# IDENTIFICATION OF LAND COVER CHANGES OF THE HAOR AREA AND ITS IMPACT ON LIVELIHOOD ASSETS

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# Identification of Land Cover Changes of the Haor Area and its Impact on Livelihood Assets

by

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedicated to My

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Beloved Parents and Sisters

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# ABSTRACT

The haor basin is a low lying bowl-shaped basin covering about 6,000 sq. km in Sylhet Division, mostly in Sunamganj district. The haor basin is important fish production area of the country and it has some commercial and ecological importance. These wetland area very important habitats for the unique and dynamic ecosystems, which have immense productive and ecological value. The state of the haor ecosystem is changing and it makes the livelihood dependent on it more vulnerable.

Climate change and land cover changes are expected to increase the risk of flash floods in the haor region. The agriculture sector of haor area is expected to be heavily impacted by land cover changes. Therefore, attempt has been made to identify the status of land cover of the haor area of between 2000 and 2008 with a view to detecting the land cover changes that has taken place in the haor area using Geographic Information System (GIS) and Remote Sensing data.

This study was aimed to detect the land cover changes, inundation area, flash flood timing and to assess of impact on livelihood assets of haor areas. This study reveals the existing scenarios of haor area and change of patterns from 2000 to 2008. This study is based on secondary data and field visits. In this study MODIS TERRA satellite images are used for detecting of the changes of Haor area and its impacts on livelihood groups and assets. MODIS data/images were processed and analyzed using ILWIS software. Studies have shown that the NDVI value is minimum in 2004, 2000 and 2002 is about 0.32, 0.34 and 0.35 respectively whereas in 2003 and 2006, the NDVI value is maximum. It is found that land cover in the study area has been changed significantly since 2000. Analysis revealed that the vegetative cover area has increased to about 8.35% compared to the 2000 vegetative cover areas whereas in 2000 (8880.892 sq. km.) and 2008 (10635.64 sq. km). The change pattern of mixed land cover is somewhat unchanged except 2001 and 2006. In contrast, the other land cover category i.e. water bodies has been reduced greatly and converted to other land cover areas.

In this study, impacts on livelihood assets due to land cover changes were assessed by focus group discussing (FGD) and interviews. In this study, a set of capitals such as natural capital, physical capital, human capital, social capital, financial capital was considered as the representatives of livelihood assets to the development of livelihood strategies of the haor areas. It has been found that the access of livelihood groups to livelihood capital i.e. natural capital, physical capital, human capital, social capital and financial capital is changed from 2000 to 2008. The impacts of land cover changes to the livelihood groups of the haor area is positive trend except the natural capital.

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## ABBREVIATION

| | |
|---|---|
| BWDB | Bangladesh Water Development Board |
| DFID | Department of Foreign and International Development, UK |
| DOE | Department of Environment |
| IPCC | Intergovernmental Panel on Climate Change |
| SL | Sustainable Livelihood |
| SLA | Sustainable Livelihood Assessment |
| BMD | Bangladesh Meteorological Department |
| EOS | Earth Observing System |
| EVI | Enhanced Vegetation Index |
| GIS | Geographic Information System |
| ILWIS | Integrated Land and Water Information System |
| NASA | National Aeronautics and Space Administration |
| NDVI | Normalized Difference Vegetation Index |
| RS | Remote Sensing |
| VI | Vegetation Index |
| WDVI | Weighted Difference Vegetation Index |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

