ data were collected for nominal 1980, 1990 and 2000 respectively.

Table 5.2: Landsat sensor characteristics

Landsat Sensor	Band no.	Spectral Resolution (µm)	Spatial Resolution (meter)	Quantization level	Earth coverage	Swath width
Landsat MSS (Landsat 1,2 and 3)	1	0.5-0.6	57	6 bit	18 days	185 km
	2	0.6-0.7				
	3	0.7-0.8				
	4	0.8-1.1				
Landsat Thematic Mapper (TM) (Landsat 4 and 5)	1	0.45-0.52	28.5	8 bit	16 days	185 km
	2	0.52-0.6				
	3	0.63-0.69				
	4	0.76-0.9				
	5	1.55-1.75				
	6	10.40-12.50				
	7	2.08-2.35				
Landsat Thematic Mapper (TM) (Landsat 4 and 5)	1	0.45-0.52	28.5	8 bit	16 days	185 km
	2	0.52-0.6				
	3	0.63-0.69				
	4	0.76-0.9				
	5	1.55-1.75				
	6	10.40-12.50				
	7	2.08-2.35				
	8(Pan)	0.52-0.90	14.25			

(Jensen, 2000)

Prior to land cover classification a classification scheme has been developed. Classification was basically oriented to existence of vegetation covers. Thus the following classification scheme was finalized.

A. Water body (Lake, stream, river)

B. Non-vegetative/non-woody/Non-forest (Bare, harvested/cultivated agriculture, Barren, fallow agriculture, fallow Jhum cultivation, clear-cut, logged area, slash and burn, very highly degraded vegetation)

C: Vegetation low density (Open fragmented forest, low-medium dense vegetative cover)

D: Vegetation high density (Closed forest, highly dense vegetative cover)

Though this classification is to identify vegetative cover, not particularly the forest area the forest types and their yearly cycle was important to map vegetative cover. Chittagong Hill Tracts (CHT) possess some deciduous trees that leave leaf during dry season (Chowdhury, 1992). Even the global GLC map (1 km resolution) also shows the presence of deciduous trees around Kaptai lake. It was assumed that all deciduous trees in the study area lost their leaves during the time of image acquisition as all images were captured during dry season (February, April). In this way it can he said that this forest map will include only evergreen or semi-evergreen vegetation as no time series data was available in hand to map seasonal variation for the nominal year 1980 and 2000. No secondary map of forest types (particularly deciduous forest) was found at Landsat resolution for 1987 and 2000. Survey of Bangladesh has some map at 1:25000 scale, produced in 1975, that shows presence of non-dense forest in non-forest/non vegetative area of Landsat image of 1978 (nominal 1980). No proportion statistics of forest types was found for the study area particularly for CHT. Thus deciduous trees remained unaccounted for this mapping exercise.

A Ground Truth (GT) survey (collecting GPS location with description of land cover) was conducted during April 2005. Only 23 GT points was collected in and around Kaptai Lake due to restriction imposed by the Army. It was not possible to do the same in Indian territory because of time and budget constraints. Land Cover for different years has been classified based on unsupervised classification approach, ground truth GPS locations, interpretation of high resolution IRS (Indian Remote

Sensing Satellite) image and False Color Composite (FCC) of Landsat. Different classes of land covers were then verified by secondary coarse resolution (1km) global dataset (Landuse Landcover map, USGS, 1992; Global Land Cover Facility (GLCF), 2000 and Forest Density Map of USGS, 2000) and overall knowledge of the landscape. Maps were verified with secondary coarse resolution land cover data. Forest areas have been compared with FAO forest cover map and found satisfactory.

5.2 Base data preparation

The following data/maps have been prepared/collected for interpretation of classes.

5.2.1 Watershed boundary delineation
5.2.2 NDVI map preparation
5.2.3 False Color Composite (FCC) of image
5.2.4 High resolution image for ground truthing
5.2.5 Secondary coarse resolution land cover map

5.2.1 Watershed boundary delineation

For this study it was first necessary to define the Kaptai watershed boundaries, which demarcates the study area. Shuttle Radar Topographic Mission (SRTM) elevation data were used for watershed delineation, which have 90m spatial resolution. This delineation process followed several steps as stated in methodology chapter in detail (Figure 3.3 to 3.10).

These watershed boundary polygons were then overlaid over the International boundary of Bangledesh. It was found that about 60% of watershed fall inside Bangladesh territory while 40% fall inside India (Table 5.3).

Table 5.3: Area statistics for watershed in Bangladesh and Indian territory.

Watershed	Bangladesh		India		Total	
	Area (Sqkm.)	%	Area (Sqkm.)	%	Area (Sqkm.)	%
Total	6819.84	60.10	4526.85	39.90	11346.91	100

5.2.2 NDVI generation from Landsat data

NDVI was generated for each masked out tile for nominal years 1980 and 2000 by following Equation 5.1 by using Near Infrared (NIR) and Red band. NDVI varies from –1 to +1 as because it is a ration and dimensionless.

$$NDVI = (NIR - Red)/(NIR + Red) \quad (5.1)$$

The nominal year 1980 is almost covered by two tiles (April 15, 1978; Nov 3, 1972). But the second one (Nov 3, 1972) covers only a very small part of the lower end of the study area, which has 5 months' and 6 years' of difference in time with the first tile (Figure 5.1). Moreover there is a horizontal gap of 7300m between the two images. Due to this big temporal, seasonal and spatial gap the second tile was not considered for the classification for 1980s. The list of images and their spatio-temporal description are presented in Table 5.4. Figure 5.1 and 5.2 shows Landsat tile's coverage for the nominal year 1980 and 2000 respectively.

Table 5.4: Spatio-temporal description and processed images

Nominal year	Date of acquisition	Path-Row	Tiles processed
1980 (Part1)	April 15, 1978	P146-R44	Processed
1980 (Part2)	Nov 3, 1972	P146-R45	Not considered
2000 (Part1)	Feb 7, 2001	P136-R44	Processed
2000 (Part2)	Feb 19, 2002	P135-R44	Processed
2000 (Part3)	Feb 14, 2000	P135-R45	Processed

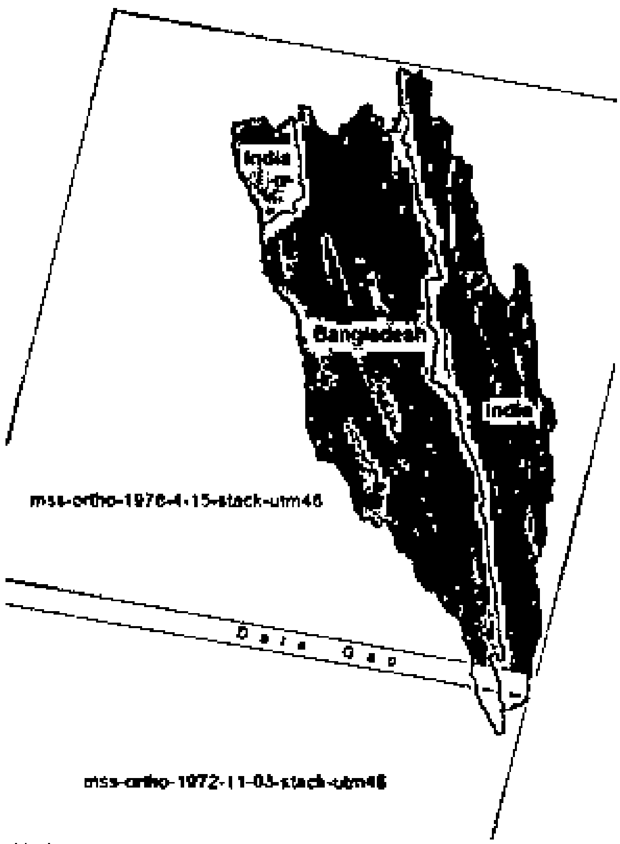


Figure 5.1: Landsat tile's coverage for the nominal year 1980

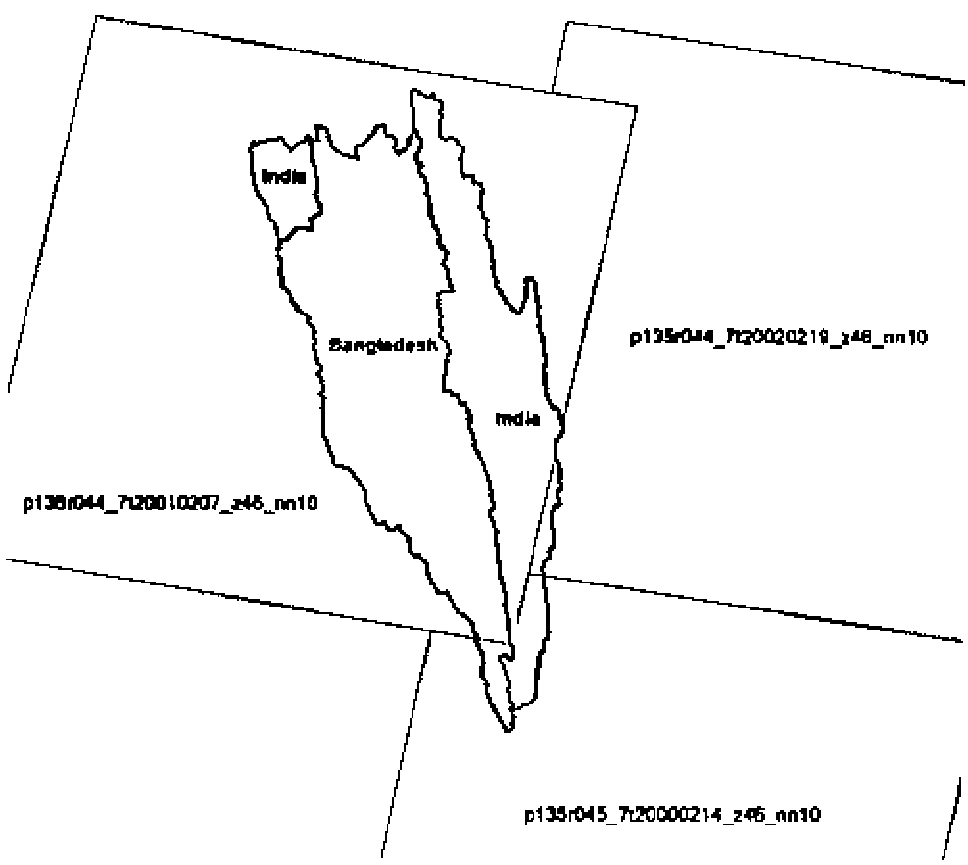


Figure 5.2: Landsat tile's coverage for the nominal year 2000

5.2.3 False and True Color Composite of Landsat data

Different False Color Composite (FCC) and True Color Composite (TCC) were selected based on different band combination and different sensor as given in Table 5.5. This was done based on the reflectivity characteristics of different bands.

Table 5.5: Different Landsat sensor and FCC combinations

Sensor	Year (nominal)	FCC1	FCC2	TCC
MSS	1980	R:3, G:2, B:1	-	-
ETM	2000	R:4, G:3, B:2	R:4, G:3, B:5	R:3, G:2, B:1

These FCC as well as TCC helped a lot in visual interpretation of differences in density of vegetation, uncovered area and water bodies.

5.2.4 High resolution image for ground truthing

High resolution IRS LISS III image was processed at 5.8m resolution level. The resolution merging technique was used to merge 24m multi-spectral bands with 5.8m pan band. It is a technique to distribute the multi-spectral band values over high resolution pan band. This enhanced the pan band with colour information to assist image interpretation better. In fact this image was the basis for visual interpretation of Landsat image and identification of land cover classes after unsupervised classification.

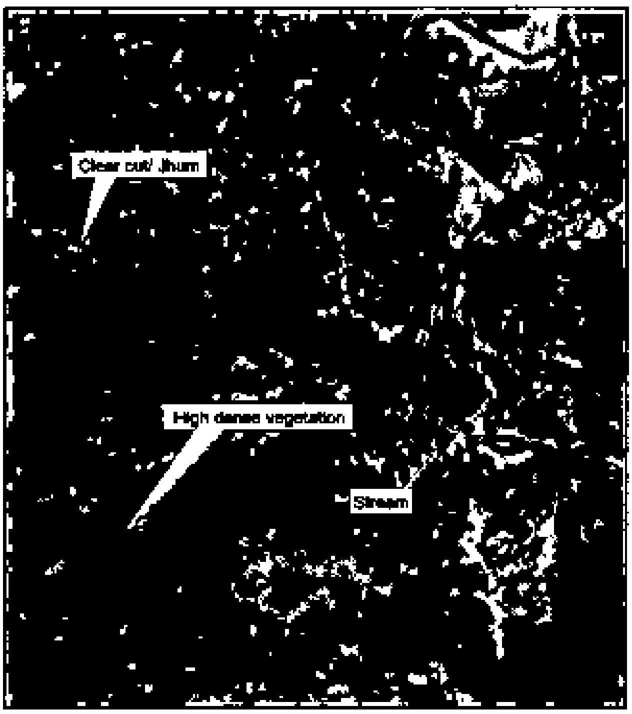


Figure 5.3: A snap shot of IRS LISS III (resolution merged with Pan band) (Date: Pan-13 march 2001, Multispectral-23 April 2001)

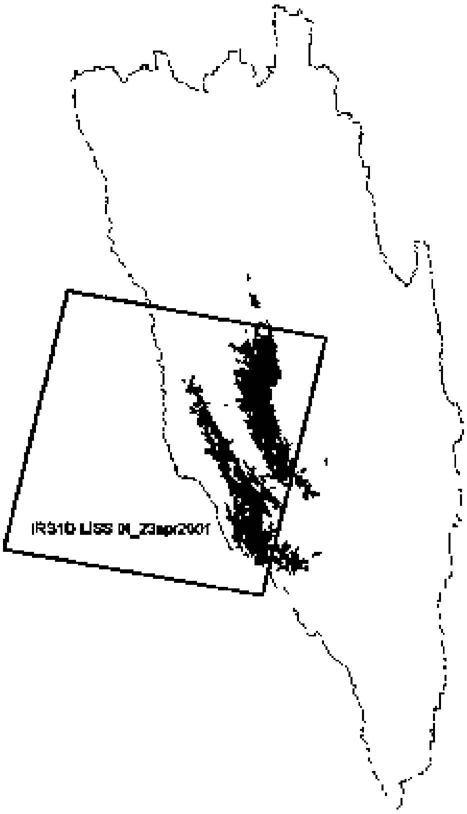


Figure 5.4: Extent of IRS LISS III image on Kaptai watershed (Black square)

5.2.5 Secondary coarse resolution land cover map

FAO forest cover map and other land use/ land cover maps of Bangladesh were collected from the Internet. These were registered to the satellite images. Coarse resolution secondary land cover maps (Landuse Landcover map, USGS, 1992; Global Land Cover Facility (GLCF), 2000) were collected from Global Land Cover Facility web site of USGS. These were registered to Landsat data..