The haor basin is a low lying bowl-shaped basin covering about 6,000 sq. km in Sylhet Division**,** mostly in Sunamganj district. The topography of haor regions is uneven. Furthermore in terms of geographical elevation they are lower than the normal plain lands. The areas are flooded for 7-8 months of the year, i.e. from Baishakh, Jaistha to Kartik (April to November). Virtually all of this land is below 8 meters and is flooded for 7-8 months to depths of 5 meters or more during the monsoon. Saucer shaped, seasonally flooded, inter fluvial areas called hoar characterize this unit (NERP, 1995). The north eastern part of Bangladesh is known locally as the haor area (Figure 3.1) of Bangladesh and consists of mainly the districts of Sunamganj, Moulovibazar, Sylhet, Kishorganj and Netrokona. The total number of haor is 414 with sizes that vary between 730 and 24292 hectares. Hakaluki haor with area of 24292ha.is one of the largest haors of Bangladesh with great significance. The haor basins are important fish production area of the country and it has some commercial and ecological importance (NERP, 1994a). Furthermore, the haor basin in the north-east region is a major reservoir of ecosystem constituting about 60% of the total standing water bodies in Bangladesh. These wetlands are a very important habitats for the unique and dynamic ecosystems, which have immense productive and ecological value e. g., storage of rainfall-runoff, groundwater recharge, providing habitats for fish, wildlife, aquatic plants and animals, resort to migratory birds, support biodiversity, haor area plant based socioeconomic activities ( firewood, timber, thatching, mat-making, livestock food, herbal medicine, etc.), fishing and recreation.

Climate change and land cover changes are expected to increase the risk of flash floods in the haor region. Thirty years ago, flash flood used to hit border area of Sunamganj and took 15 days to reach the hoar of Jamalganj Upazilla. In the recent years, flash flood hits Jamalganj 10 to 15 days earlier. The early flash floods of April 2004 in the northeast have been the worst of its kind in the history of floods in the country.

The agriculture sector of Bangladesh is expected to be heavily impacted by climate change and land cover changes. This constrains agriculture activities. Only one crop is grown annually in the haor area, i.e. the Boro season rice (local and HYV variety of rice) is cultivated only during winter. Land-less and marginal farmers in particular are affected. The people of the most of the haors are living in a very poor and distressed condition. A livelihood comprises the capabilities, assets and activities required for a means of living. The livelihood of the haor areas have been highly depended on the haor resources like fish, vegetation, timber, aquatic food, wildlife, fuel wood etc. They depend primarily on agricultural activities for the livelihood. Lacks of agricultural activities render them unemployed. This has a cumulative effect of depressing aggregate demand, which in tern lower consumption, incomes and employment (Nishat, 1995). Secondly there are many *beels* in the haor area. This is an important source of food and income to local communities. Fishing takes place in these areas. Activities are intensive from the period kartik to falgun (November to March). Fishing Activities are less intensive from the period Chaitra to Ashar (March to July). Thirdly, economic depression during the monsoon period forces people to migrate to other areas in the search of employment. Productive activities are negligible during this period. The overall livelihood situation is much below compared to the national standard (CEGIS, 2006). The CEGIS study found that around 55% households in the haors are living with more or less deficit round the year. Number of these households is found to be increasing in the whole area due to recurring flood. As a result, the region is depressed economically and socially.

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn, 1996).

Therefore, attempt has been made to identify the status of land cover of the haor area of between 2000 and 2008 with a view to detecting the land cover changes that has taken place in the haor area using Geographic Information System (GIS) and Remote

Sensing data. So study is needed to identify the land cover changes of haor area and its impacts on livelihood assets for the development of livelihood resilience model and livelihood strategies of the haor areas.

### 1.2 Objectives of The Study

The specific objectives of this study are as follows:

1. To detect the land cover changes of haor area in terms of land use pattern, areal, and climatic condition e.g. rainfall, temperature etc.
2. To identify the inundation area by MODIS images analysis and the timing of flash flood such as starting and ending of flood by using remote sensing data and water level station data.
3. To assess of impact on livelihood assets of haor areas.

### 1.3 Possible outcome of The Study

This study will reveal the existing scenarios of haor area and change of patterns over the last 9 years period of time (from 2000 to 2008). The outcome of the proposed study will be very helpful for the development of livelihood strategies to achieve livelihood outcomes of the haor areas.

### 1.4 Limitations of The Study

The main limitations of the study are-

- The non-availability of the high resolution images of the study area. The study results could be tuned more accurately, if remote sensing image of higher resolution for the study area could be used.
- Fund constraint is inhibited the frequently study area visit, buying high resolution images.
- Study area is so remote that sometimes it becomes inaccessible to go there.