Fig 5.5: Land cover map, FAO

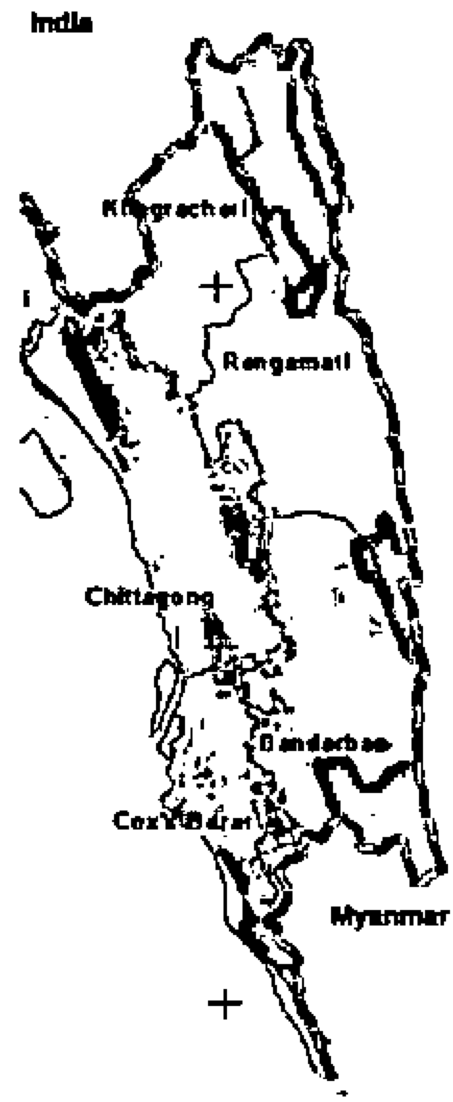


Fig 5.6: Forest cover map (Closed forest in green), 2003, Forest Department

USGS and GLC maps have 15 and 12 classes respectively in Kaptai watershed. These classes were merged and categorized into 4 classes for the sake of simplicity of the map. These secondary maps helped to identify particular threshold for NDVI for classifying Landsat data.

Fig 5.7: Land cover of Kaptai watershed.
USGS, 1992-93
Resolution: 1 km

Fig 5.8: Land cover of Kaptai watershed.
GLC, 2000
Resolution: 1 km

5.3 Classification

Each tile for 1980 and 2000 were classified based on unsupervised classification technique. Following are the steps of class identification process.

5.3.1 Tile by tile approach

Initially it was decided to mosaic all tiles for each nominal year, but it increases the data variability because of the difference in dates of images. It was observed that the mosaic of Normalized Difference Vegetation Index (NDVI) for different year's images have clear distinction along the edge of the mosaic lines, which indicates the reflectivity of band 3 and 4 for different dates are certainly different for a particular land use. So finally each Landsat tile was masked out separately by the study area (Kaptai watershed boundary). This tile by tile approach reduced the range of values in each image which enhanced the image better and made good contrast in image (FCC*/TCC*) for better visual interpretation and thus help in identification of classes after unsupervised classification.

5.3.2: Unsupervised classification for 25 classes for each tile

Each tile for 1980 and 2000 was classified into 25 classes based on unsupervised classification technique which is a statistical process to identify variability into multivariate data (ENVI 3.6 help file). Standard deviation 2 was used for this process with maximum iteration 99 and 0.97 as threshold. For more information on unsupervised classification please see ENVI 3.6 help file.

5.3.3: NDVI plot

Each of the 25 class's average NDVI was plotted to see the variation among classes. NDVI is an index of Red and Near Infra Red (NIR) band as discussed in the previous chapter. NDVI has a positive correlation with vegetation cover and density (FEWSNET, n.d.; US Water Conservation Laboratory, 2005) which helps to identify classes logically.

* FCC: Stands for False Color Composite which is any combination of image bands displayed using red, green and blue color.

* TCC: Stands for True Color Composite which is the combination of three optical bands (certain range of frequency of light which is visible) display satellite image in natural color.

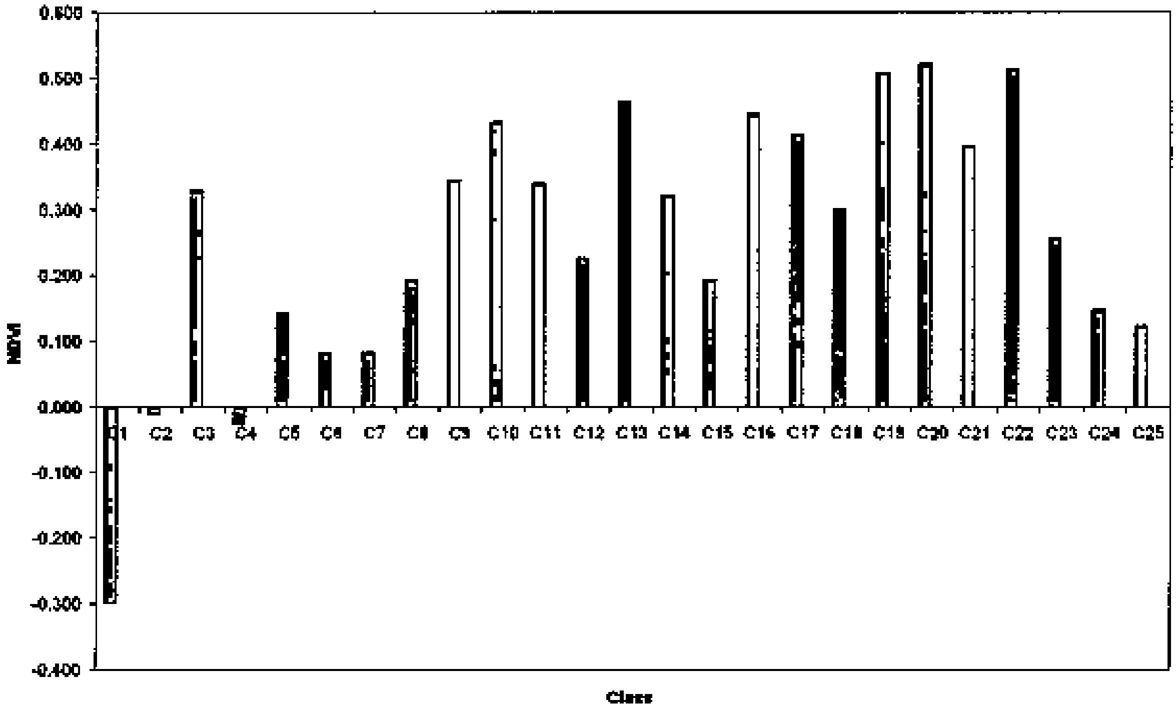


Figure 5.9: NDVI of 25 classes of 15 April 1978 Landsat MSS image.

NDVI values range between -1 and +1, with dense vegetation having higher values (e.g., 0.4 - 0.7), and lightly vegetated regions having lower values (e.g., 0.1 - 0.2). (FEWSNET, n.d.).

5.3.4: Bi-spectral plot

It is another effective technique for identification of classes based on wetness, greenness and dryness state of the class over 2 dimensional feature space. Average Red and NIR band values of Landsat for each class were plotted on 2 dimensional space like below.

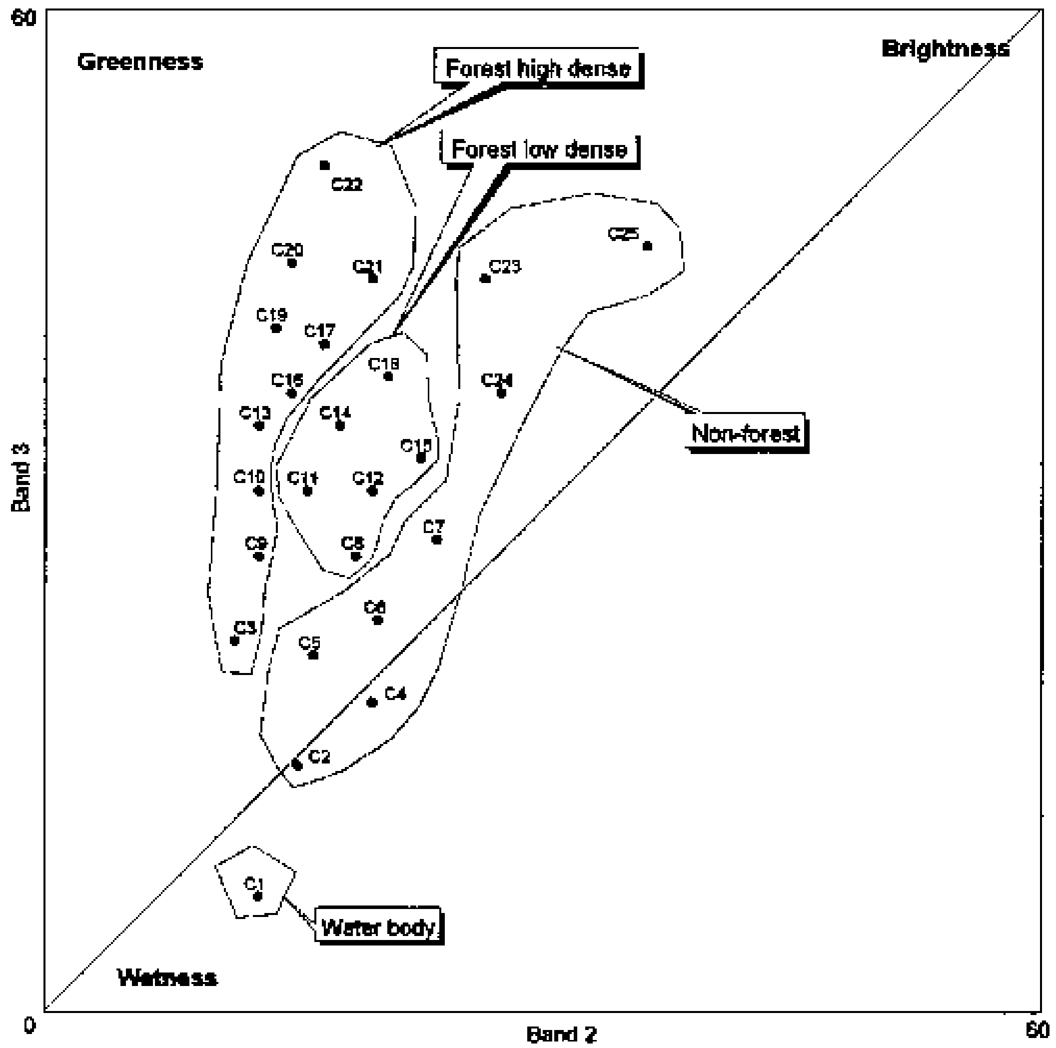


Figure 5.10: Bi-spectral plot of 25 classes derived from 1978 Landsat image

Here X axis represents Red band and Y axis represents NIR band. The middle line across the plot at 45 degree angle is called Soil Line which is the equilibrium of X and Y axis.

5.3.5: Class identification

As a particular class comes close to zero in bi-spectral plot, it gets more moisture/water. If it goes up and parallel to NIR band axis the difference between NIR and Red increases this gives higher NDVI. This class must have high density of vegetation. Certainly classes close to soil line has very little/no vegetation. Any class below soil line is considered as water/ very moist land. As class goes up along soil line it gets more dry. (Thenkabail et al., 2006). These characteristics of classes on bi-spectral plot were related with NDVI plot (Figure 5.10) and visual interpretation (Figure 5.12). Usually if NDVI is negative it certainly represents water/moist class. If NDVI goes up it represent existence of vegetation. Higher NDVI means higher density of vegetation. (FEWSNET, n.d.)

Thus these two plots are has played the key role in identification of primary classes. These primary classes were then compared with GT points and visual interpretation of high resolution IRS image, Landsat image and secondary coarse resolution maps. There were some classes which were difficult to identify because they had some mixing with other classes. In such cases classes were examined carefully and labeled based on majority and probably to be under particular map unit. For example if majority pixels fell under non-forest class and bi-spectral characteristics showed the proximity to non-forest classes, it was labeled as non-forest.

Finally the following classes were identified.

A. Water body (Lake, stream, river)

B. Non-vegetative/non woody/Non-forest (Bare, harvested/cultivated agriculture, Barren, fallow agriculture, fallow Jhum cultivation, clear-cut, logged area, slash and burn, very highly degraded vegetation)

C: Vegetation low density (Open fragmented forest, low-medium dense vegetative cover)

D: Vegetation high density (Closed forest, highly dense vegetative cover)

5.3.6: Filtering

After classification of each tile, Majority filtering function was used to remove isolated/scattered pixels. A 3X3 neighbourhood was selected to examine all values of 8 surrounding pixels (neighbors) around a particular cell and only the majority value was assigned to that pixel.

5.3.7: Mosaic

All tiles for a particular year were finally mosaiced to get a continuous surface. This was not necessary for the 1978 image because only one tile was considered for nominal 1980. But tiles for nominal year 2000 were mosaiced to have a single surface. The land cover maps for the nominal year 1980 and 2000 were prepared thus.

5.4 Final Mapping

Classification was done at different resolution for different years (Table 5.6)

Table 5.6: Scale of classification for different years

Sensor	Nominal Year	Mapping scale/resolution
ETM+	2000	28.5m
MSS	1980	57m

ETM+ was classified at 28.5m resolution for nominal year 2000s as NIR and Red bands (used to generate NDVI) have that resolution, though Pan band has 14.25m resolution. MSS image (1980s) was processed at 57m resolution. Finally the land cover for 1980s was resampled into 28.5m to match with 2000s for the easement of further calculation and comparison.

Figures 5.11 and 5.12 show the final maps of nominal year 1980 and 2000. Table 5.7 describes the area by percentage and average NDVI of different land covers. Water body in year 1978 (nominal 1980) was found much less than in 2000 as because of the late monsoon in 1978. Non forest area has increased by 8% and low dense forest area has decreased by 19%. High density forest has increased by 7.5%. But overall forest coverage (low+high dense) has decreased by 11.6%. This has probably happened because of increase in non-forest areas though government has implemented many afforestation/plantation program in Chittagong Hill Tracts since after independence (Chowdhury, 1992).

Table 5.7: Area statistics and percentage of land covers in Kaptai watershed

Land cover	Year 1978			Year 2000		
	Area_sqkm	%	Avg NDVI	Area_sqkm	%	Avg NDVI
Water body	184.89	1.66	-0.30	601.19	5.30	-0.22
Non-forest	2109.02	18.98	0.10	3059.13	26.95	0.15
Forest low dense	3814.13	34.33	0.26	1726.35	15.21	0.31
Forest high dense	5001.86	45.02	0.44	5964.91	52.55	0.36
Total	**11109.89**	**100.00**	-	**11351.57**	**100.00**	-

The underlying cause of this decrease in overall forest area could be related to the population as it has increased by double from 1901 to 2000 (Tripura et al, 2003) and increased by 158 thousand during 1981-1991 (BBS, 1992). So the pressure on land has intensified which led to the intensification of *jhum* cultivation. Before *jhum* farmers used to cultivate a particular land every 10/15 years, which has now intensified to 3/4years. In Khagrachari district this intensification is even lower than 3 years interval (Tripura et al, 2003). Though many plantation programs, social forestry programs have implemented and still under implementation, but they have not been enough to cover the combined loss of *jhum* and logging. Thus vegetative cover is decreasing over time.

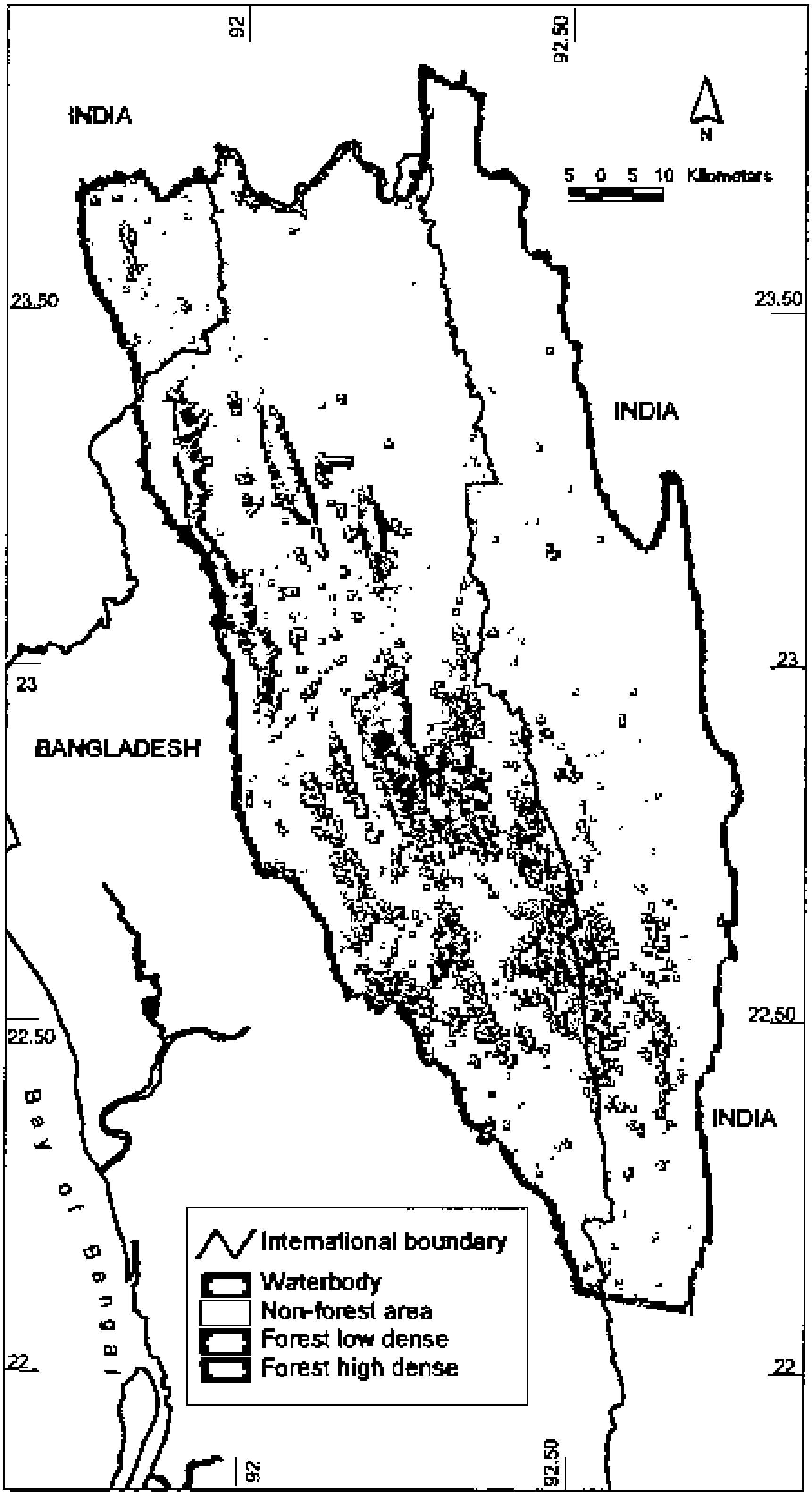


Figure 5.11: Final Maps of 4 classes for 1980

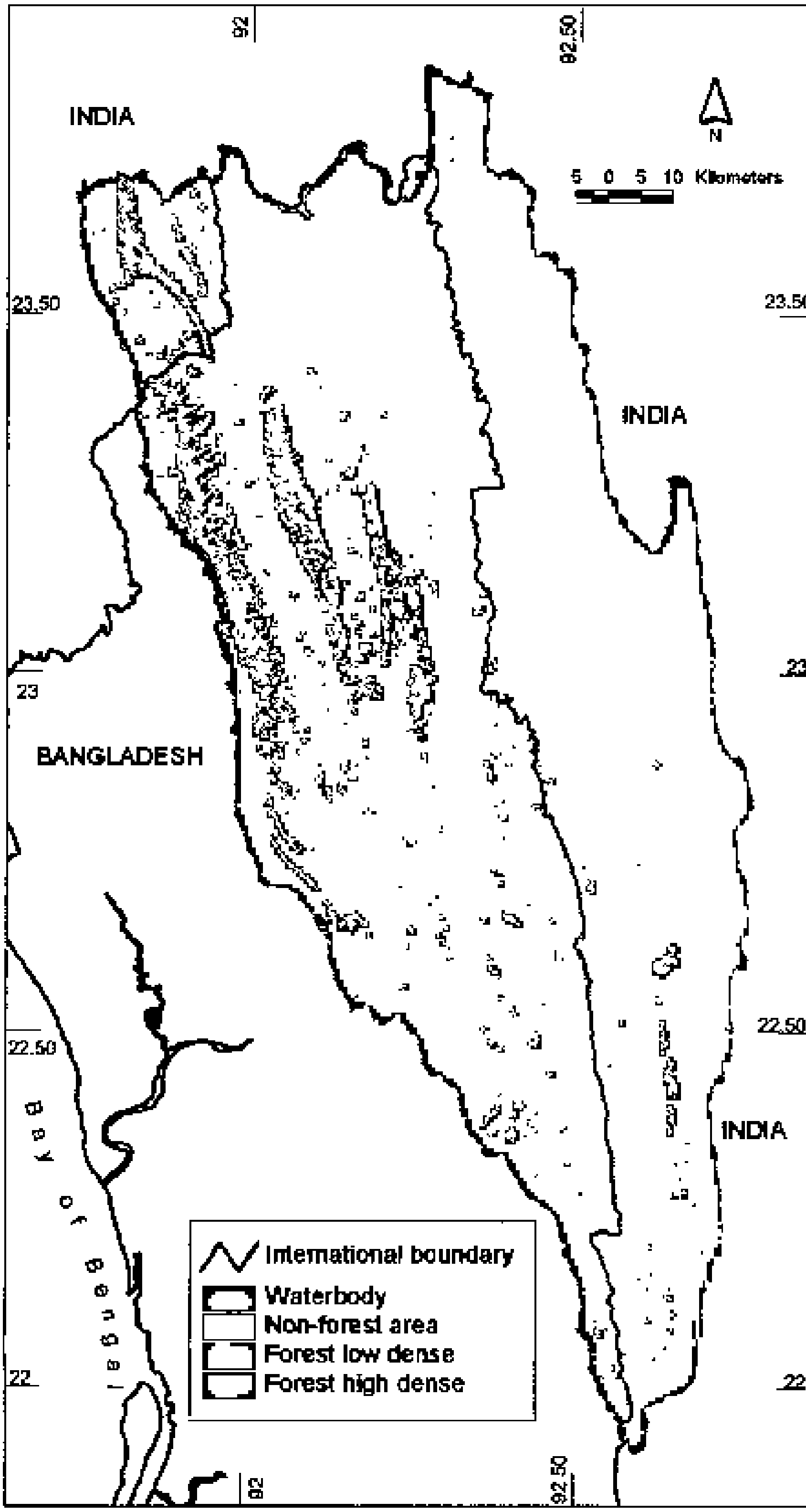


Figure 5.12: Final Maps of 4 classes for 2000

5.4 Change Analysis

Two land cover maps for nominal years 1980 and 2000 were analyzed to identify spatio-temporal changes over time. To do this it was necessary to keep the waterbody as constant over time. It was assumed that the extent of water body would be the same over time since it basically depends on of amount rainfall or drought period in a particular year. Moreover this study dealt with vegetation coverage, not water body or it's seasonal flood plain area. Thus water level rise did not have any effect on area coverage statistics of other land covers.

It was found that water body area of year 2000 covered the whole water body of 1978 map (nominal 1980). So water body area of 2000 was superimposed onto 1980 map and replaced other land covers falling under. Some variation in area coverage is noticed after this merging operation. To maintain more accuracy in comparison, map 2000 was clipped by the extent of map 1980 which is named as 2000 (common). So other map of 2000 covering the entire watershed is then renamed as 2000 (whole). After this extent adjustment the 1980 map was compared with 2000 (common) map and found that non forest area had increased by 10.6%, forest low density decreased by 18.4% and high density forest increased by 7.9% (Table 5.8 and Figure 5.13). Overall forest coverage has decreased by 10.6% which is a really high depletion rate over a 20 year period.

Table 5.8: Temporal variation of land covers in Kaptai watershed

Land covers	1980		2000 (common)		2000 (whole)	
	Area_sqkm	%	Area_sqkm	%	Area_sqkm	%
Water body	600.56	5.4	600.56	5.4	601.19	5.3
Non-forest	1819.61	16.4	2996.93	27.0	3059.13	26.9
Forest low dense	3734.84	33.6	1683.31	15.2	1726.35	15.2
Forest high dense	4954.88	44.6	5829.08	52.5	5964.91	52.5
Total forest	**8689.72**	**78.2**	**7512.39**	**67.6**	**7691.26**	**67.8**
Total	**11109.89**	**100.0**	**11109.89**	**100.0**	**11351.57**	**100.0**

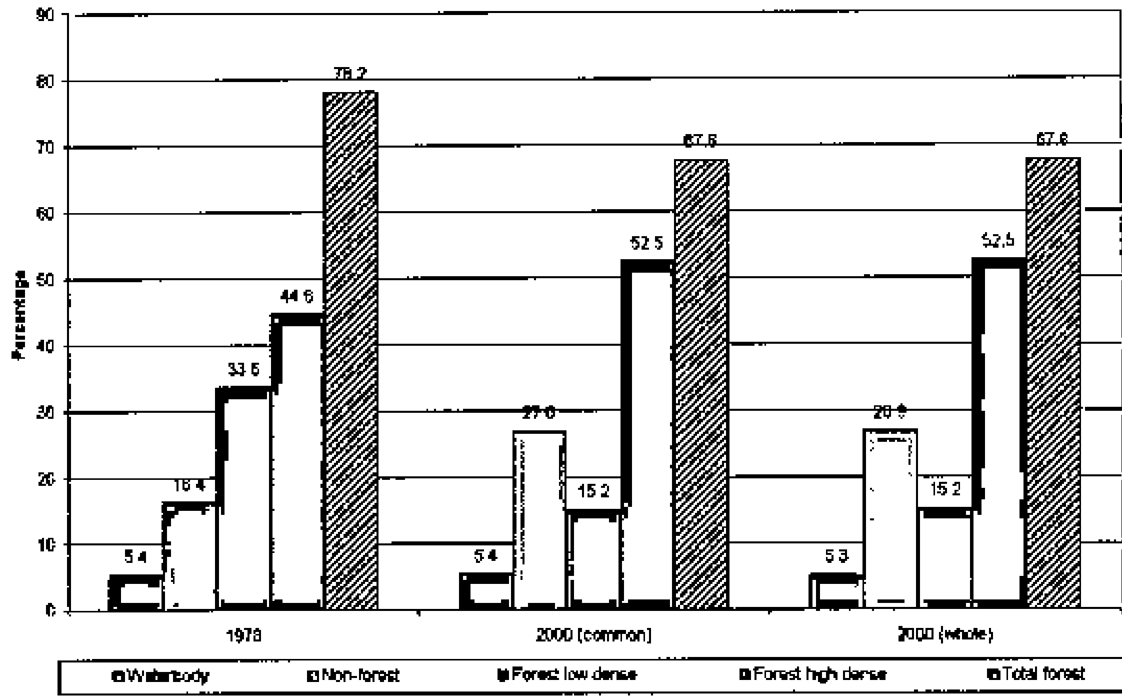


Figure 5.13: Percentage of land covers over time in Kaptai watershed

Area statistics of two land cover maps were generated based on international territory (Figure 5.14). It was found that Bangladesh had lower percentage of high density vegetative cover though it has a higher percentage of low density vegetation and more higher non-vegetative areas in 1980. In 2000 the situation had improved a bit. Figure 5.15 explains that the high density vegetation of Bangladesh was just half of the same in India in 1978. But low density vegetation was higher than in India by 12%. At the same time non-forest/non-vegetative area was 9% higher. This indicates the better situation in India than in Bangladesh in 1980 though India occupies lower percentage (40%) of watershed than Bangladesh. In 2000 high density vegetation increased in Bangladesh territory but it was still lower than in India by 23%. Low density vegetation decreased and non-vegetative/non forest area increased substantially in both countries. Thus total vegetative cover (low density, high density) decreased substantially by 13% in Bangladesh (from around 71% to 58%) while in India vegetation loss was only 7% (from around 87% to 80%) over the 20 year time period. Non vegetative/non forest area increased by 13% and 3% in Bangladesh and India respectively.