### 1.5. Organization of The Thesis

The structure of the thesis tries to follow the below mentioned sequence to achieve the objective of the study. The organization of the Thesis is as follows

**Chapter I:** Introduction

The introductory aspects like background and present state of the problem, objectives of the study, possible outcome of the study, limitations of the study and definition of terms and how the thesis is organized are discussed in this chapter.

**Chapter 2:** Literature Review

The available literatures related to the study have been reviewed in this chapter This chapter also covers previous research carried out in the field of land cover changes as well as role of remote sensing and GIS technology and its impacts on livelihood assets.

**Chapter 3:** Overview of the Study area

The chapter gives a brief overview of the study area.

**Chapter 4:** Data and data collection

The chapter describes about the data and data collection techniques.

**Chapter 5:** Methodology

This chapter outlines the methods which were followed in this study to achieve the intended objectives. This chapter also illustrates about the image processing and analysis of MODIS images.

**Chapter 6:** Livelihood in the Haor Area

This chapter presents the livelihoods of the haor area. It also describe the background of livelihoods, sustainable livelihood, sustainable livelihood approach, sustainable livelihood assets/ capitals, livelihoods strategy, land cover dependant livelihoods, impacts on livelihood assets due to land cover changes.

**Chapter 7:** Results and Discussions

This chapter covers the final output of long-term NDVI temporal images to identify the land cover changes in the haor area. This chapter also describes about the results obtained after the analysis has been done. Also what effect does on livelihood assets have as a result of land cover changes is being discussed.

**Chapter 9:** Conclusions and Recommendations

The last chapter is concluding chapter covering the conclusion of the study being done as well as recommendations for future study and what could not be handled in this study as well.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

The study focuses on the land cover changes of the haor area over the last 9 years period of time during 2000 to 2008 and tries to relate it with the livelihoods of the haor area. A brief review is presented in this chapter on the haor system, flash flood, land cover, land cover changes, satellite images, remote sensing, GIS, NDVI and livelihoods.

## 2.2 Haors in the North-east Region of Bangladesh

The haor basin is a low lying bowl-shaped basin covering about 6,000 sq. km in Sylhet Division**,** mostly in Sunamganj district. Virtually all of this land is below 8 meters and is flooded to depths of 5 meters or more during the monsoon. Saucer shaped, seasonally flooded, inter fluvial areas called hoar characterize this unit (NERP, 1995). The north eastern part of Bangladesh is known locally as the haor area (Figure 3.1) of Bangladesh and consists of mainly the districts of Sunamganj, Moulovibazar, Sylhet, Kishorganj and Netrokona. In Bangladesh, the total number of haor is 414 with sizes that vary between 730 and 24292 hectares (Appendix I).

The haor basin is bounded to the north by the hill ranges of Meghalaya, to the south by the hills of Tripura and Mizoram, and to the east by highlands of Manipur. The numerous rivers rising in these hills provide an abundant supply of water to the plains and cause extensive flooding during the monsoon season, with much of the region being flooded to a depth of up to six metres (NERP, 1995).

The Northeast Regional Water Management Project (NERP) wetland investigations (NERP, 1995) found nine wetland sites in the region that meet one or more Ramsar Convention criteria for international significance. Theses are Tanguar Haor, Pasua Beel-Gurmar Haor, Hakaluki Haor, Hail Haor, Kaliajuri Area, Companiganj Area, Bara haor, Kawadighi Haor and Balai Haor. The wetland of the basin support large natural wetland plant communities. These are extensively exploited by local people, particularly the poor, landless, underprivileged and provide significant amount of food, fodder, fuel, building material, and medicines to them.

The Haors, beels, and ponds support major subsistence and commercial fisheries, the seasonally flooded plains support a major rice growing industry, and the abundant aquatic vegetation provides rice grazing for domestic livestock and a source of fuel, food and fertilizers foe the local people.

Haors and Floodplains in Bangladesh are important sources of fisheries resources for the country. *Kalibaus, Boal, Rui, Ghagot, Pabda* and *Chapila* are the main fish species of the Haor. From the Kushiyara there are frequent upstream movements of fish towards the *beel*s and tributaries of Hakaluki. *Beel*s in Hakaluki haor are important for fisheries. They provide the winter shelter for the mother fisheries, and in early monsoon these mother fisheries produce millions of fries for the entire downstream fishing communities. Consequently, protection of these fisheries not only benefits local people, but also all the people in the lower floodplains (IUCN-Bangladesh, 2006).

As per IUCN (2006), the wetlands of Bangladesh have been subjected to rapid degradation due to population pressure, massive withdrawal of water for irrigation, destruction of swamp forest and a number of other anthropogenic and natural causes. Large scale habitat conversion, unsustainable harvesting practices, lack of wetland policies and ecological considerations have led to the destruction of valuable wetlands.

Wetlands in Bangladesh have long been facing serious degradation and loss, due to many natural and anthropogenic factors. Besides natural causes, factors like overuse of resources, lack of property rights, human encroachment, and conversion to other uses and also absence of effective enforcement of laws are some of the most important factors for the decline in wetland biodiversity of the country.

There are basically two important problems in the haor areas of Bangladesh, one occurs in the early monsoon and the other in the late monsoon. The problem in the early monsoon (late April-May) is scarcity of food due to crop damage by flash floods. The problem in the late monsoon (August- September) is danger to life and property from wave attacks.

## 2.3 Flash Flood in the North Eastern Region in Bangladesh

Northeastern part of Bangladesh especially Sunamganj, Sylhet and Netrokona districts are located in one of the depressed geographical regions of the country. Most of the rivers in these areas originated from nearby hilly areas of India. These rivers are extremely fleshy and are characterized by sudden and wide variations in flow as a result of excessive rainfall. When heavy rainfall occurs in the hilly regions of India, water quickly moves towards the haor area of Bangladesh through a number of rivers and canals. The flood water not only carries the water but also carry a huge amount of sediment. Over time, these sediments have deposited on the rivers and canals beds and have reduced the storage and conveyance capacity more or less of all of the hydrological systems within the haor area.

As a result, when flash flood due to sudden heavy upstream rainfall creates pressure on the local hydrological systems, water easily overtops and creates breaching at several locations on the submersible embankment, eventually water quickly enters into the haor. In most cases, flood water comes into the haor very early in the monsoon and farmers do not get sufficient tine to harvest the standing boro crops.

Flash flood occurs in the area almost every year. Intensity differs from year to year and in various basin locations. Severity depends on time and quantity of rainfall in the hill and drain out capacity of main rivers. Pressure of hilly flow plus rain fed water in the rivers reach to such a level to overflow or wash out the embankment/dams or banks of the rivers/canal and to enter into the haor. This situation is locally called *apor mara*. Basically apor means the embankments or raised banks of river/canal. Early invasion of flash flood causes heavy damage to the standing crops of the haor leaving no or limited scope for harvesting. Flash flood not only damages crops but also causes water logging within the haor due to low runoff capacity of rivers and canals.

Though the most devastating flash flood occurs generally during the end of chaitra to baishakh, people informed that 2 -4 times there is sudden increase of water level till agrahayon. In recent times, flash flood causes more damages than the past. In recent past, the most severe one occurred in 2004. People reported that this was the first time they experienced such kind of flash flood damages.

## 2.4 Land Cover

According to Meyer (1999), every parcel of land on the Earth's surface is unique in the cover it possesses. Land use and land cover are distinct yet closely linked characteristics of the Earth's surface. The use to which we put land could be grazing, agriculture, urban development, logging, and mining among many others. While land cover categories could be cropland, forest, wetland, pasture, roads, urban areas among others. The term land cover originally referred to the kind and state of vegetation, such as forest or grass cover but it has broadened in subsequent usage to include other things such as human structures, soil type, biodiversity, surface and ground water (Meyer, 1995).