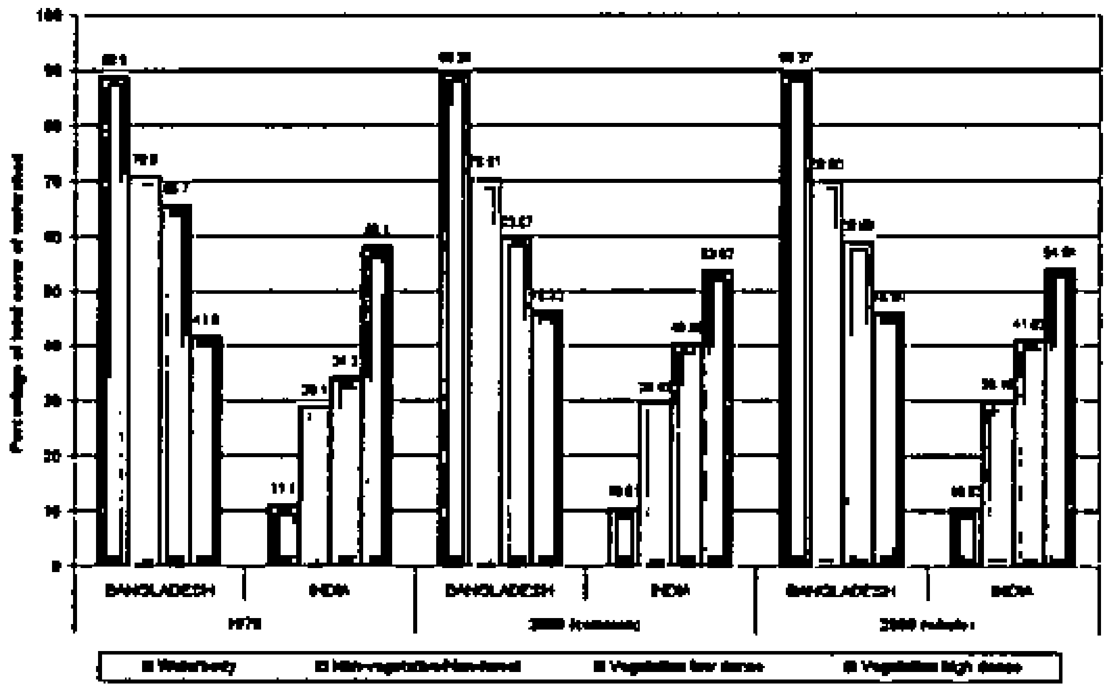


Figure 5.14: Land cover distribution in Bangladesh and India

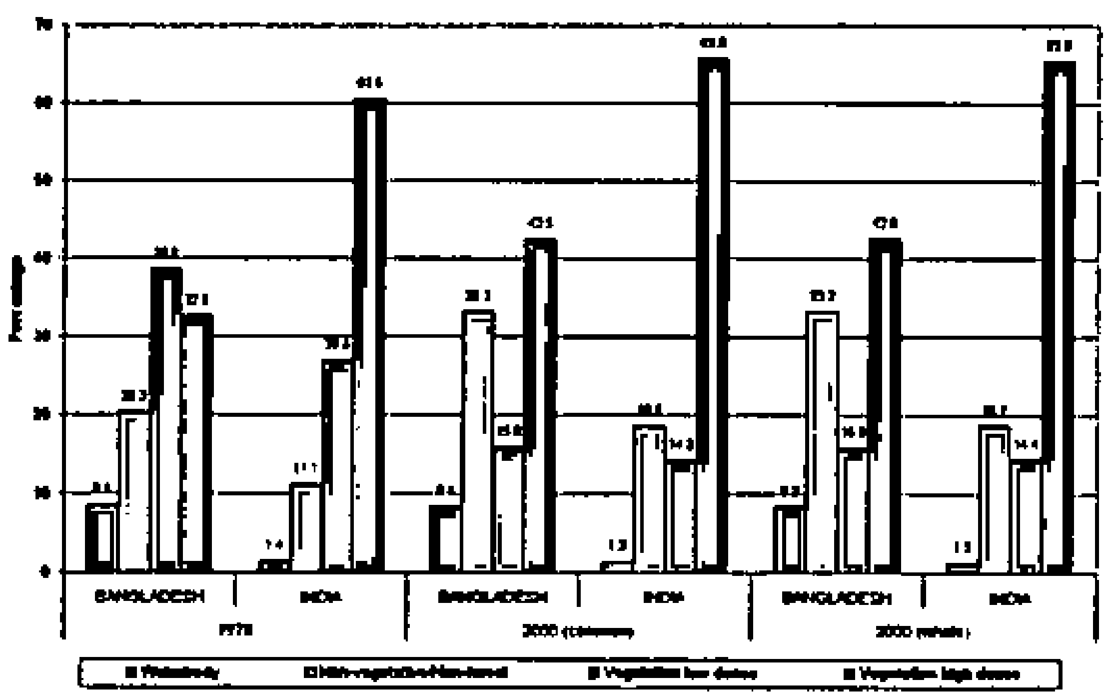


Figure 5.15: Land cover distribution inside Bangladesh and India

5.4.1 Loss and gain analysis

Though it is clear that vegetation has depleted in Kaptai watershed over 20 years, it was important to see the qualitative change in vegetation in terms of loss and gain over time both at aggregated and disaggregated level. At the disaggregated level, three classes are considered - non-vegetative/non woody/non forest, vegetation low density and vegetation high density. At the aggregated level only two classes are considered - non-vegetative/non woody/non forest and vegetation of both densities which is mainly closed and open forest area. Disaggregated analysis was mosly concentrated on distribution of loss and gain but aggregated analysis was more elaborate because of small number of classes and simplicity of analysis.

(a) Disaggregated level loss and gain

Before performing this analysis water body area was deducted from the maps of 1980 and 2000 (common). Then non vegetative/non forest area, vegetation low density and vegetation high densirt area were recoded to 1, 2, and 3. The recoded map of 1980 was then deducted from map 2000 (common) (Figure 5.16). This pixel to pixel comparison gave the following result (Table 5.9).

Table 5.9: Loss and gain in Kaptai watershed during 1980- 2000 at disaggregated level

Value	Loss/gain of vegetation	% of total watershed area
-2	High loss	6.06
-1	Low loss	19.20
0	No change	51.91
1	Low gain	16.95
2	High gain	5.84

Here the number 2 in the value field indicates a value which is always a deduction of 1 from 3 in 1 to 3 scale. So as 3 is high density vegetation and 1 as non-vegetative, -2 is the change from high dense vegetation in 1980 to non vegetative condition in 2000 (1-3 = -2) which indicates a high loss. In the same way +2 or 2 indicates a gain. -1 indicates change of vegetation from high dense to low dense or low dense to non-vegetative condition. Zere (0) indicates no change. Around 52% of the Kaptai watershed did not have any change over time while total gain was about 22% but losses were observed in 25% area.

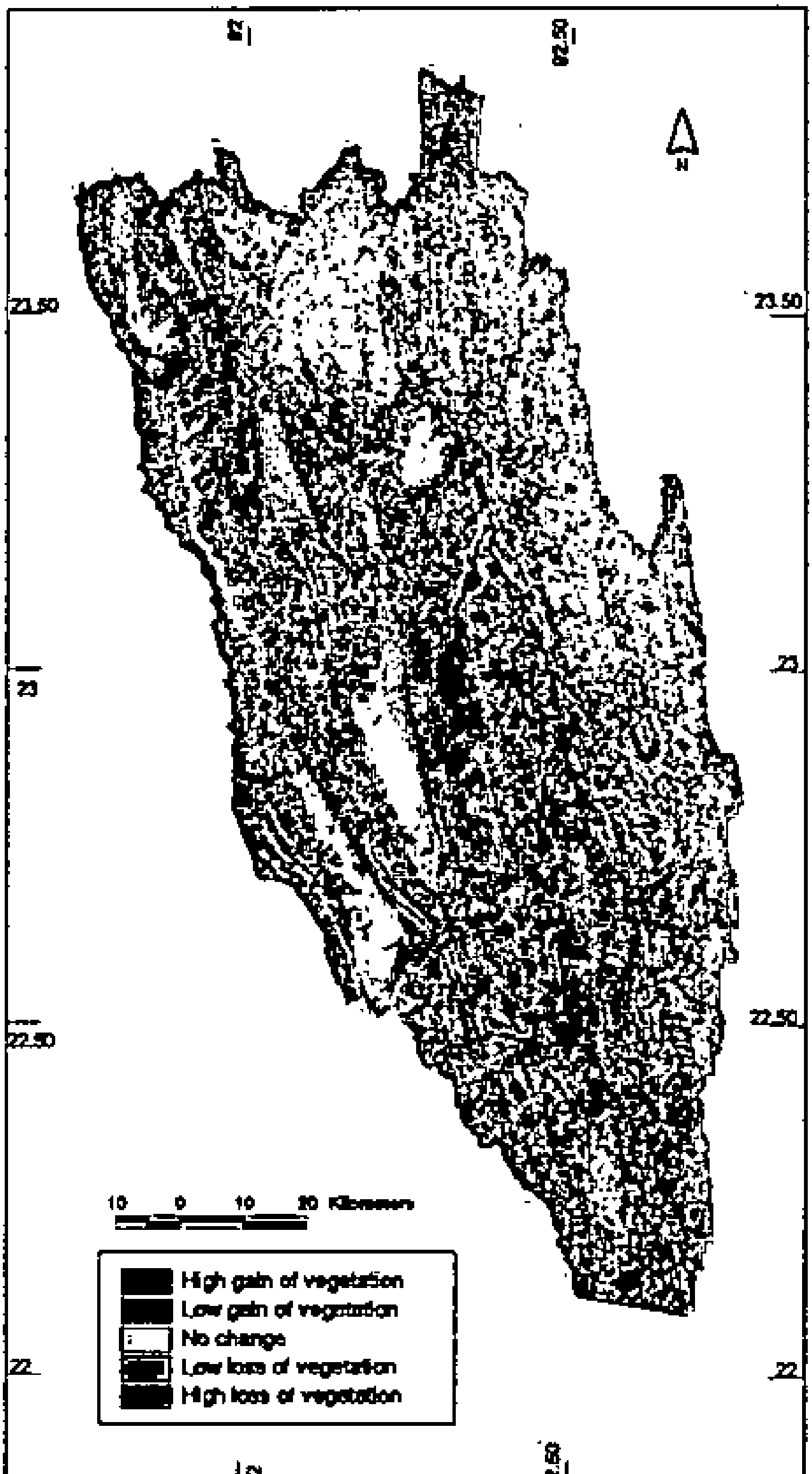


Figure 5.16: Distribution of vegetation loss and gain over the watershed for disaggregated classes.

(b) Aggregated level loss and gain

First water body area was deducted from the maps of 1980 and 2000 (common). The non vegetative/non forest area, vegetation low dense and vegetation high dense area were recoded to 1, 2, and 2 respectively. The recoded map of 1980 was then deducted from map 2000 (common) (Figure 5.17) (Table 5.10). It was observed that about 70% of watershed did not have any change. Loss was for 20% and gain for 9% of the watershed area.

Table 5.10: Loss and gain in Kaptai watershed during 1980-2000 at aggregated level

Value	Loss/gain of vegetative/forest cover	% of total watershed area
-1	Loss	20.31
0	No change	70.56
1	Gain	9.12

This aggregated gain-loss layer was then compared with slope and elevation map. Both maps were classified at irregular interval and then overlaid on gain-loss map. Area of gain-loss under each interval/range of elevation and slope were calculated. It was found that maximum loss happened in 50-100m elevation range while maximum gain happened in 100-250m range (Figure 5.18). The maximum of no change area fell in 100-250m range. Both loss and gain increased with elevation but decreased after reaching 250m. Maximum difference between loss and gain was in 50-100m elevation.

In the same way the aggregated loss-gain map was compared with slope range map (Figure 5.19). Maximum loss happened in 2-5 degree slope range while maximum gain happened in 10-20 degree slope range. Maximum unchanged area was under 10-20 degree slope. Maximum difference between loss and gain was in 0-0.5 degree slope. This difference decreased as slope increased, which means gain increases as slope increases but start to fall after 5 degree slope. There was almost no gain or loss after 40 degree slope because this type of slope is not suitable for cultivation or logging.

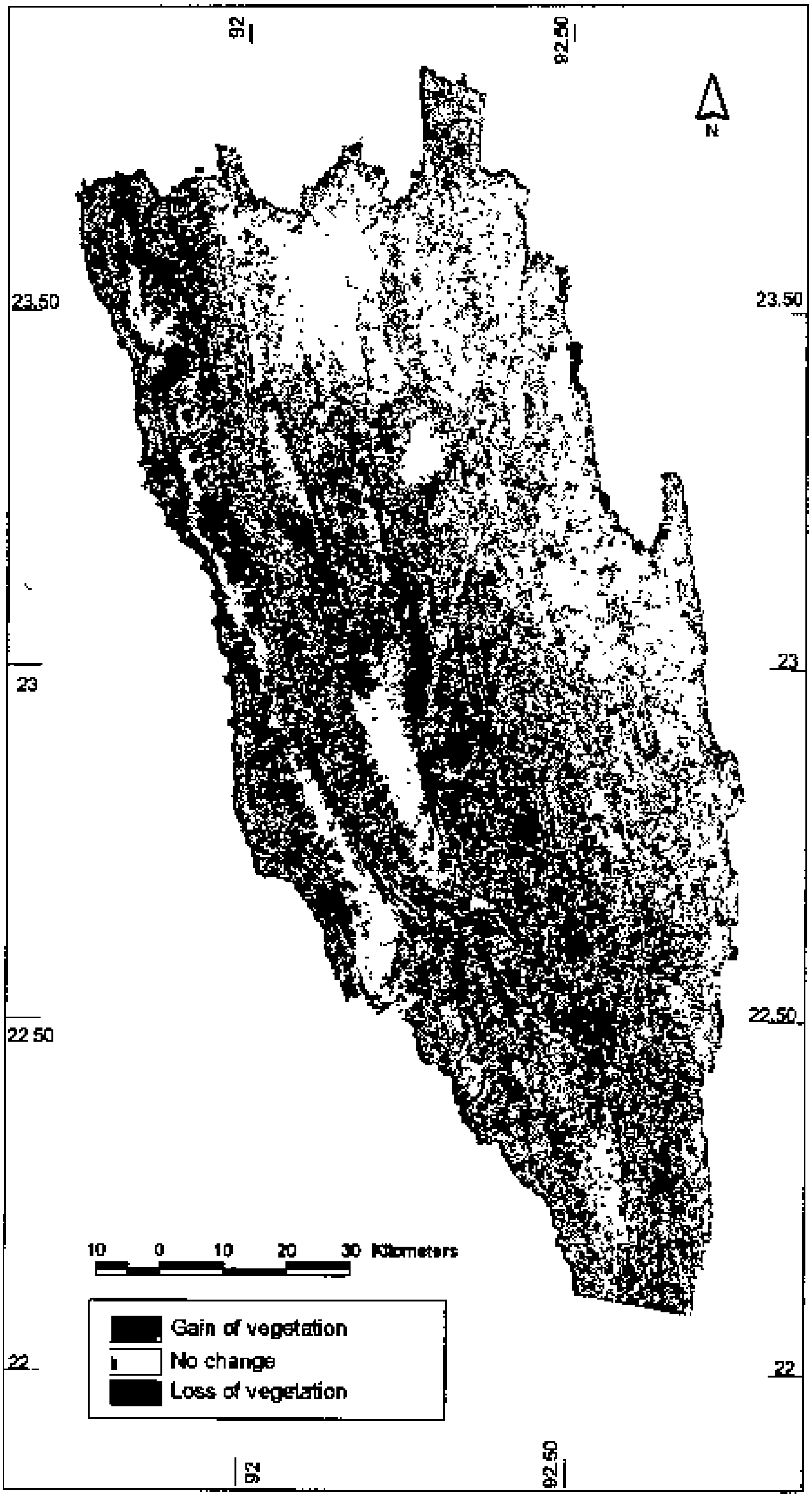


Figure 5.17: Distribution of vegetation loss and gain over the watershed for aggregated classes.