Land cover is the physical material at the surface of the earth. Land covers include grass, asphalt, trees, bare ground, water, etc. There are two primary methods for capturing information on land cover: field survey and thorough analysis of remotely sensed imagery. The nature of land cover is discussed in Comber et al. (2005)

Land cover can be altered by forces other than anthropogenic. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover. Globally, land cover today is altered principally by direct human use: by agriculture and livestock raising, forest harvesting and management and urban and suburban construction and development. There are also incidental impacts on land cover from other human activities such as forest and lakes damaged by acid rain from fossil fuel combustion and crops near cities damaged by tropospheric ozone resulting from automobile exhaust (Meyer, 1995).

Modification of land cover by land use change (e.g., rural to urban, agriculture to urban, forest to agriculture, etc.), encroachment of floodplains and wetlands, deforestation of hill cutting brings changes in the physical properties of land surface. These land use activities modify landscape that brings changes in the infiltration and groundwater recharge processes and surface runoff and sediment transport processes that cause increased flood flow and decreased dry season flow in the river and alteration of river regime. Road, water control and hazard prevention infrastructures trigger land use changes, modify drainage pattern and transfer hazard risk elsewhere. Elimination of lowlands and wetlands that rich in ecological resources reduces storage space for flood water. Changes in hydrological process can cause increased risks of extreme flood, riverbank erosion, and excessive sediment in water, very low flow and environmental degradation.

Human activities combined with natural events are increasingly altering the Earth's land cover. These land cover changes alter the land surface roughness and albedo, which affect the exchanges of sensible heat, latent heat (water vapor) and carbon dioxide and other greenhouse gases between the land surface and the atmosphere (Sellers et al., 1996) and consequently cause regional and even global climatic changes (Dickinson & Henderson-Sellers, 1988; Nobre, Sellers, & Shukla, 1991; O'Brien, 1996; Xue, 1996). Therefore, more reliable land cover change information and data sets are needed in global change studies, especially in increasingly sophisticated Earth system models (Townshend, Justice, Li, Gurney, & McManus, 1991; Townshend et al., 1994).

## 2.5 Land Cover Changes

Changes in land cover affect land use. A change in either however is not necessarily the product of the other. Changes in land cover by land use do not necessarily imply degradation of the land. However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affects biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere (Riebsame, Meyer, and Turner, 1994).

Land cover changes play a major role in the study of global change. Land cover and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disaster-flooding [Mas, J.F.; Velazquez, A.; Gallegos, J.R.D.; Saucedo, R.M., Alcantare, C.; Bocco, G.; Castro, R.; Fernandez, T.; Vega, A.P, 2004; Zhao, G.X.; Lin, G.; Warner, T, Dwivedi, R.S.; Sreenivas K.; Ramana, K.V, 2004). These environmental problems are often related to land cover changes. Therefore, available data on land cover changes can provide critical input to decision-making of environmental management and planning the future (Fan, F.; Weng, Q.; Wang, Y., Prenzel, B, 2007).

The growing population and increasing socio-economic necessities creates a pressure on land cover. This pressure results in unplanned and uncontrolled changes in land cover (Seto, K.C.; Woodcock, C.E.; Song, C.; Huang, X.; Lu, J.; Kaufmann, R.K, 2002). The land cover alterations are generally caused by mismanagement of agricultural, urban, range and forest lands which lead to severe environmental problems such as landslides, flash floods etc

Land cover changes modify the reflectance of the land surface, determining the fraction of the Sun's energy absorbed by the surface and thus affecting heat and moisture fluxes. These processes also alter vegetation transpiration and surface hydrology and determine the partitioning of surface heat into latent and sensible heat fluxes

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest.

Macleod and Congation (1998) list four aspects of change detection which are important when monitoring natural resources:

i. Detecting the changes that have occurred
ii. Identifying the nature of the change
iii. Measuring the area extent of the change
iv. Assessing the spatial pattern of the change

The basis of using remote sensing data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computer power.