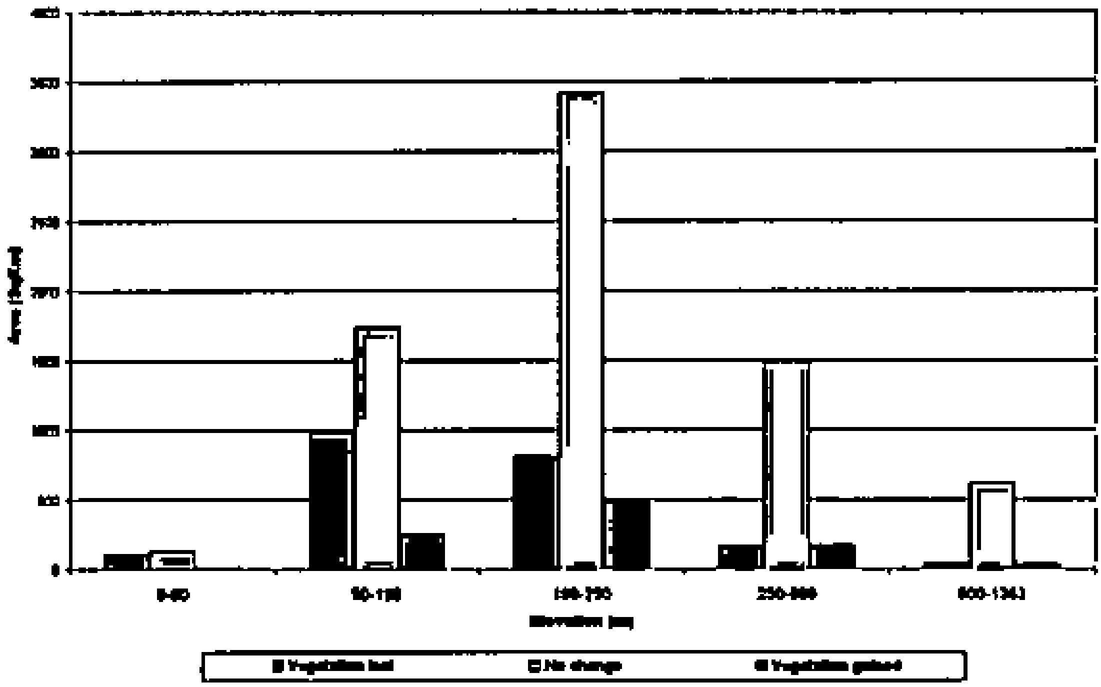


Figure 5.18: Vegetation loss or gain at different elevation range

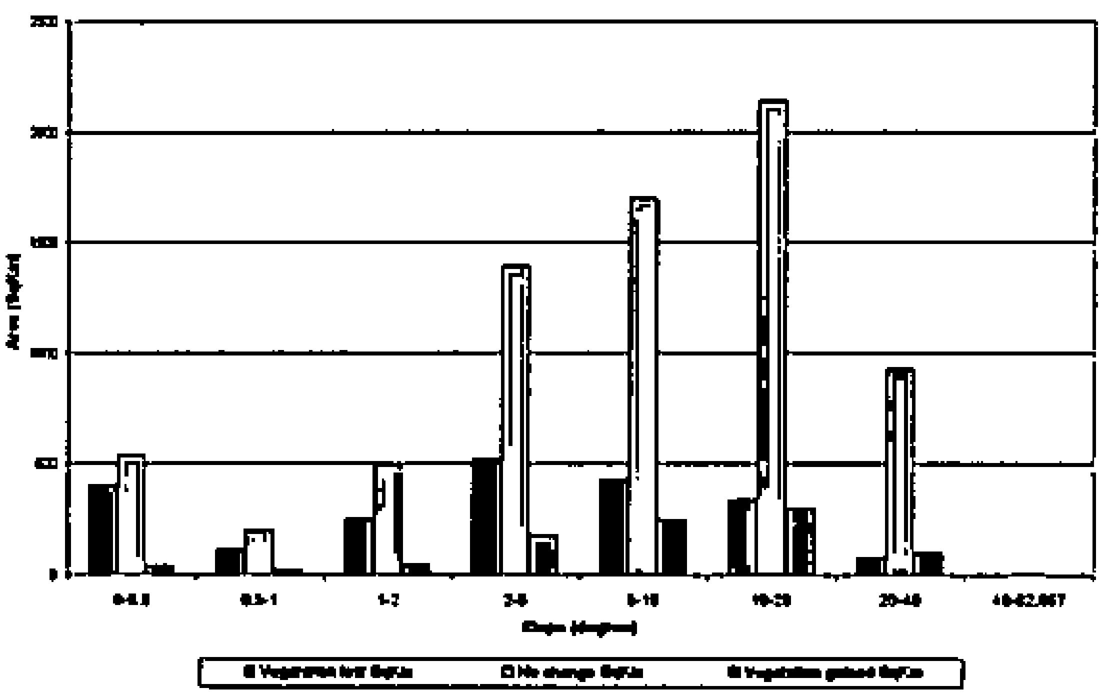


Figure 5.19: Vegetation loss or gain at different slope range

Change also was analyzed within each range of elevation and slope (Figure 5.20. 5.21). It was found that maximum change took place in 0-50m elevation. This might be because of the elevation range suitable for agricultural activities. Vegetation was lost substantially (42%) since gain was very less (4.8%) at 0-50m range. Vegetation loss decreased as elevation increased. Proportion of non vegetative/non forest area increased substantially as elevation went up. The difference between loss and gain is least after 250m elevation.

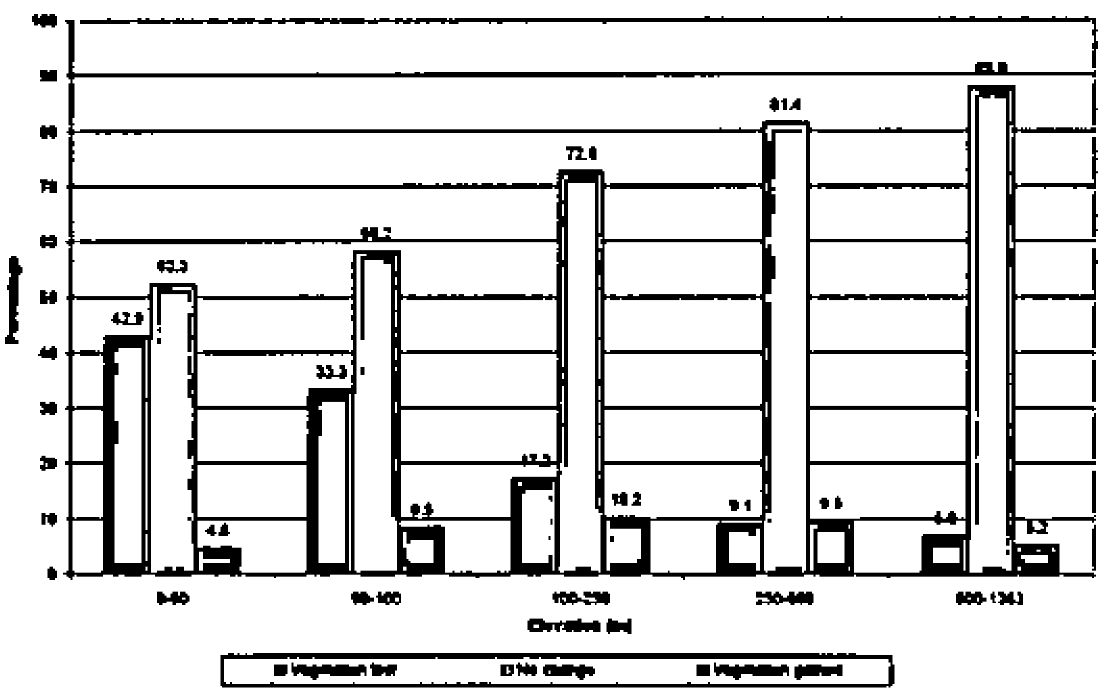


Figure 5.20: Proportion of vegetation loss and gain within different elevation range.

In the same way loss-gain was compared with slope map within each range of slope (Figure 5.21). Maximum proportion of vegetation depletion (loss) happened in 0-0.5 degree slope. After that depletion decreased as slope increased. Vegetative/forest cover and unchanged proportion increased with slope substantially. The proportion of gain was higher in greater than 20 degree slope range and highest in greater than 40 degree slope range.

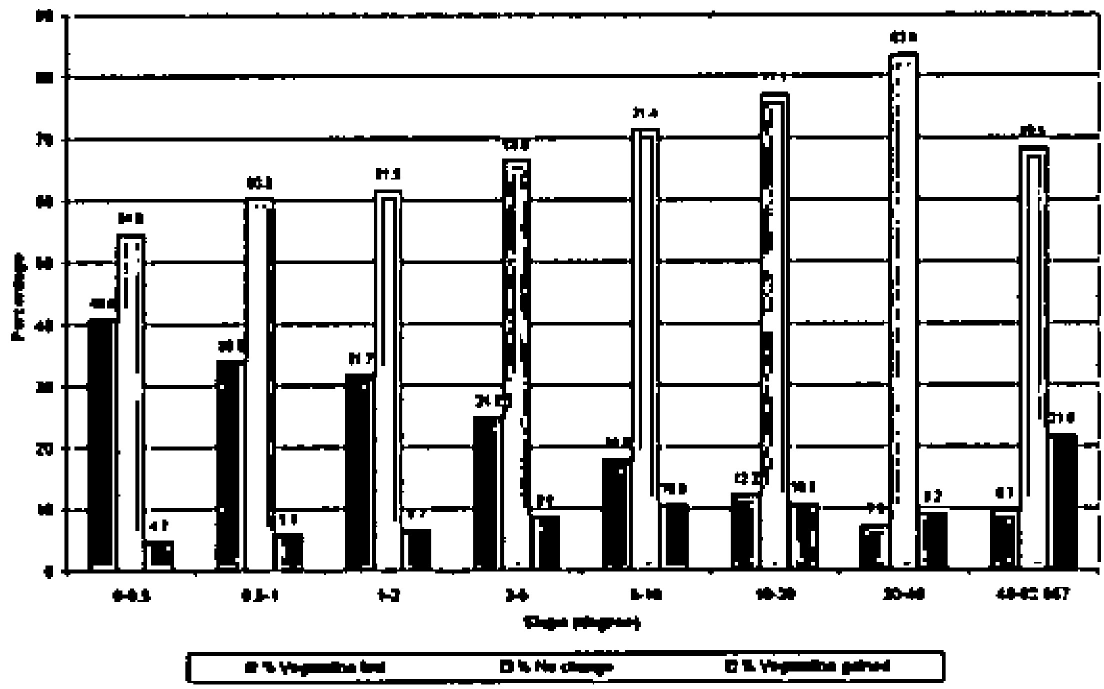


Figure 5.21: Proportion of vegetation loss and gain within different slope range.

The district of CHT was overlaid on the loss-gain map derived from aggregated classes to the distribution in CHT (Figure 5.22, 5.23). Loss happened substantially both in Khagrachari and Rangamati district but gain was higher in Rangamati district. Bandarban was not considered because it covers only 1.1% of the watershed falls inside Bangladesh. The highest percentage of area remains unchanged in Khagrachari district. In fact situation in Khagarchari is worse than in Rangamati because Khagarachari has occupies only 26% of watershed inside Bangladesh while Rangamati occupied 73%. But Rangamati has higher vegetative/forest percentage than Khagrachari since both of them have almost the same proportion of non-vegetative/non-forest area.

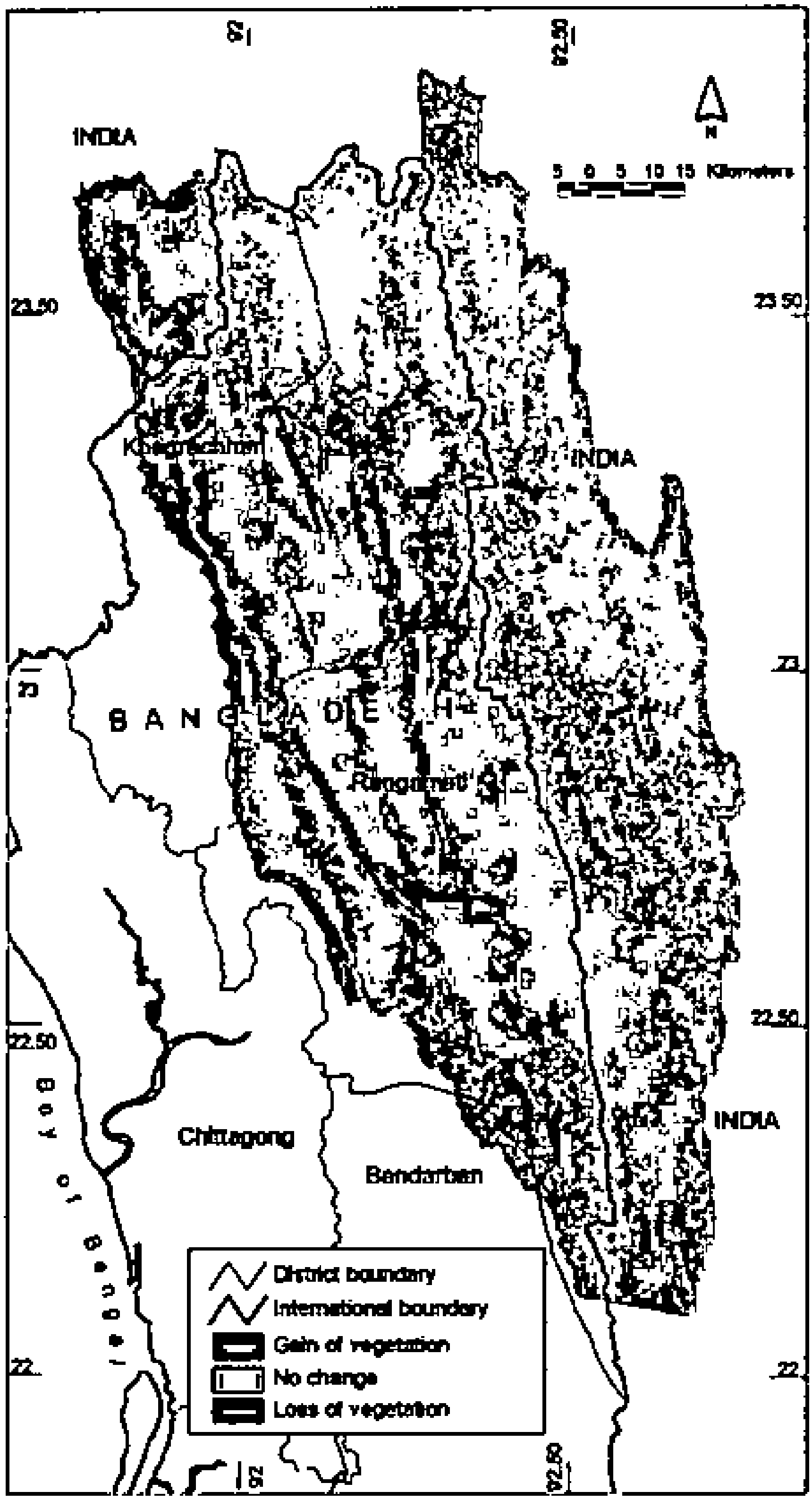


Figure 5.22: District of CHT and distribution of loss and gain over the watershed for aggregated classes.

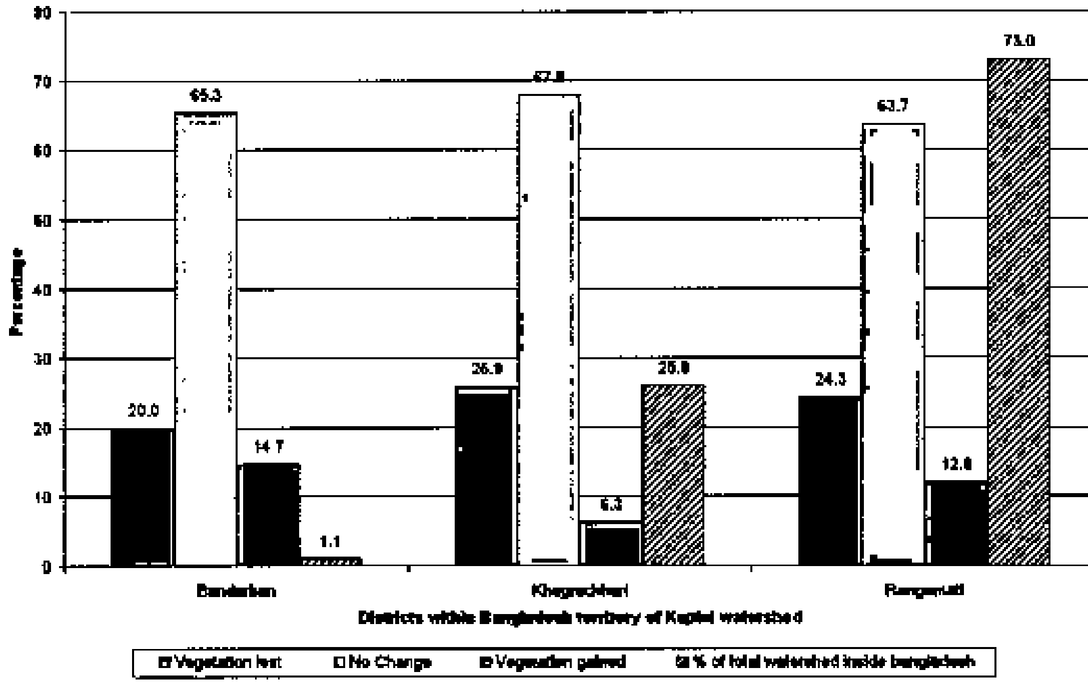


Figure 5.23: District wise change within Bangladesh territory

5.5 Accuracy Assessment

Kappa accuracy assessment was done for the year 2000 after classification. Assessment was done based on three data sets.

- Ground Truth (GT) data
- Forest Cover of Bangladesh (Forest department of Bangladesh)
- Global Land Cover data (GLCF)

The following tables (Tables 5.11 to 5.13) show the accuracy assessment levels, coding of reference land covers and error of the classification at different levels. Disaggregated level contains four classes and aggregated level contains three classes where low and high density vegetation have become one class called vegetative cover.

Table 5.11: Accuracy assessment levels

Class	Code_disaggregated Level (4 classes)	Code aggregated Level (3 classes)
Water body	1	1
Non-vegetative/non-forest	2	2
Low densed vegetation/Open fragmented forest	3	3
Highly densed vegetation/Closed forest	4	3

Table 5.12: Classes of reference data and equivalent class code in different level.

Reference data type	Land cover	Code_Disagregated level	Code_Aggregated level
GT data	Water body	1	1
	Bare/Builtup/Shifting cultivation	2	2
	Degraded shrub	3	3
	Moderate dense shrub-grass	3	3
	Dense canopies	4	3
	Shal forest	4	3
	Dense shrub, grass, canopies	4	3
FAO forest map	Water	1	1
	Open fragmented forest	3	3
	Closed forest	4	3
	Other wooded lands	4	3
GLC map	Water Bodies	1	1
	Slope Grasslands	2	2
	Irrigated Intensive Agriculture	2	2
	Irrigated Agriculture	2	2
	Degraded Forest	3	3
	Abandoned Jhum	3	3
	Bush	3	3
	Tropical Evergreen	4	3
	Tropical Semi evergreen	4	3
	Temperate Conifer	4	3
	Tropical Moist Deciduous	4	3
	Tropical Dry Deciduous	4	3

Note:

At disaggregated level code 1 = Water body, 2 = Non-vegetative/non-forest 3=Vegetation low dense and 4=Vegetation high dense. At aggregated level code 1 = Water body, 2 = Non-vegetative/non-forest, 3 = Vegetative cover (low+high dense)

Table 5.12 shows the classes of reference data and equivalent class of the classified map at two aggregation levels. This labeling to equivalent class was done based on the class names present in reference data. This was done because accuracy assessment needs to match both reference and classified map's classes. Otherwise it will cause wrong assessment.

Table 5.13: Accuracy at different level for different reference data.

Reference data type	Level	Number of class	Overall Accuracy (%)	Overall Misclassification Rate (%)	Overall Omission Error	Overall Commiss-ion Error
1. Ground truth data	Disaggregated	4	78.26	21.74	21.74	7.25
	Aggregated	3	82.60	17.39	17.39	8.69
2. Forest Cover Map of BD	Disaggregated	3	56.36	43.64	43.64	14.55
	Aggregated	2	85.38	14.62	14.62	7.31
3. Global Land Cover Map	Disaggregated	4	49.86	50.14	50.14	16.71
	Aggregated	3	91.19	8.81	8.81	4.41

Table 5.13 concludes that overall accuracy of classification at disaggregated level is very good when it is compared with GT data (78.26% accuracy). But at aggregated level all the reference data shows very high accuracy (more than 80%) where Global Land Cover map proves the highest accuracy of the classification. Overall accuracy is found based on following equation

Overall accuracy = Number of reference points matching with classified class / Total number of reference points. (5.2)

Reference GLC map and Forest cover map of Bangladesh shows very high omission error at disaggregatad level. This is because the two types of vegetation density in classified map (low dense, high dense) do not match well with GLC and Forest Cover map. But this error came down to around 10 % when these two classes were aggregated to one single class. Overall commission error is highest for GLC map at disaggregated level (16.71%), but lowest at aggregated level (4.41%).

In a nut shell it can be concluded that accuracy is very much satisfactory at aggregated level (3 classes) for all reference data while it is not satisfactory at disaggregated level for GLC and Forest Cover map of Bangladesh which is around 50%, but very satisfactory (78.26%) when compared with GT data. In this circumstance it is very hard to judge the overall accuracy. To resolve this situation all accuracies were averaged.

So at disaggregated level average accuracy is (78.26+56.36+49.86)/3 = 61.49 %
At aggregated level average accuracy is (82.60+85.38+91.19)/3 = 86.39 %

This overall accuracy shows very satisfactory result at aggregated level but moderately satisfactory result at disaggregated level.

Chapter Six

Modelling Erosion Prone Areas

Chapter Six

Modelling Erosion Prone Areas

Literatures study revealed that Universal Soil Loss Equation (USLE) is the most widely used model for soil erosion pattern due to its simplicity. But that also needs some inputs, which were not available for the study area. For example, there was no rainfall erosivity index available for study area. Values required to calculate soil erobility factor such as percentage of clay, sand and fine sand were not available as well. Moreover soil information for the reserved forest areas in Bangladesh as well as areas under Indian Territory are not available. Global level Food and Agriculture Organization (FAO) soil map is very crude to consider as a factor map. This unavailability of data necessitates a new approach to map erosion pattern in Kaptai Watershed in data constraints environment.

6.1 Modeling Approach

Different factors were considered which affects the erosion pattern. These are namely land cover (major land cover), rainfall (annual average), slope (in percentage) and soil texture. All these factor maps were then rescaled at 0 to 1 scale. And finally multiplied together to derive erosion poteutiality map. Seasonal variation of erosion pattern was not examined because of the lack multi temporal Landsat data.

6.2 Land Cover Factor Map

Land cover was identified mainly by visual interpretation of Landsat ETM+ data. Ground Truth points and secondary land cover map of USGS along with slope assisted lot to set the threshold for derived NDVI and make the interpretation better. Laud cover identification procedure has been described in previous sections in detail. Three land cover maps were prepared for nominal year 1980s, 1990s and 2000s. Land cover map of 2000s was used as an erosion factor in this model as the focus was to know the current erosion pattern in study area.

The land cover map has four values (1, 2, 3 and 4), which has been rescaled to 0 to 1 by giving weightage to different classes (Table 6.1)

It was assumed that water body has no erosion, while highly dense vegetation has very low erosion because it has less/no openings. Low density vegetation was given factor 0.5 while non vegetative/non woody/non forest land was given high because of its high susceptibility to erosion (Figure 6.1).

Table 6.1: Land cover of 2000 and scaled erosion factor.

Land cover	Erosion factor
Water body	0
Highly densed vegetation	0.1
Low densed vegetation	0.5
Barren/ no vegetation	0.75

6.3 Precipitation Factor Map

There was only one rainfall station within Bangladesh area that had continuous rainfall measurement located in Rangamati (at the lower left corner of Kaptai Lake). So Climatic Research Unit (CRU) global rainfall data were used at 50 km spatial resolution. Data were collected from CRU web site, which is available from 1960 to 2000 on monthly basis. The text data in FORTRAN ASCII format were converted into windows ASCII format and finally processed by a program developed with Avenue language of ArcView. This automated program generated grid for every month over 40 years in ArcInfo GRID format. Finally 10 years data (1991-2000) were clipped for the study area, summed up and averaged to have average annual rainfall.

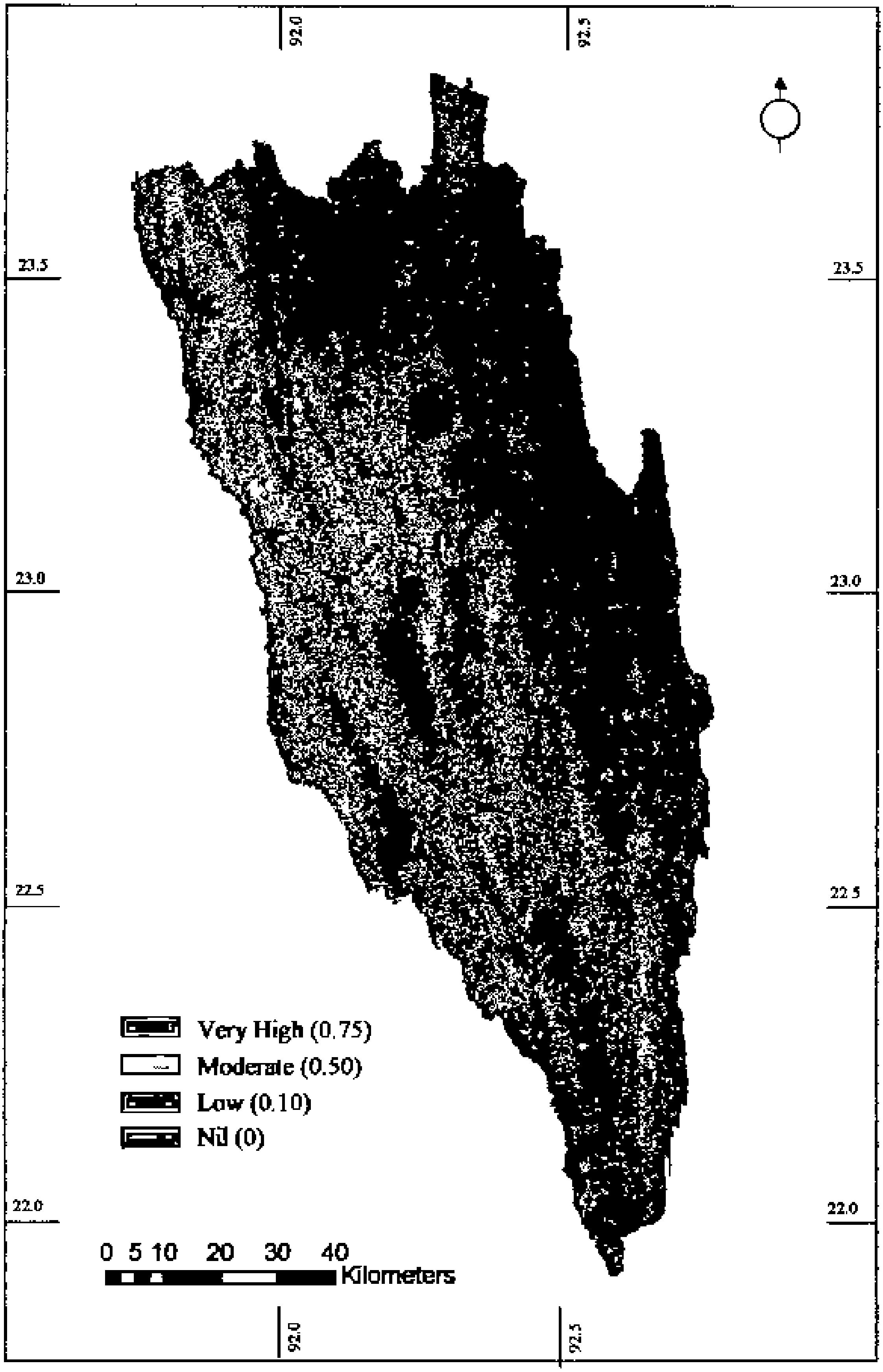


Figure 6.1. Normalized land cover factor map (Normalized at 0 to 1 scale)

Point data were extracted from the final average annual rainfall GRID and were re-projected into UTM46N projection to match other factor maps. Finally it was interpolated at 28.5m resolution following Spline method (weight: 0.1, no. of points:12, interpolation type: regularized) to get a continuous surface. This continuous surface was then rescaled from 0 to 1, where 0 = minimum rainfall and 1 = maximum rainfall (Figure 6.2). The following equation was used for rescaling.

$$V_S = V / V_{max} \qquad (6.1)$$

where V_S = Scaled value of rainfall in a particular cell.

V = Rainfall value of that cell.

V_{max} = Maximum rainfall value among all cells

6.4 DEM Processing

The Shuttle Radar Topographic Mission (SRTM) DEM was used for the study which is at 90m resolution. First all the sinks (spatially connected cells whose flow direction cannot be assigned to any neighbour cell) were filled to correct the DEM and then it was resampled to 28.5m. These sinks were filled by FILL command in ArcInfo 9 GRID module to generate a hydrologically corrected DEM.

6.5 Slope factor Map

Slope map was generated in percentage from processed DEM by using GIS. This percentage slope map was then rescaled from 0 to 1 (where 0 = minimum and 1 = maximum) by following Equation 6.1. The output is presented in Figure 6.3.

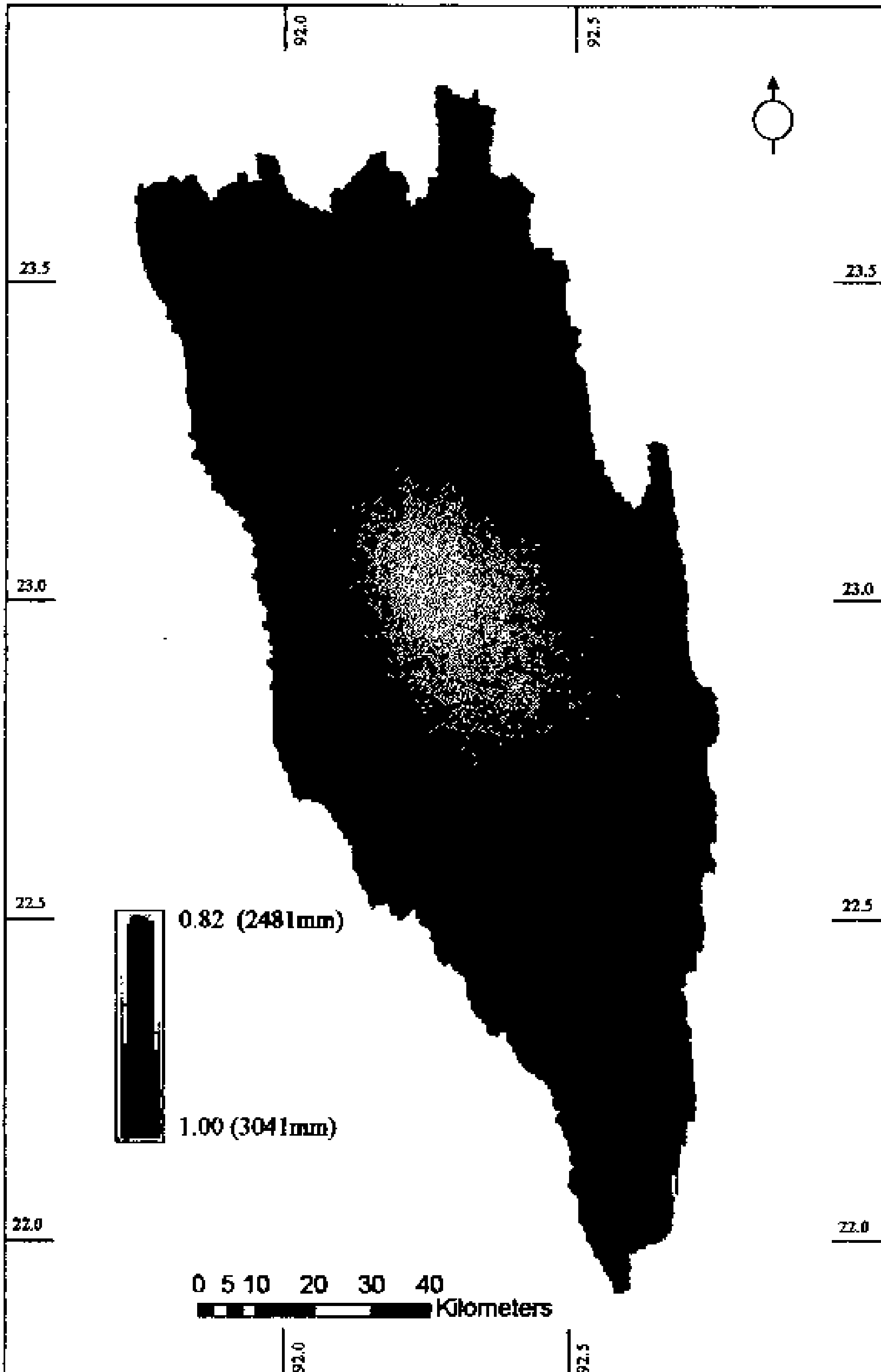


Figure 6.2: Normalized mean annual rainfall map (Normalized at 0 to 1 scale)

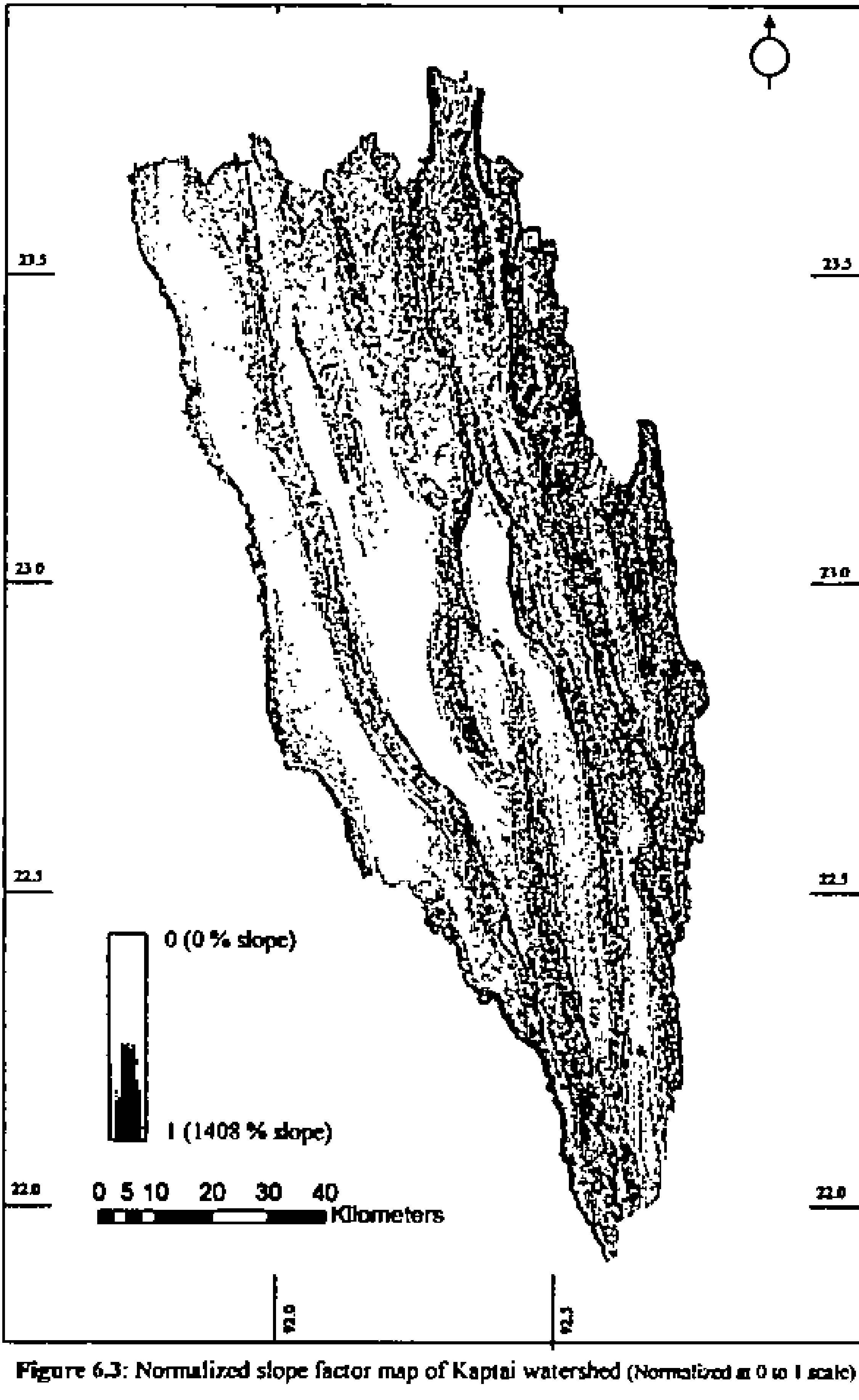


Figure 6.3: Normalized slope factor map of Kaptai watershed (Normalized at 0 to 1 scale)

6.6 Soil Factor Map

The GIS database of soils of Bangladesh was prepared under Flood Action Plan 19 (ISPAN, 1995). Soil map was processed through different steps.

A. Soil map was registered and rectified to satellite image in UTM zone 46 projection and World Geodetic System (WGS) 84 Datum.

B. Soil texture was identified from the attribute database and classified into four categories (Very high, High, Moderate, Low) based on its erosion potentiality (RAC Soils Research, n.d.).

Reserved forest areas did not have any soil information so those areas were merged with mixed soil category to have a moderate weightage value. Finally all were assigned a factor value from 0 to 1 scale based on soil texture's potentiality of erosion (see Table 6.2 and Figure 6.4).

Table 6.2: Soil texture and erosion potentiality

Soil Texture	Erosion potentiality	Weightage Factor
Loamy sand	Very high	1.00
Silt loam	High	0.75
Sandy loam	Moderate	0.50
Mixed	Moderate	0.50
Loam	Low	0.25
Silty clay loam	Low	0.25

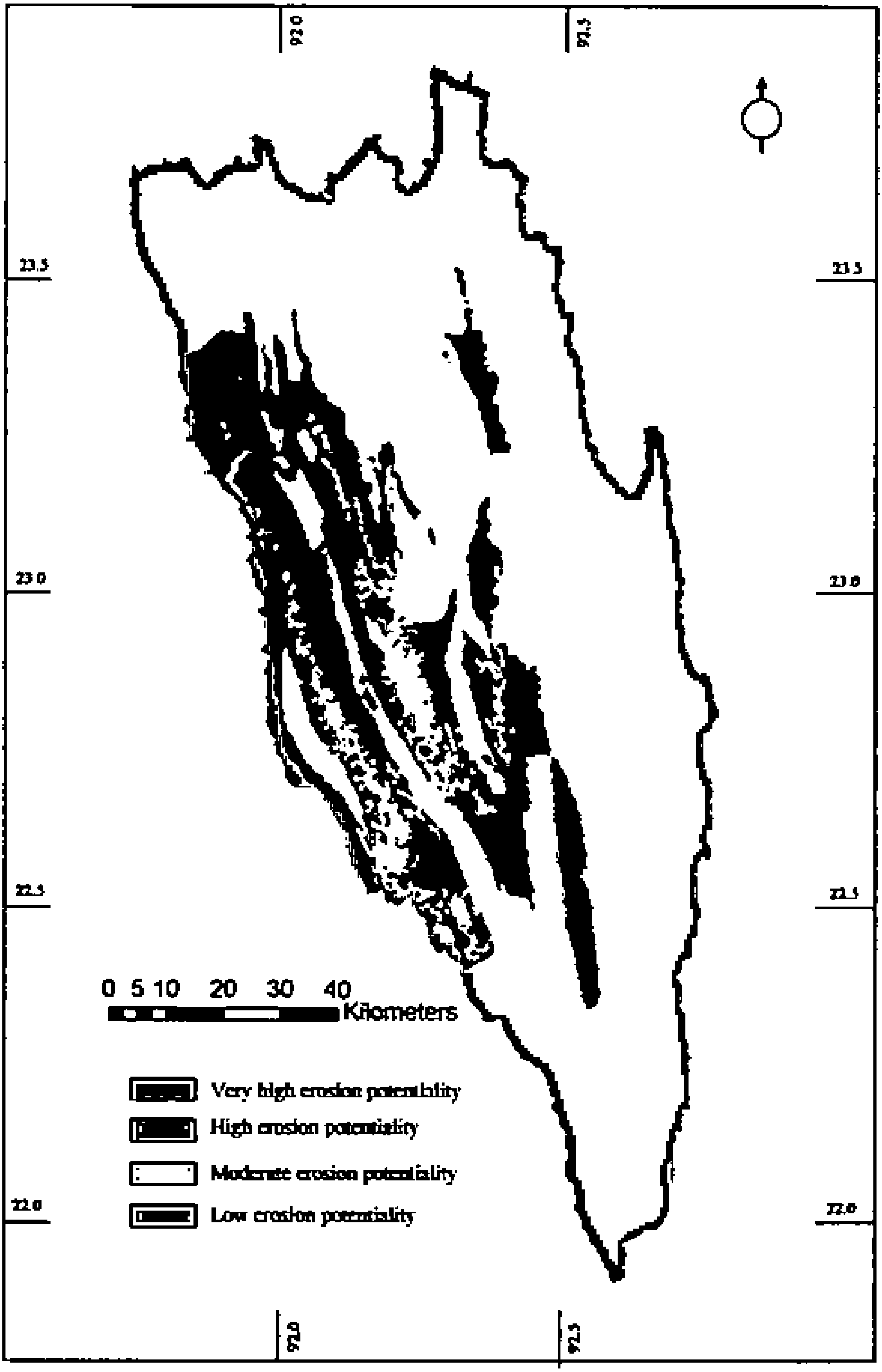


Figure 6.4: Normalized soil factor map (Normalized at 0 to 1 scale)

6.7 Model Result

Finally all factors (slope, rainfall, land cover and soil) were multiplied and final erosion factor map was obtained. It was normalized based on the following equation:

$$V_n = V / V_{avg} \qquad (6.2)$$

where V_n = Scaled value of a particular cell.

V = Value of that cell.

V_{avg} = Average value among all cells

The following criteria were used to set thresholds where 1 is considered as average. So values around 1 is considered as average erosion potential while the other two extremes are considered as low and high erosion potential area.

0-0.5 = Low erosion

0.5-1.5 = Average erosion

>1.5 = High erosion prone area

See Figure 6.5 and Figure 6.6 for a schematic diagram and the output of the model process.

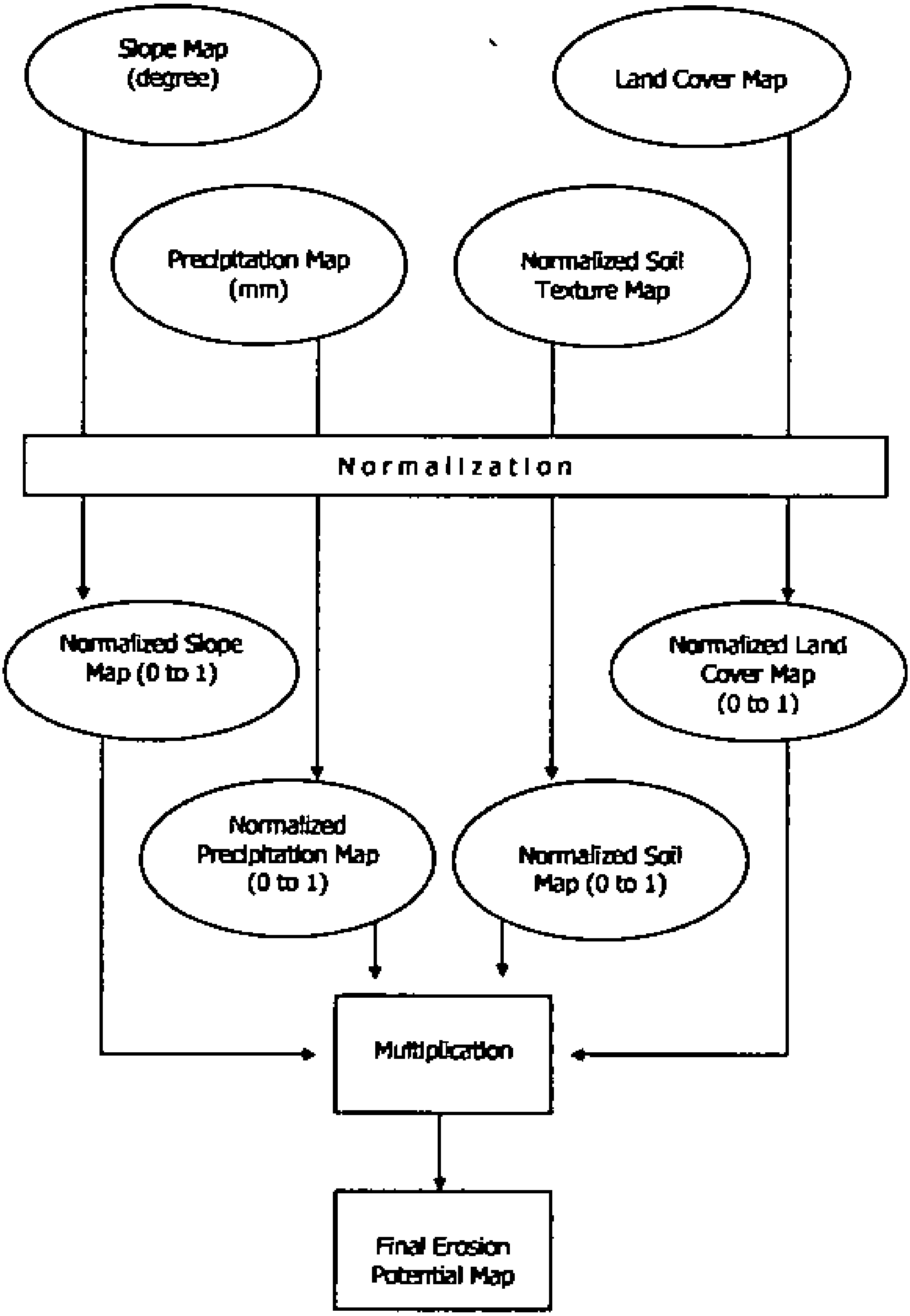


Figure 6.5: Potential erosion modelling process.

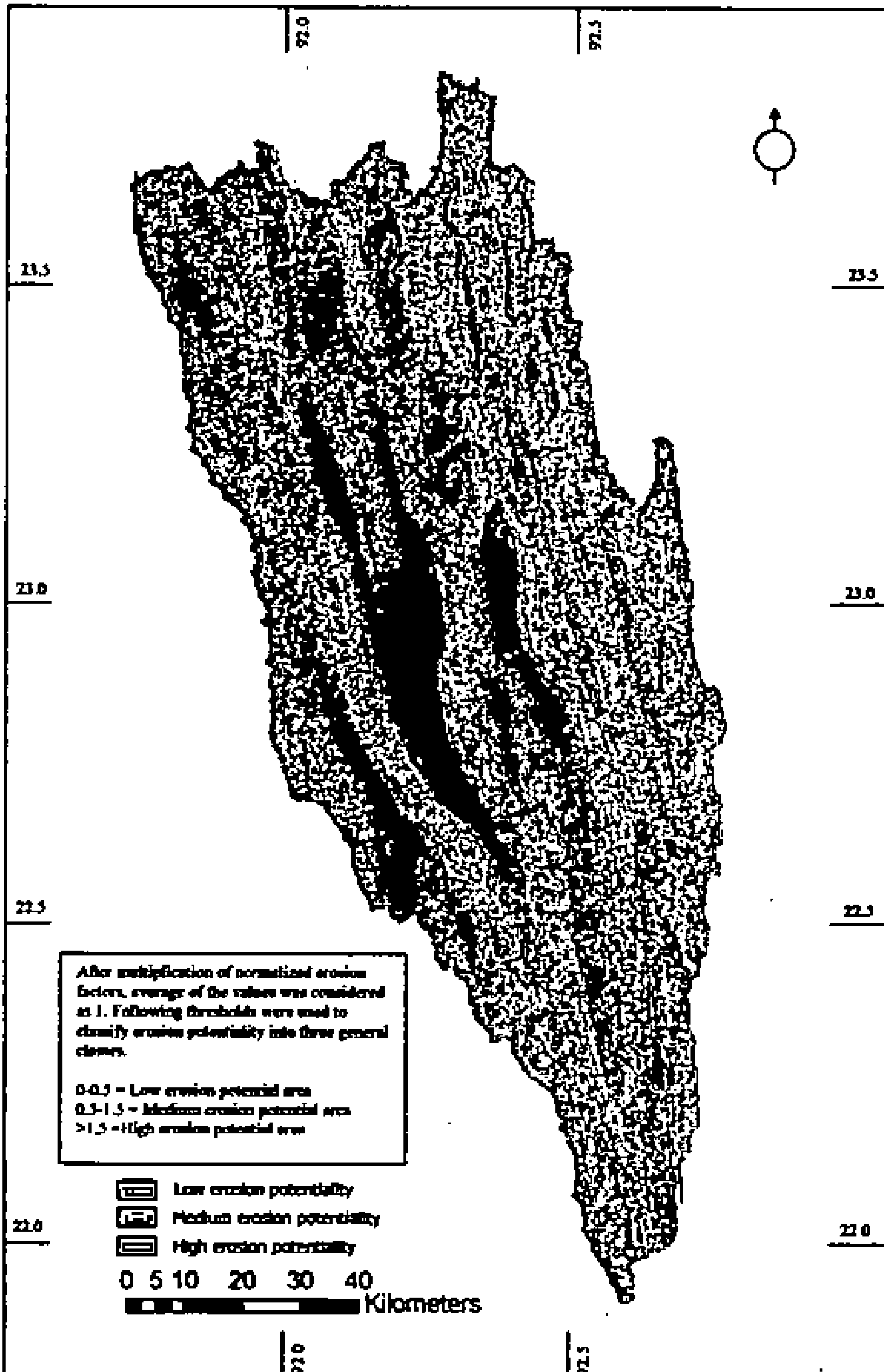


Figure 6.6: Normalized erosion potential map showing erosion prone areas

The area statistics of the result have been given in the table below.

Table 6.3: Area statistics for different erosion potential areas.

Erosion level	Area (sqkm)	Percentage
Low	5165.64	45.52
Moderate	4191.87	36.94
High	1989.41	17.53
Total	11346.91	100.00

Modelling result shows that 45% of the area has low erosion risk while 17% has high erosion risk. The rest 36% falls into average erosion category. This is an indication of how much area is to be conserved for erosion management in Kaptai Watershed. High and average erosion prone areas should be taken care well, which may require intensification of vegetation cover or change in species. This may lead to study the reason in depth which is not possible to accomplish in limited time and resource in current study. Anyway this erosion potential result might be very helpful in identifying areas for the conservation and thus keeping erosion within tolerable limits.

The erosion result map was compared with the slope and elevation map following the same way which was adopted in case of land cover map. Slope map were classified into 9 classes and elevation map into 5 classes at irregular interval. Areas of three types of erosion potentiality (low, medium and high) were calculated under each slope and elevation class. Finally following result were found (Figure 6.7, 6.8).

It was found that erosion potentiality increased as slope and elevation increased. Very high erosion potentiality was found in 40-82 degree slope category but highest medium erosion potentiality was found in 10-20 degree slope class. Substantial medium and high erosion potential areas have found in 5-10 degree slope. So it can be concluded that erosion potentiality is high at slope >= 5 degree. Large proportion of Low erosion potentiality was found under 0-5 degree slope.

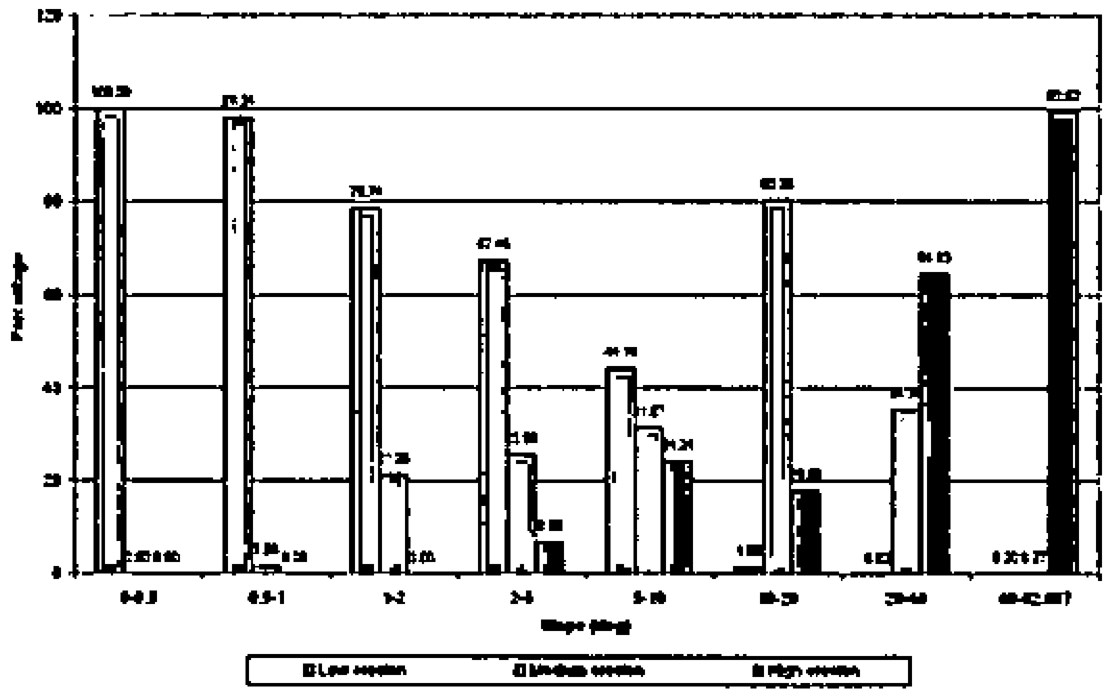


Figure 6.7: Potential erosion by slope.

Very high erosion potentiality found in >500m elevation class. Highest medium erosion potentiality found in 250-500m class.

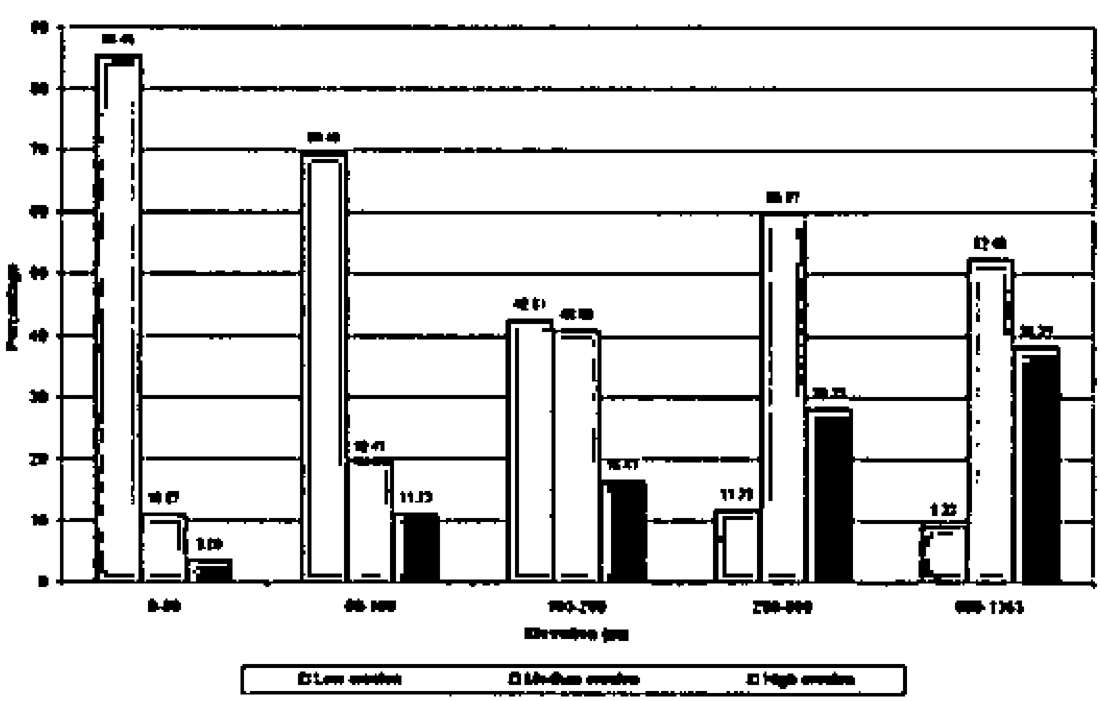


Figure 6.8: Potential erosion by elevation.

Substantial medium and high erosion potential areas have found in 100-250m elevation. So here the bottom line is erosion potentiality is high at elevation >= 100m. Large proportion of low erosion potentiality was found under 100m elevation.

This is a schematic model to identify erosion potential areas. If considerable amount of field measurements of erosion were taken then it might be possible to calibrate the model by setting up appropriate threshold value for the result of multiplied factor maps. This might be useful in analyzing the erosion potentiality in data scarce situation and to get an idea about the location of erosion prone areas in the watershed. Thus it would be useful for further study of erosion in Kaptai watershed

Chapter Seven

Recommendation and Conclusion

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Recommendation and Conclusion

In the beginning of this study the hypothesis was that "The vegetative cover has been depleted in Kaptai watershed." After analyzing two nominal years Landsat image it was found that non forest area has increased by 10.6%, forest low density decreased by around 18.4% and high density forest increased by 7.9%. Overall forest coverage has decreased by 10.6% which is really a high depletion over 20 year's period. So the hypothesis is proven to be true. This is an indication of low conservation practice in the watershed.

Change analysis shows that better vegetative situation exists in India than in Bangladesh in 1980. Low density forest has decreased and non-vegetative/non forest area has increased substantially in both countries over last two decades (1980-2000). Total forest cover (low density, high density) has decreased substantially by 13% in Bangladesh (from around 71% to 58%) while in India forest loss was only 7% (from around 87% to 80%) over the 20 years time period. About 70% of watershed did not have any change. Forest loss was 20% and gain 9% in the watershed over two decades

All these statistics say that vegetation in Kaptai reservoir has decreased substantially. Proportion of vegetation coverage in watershed under Bangladesh territory is still lower than the area under India. This is an indication of better forest conservation or management practice in India than in Bangladesh. Governments of both countries (particularly Bangladesh) should concentrate more on forest management practices to increase vegetative cover, to reduce erosion in Kaptai watershed. Initially foresters may concentrate on some areas where depletion is high. As found in the study, maximum vegetation loss was in the 50-100 m elevation range and in the 2-5 degree slope range. These critical areas should be taken under consideration first for management and conservation practice.

A simple model has been developed in this study to assess the potential erosion prone areas in Kaptai watershed. This model was not calibrated, but it can be done if the governments take such expensive steps to measure the erosion throughout the year and finally try to relate this with rainfall, soil, elevation, slope or slope length etc. The model result shows that 45% of the area has low erosion risk while 17% has high erosion risk. The rest 36% falls into average erosion category. This is an indication of the area to bring under conservation in Kaptai watershed. High and average erosion prone areas should be taken care of well, which may require intensification of vegetation cover or change in species. This may need further study in depth that was not possible to accomplish with the limited time and resource in the current study. Anyway, the results of this study might be useful if it is cross checked in the field and calibrated accordingly.

The schematic modeling tool developed in this study might be useful in analyzing the erosion potentiality in data scarce situation to get an idea about the distribution of erosiou prone areas.

Considering the extent and understanding of the erosion problem of Kaptai watershed the following studies are suggested for in depth study of the problem.

a. Development of erosion parameters by finding out the relationship amoug quantity of erosiou, rainfall, slope, elevatiou and soil.
b. Physical and socio-economic effects of sedimentation in Kaptai reservoir.
c. Why and how vegetation cover changes in Kaptai watershed? A historic socio-economic perspective.
d. Assessment of the spatial distribution of irrigated and rain fed agricultural areas in Kaptai watershed.

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Appendix

Ground Truth Data (GPS Survey data)
Surveyed in April 2005

LONG_DD	LAT_DD	Landuse
92.1958	22.6503	Road intersection. Builtup area
92.1894	22.6307	Road, surrounded by canopies, Parjatan area
92.1909	22.6263	Open land, grass, edge of hill, beside bridge; surrounded by degraded shrub
92.1878	22.6397	Tabalchori bazar ghat, builtup area along lake edge
92.2282	22.6551	Peda ting ting, Plantation-shal tree, deciduous, 30–40m height
92.2109	22.5910	Shifting cultivation along western hill
92.2128	22.5630	Surrounded by islands covered by shrub-scrub, densed grass
92.2082	22.5584	Surrounded by islands covered by shrub-scrub, densed grass
92.2090	22.5490	SW hills-shifting cultivation, slash & burn, 50% canopy cover, NE island-shrub & grass
92.2151	22.5438	Surrounded by islands covered by densed shrub-scrub, grass
92.2335	22.5409	Densed shrub-scrub, grass, some canopies on both sides of lake, road on lake side hills
92.2409	22.5422	Densed shrub-scrub, grass, some canopies on both sides of lake, road on lake side hills
92.2480	22.5385	Shifting cultivation mainly banana on hills on both sides of waterbody
92.2446	22.5238	Very densed (4/5 years old) shrub-scrub on hills of both sides of lake, few canopies
92.2388	22.5180	Very densed (4/5 years old) shrub-scrub on hills of both sides of lake, few canopies
92.2311	22.5059	West hill-slash & burn, shifting cultivation, 40/50% deciduous trees.
92.2277	22.5002	Kaptai barrage on east, left hill-deciduous trees, right plain land-crossed by road, few canopies
92.2201	22.4997	Ghat-wood & bamboo trade, kaptai town after 70m from lake edge
92.2107	22.5031	Reserved forest (deciduous trees) on southern & northern hills
92.1968	22.5004	Reserved forest (deciduous trees) on both sides of road
92.1944	22.4950	Play field, north & west has reserved forest (deciduous trees)
92.1960	22.4953	Builtup area on lake bank, mainly tin shade roofs
92.1960	22.4800	Builtup area