A wide variety of digital change detection techniques have been developed over the last two decades. Singh (1989) and Coppin & Bauer (1996) summarize eleven different change detection algorithms that were found to be documented in the literature by 1995. These include:

1. Mono-temporal change delineation.
2. Delta or post classification comparisons.

3. Multidimensional temporal feature space analysis.
4. Composite analysis.
5. Image differencing.
6. Multitemporal linear data transformation.
7. Change vector analysis.
8. Image regression.
9. Multitemporal biomass index
10. Background subtraction.
11. Image ratioing

In some instances, land use and land cover changes may result in environmental, social and economic impacts of greater damage than benefit to the area (Moshen A, 1999). Therefore data on land use change are of great importance to planners in monitoring the consequences of land use change on the area. Such data are of value to resources management and agencies that plan and assess land use patterns and in modeling and predicting future changes.
The study of land cover change is an important problem in the Earth Science domain because of its impacts on local climate, radiation balance, biogeochemistry, hydrology, and the diversity and abundance of terrestrial species.

## 2.6 Land Covers Changes, Remote Sensing and GIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) is one of the remote sensing instruments onboard the first NASA Earth Observing System (EOS) satellite, Terra. As one of the efforts of the MODIS Science Team, a 250 m resolution land cover change data product is being generated from MODIS data.

According to Olorunfemi (1983), monitoring changes of land cover and time series analysis is quite difficult with traditional method of surveying. In recent years, satellite remote sensing techniques have been developed, which have proved to be of immense value for preparing accurate land use land cover maps and monitoring changes at regular intervals of time. In case of inaccessible region, this technique is perhaps the only method of obtaining the required data on a cost and time – effective basis.

A remote sensing device records response which is based on many characteristics of the land surface, including natural and artificial cover. An interpreter uses the element of tone, texture, pattern, shape, size, shadow, site and association to derive information about land cover.

Remote sensing can be defined as any process whereby information is gathered about an object, area or phenomenon without being in contact with it. Given this rather general definition, the term has come to be associated more specifically with the gauging of interactions between earth surface materials and electromagnetic energy.

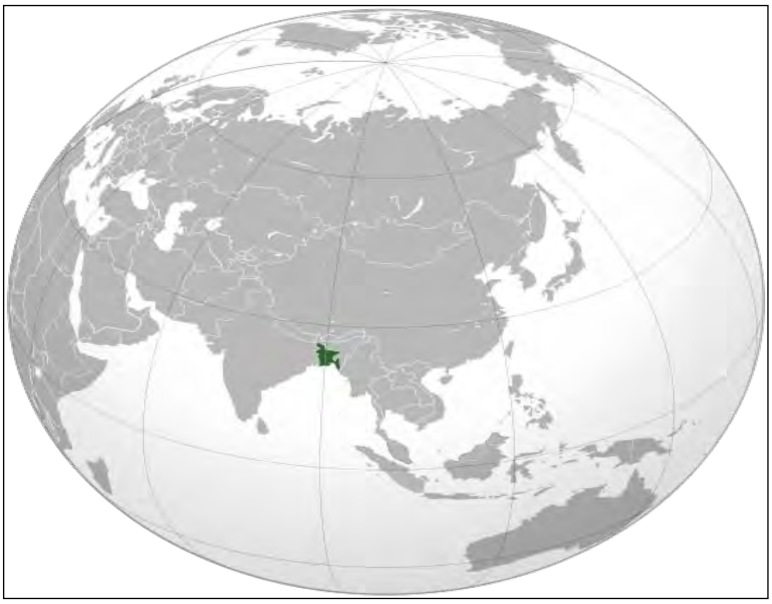


Figure 2.1: Map of Bangladesh in Globe.

Xiaomei Y, and Rong Qing L.Q.Y in 1999 noted that information about change is necessary for updating land cover maps and the management of natural resources. The information may be obtained by visiting sites on the ground and or extracting it from remotely sensed data.

Shosheng and Kutiel (1994) investigated the advantages of remote sensing techniques in relation to field surveys in providing a regional description of vegetation cover. The results of their research were used to produce four vegetation cover maps that provided new information on spatial and temporal distributions of vegetation and allowed regional quantitative assessment of the vegetation cover.

Geographic Information system (GIS) is a computer assisted system for the acquisition, storage, analysis and display of geographic data. GIS is defined as a computerized system capable of capturing, storing, analysing, and displaying geographically referenced information, that is, data identified according to location (Longley et al. 2001).

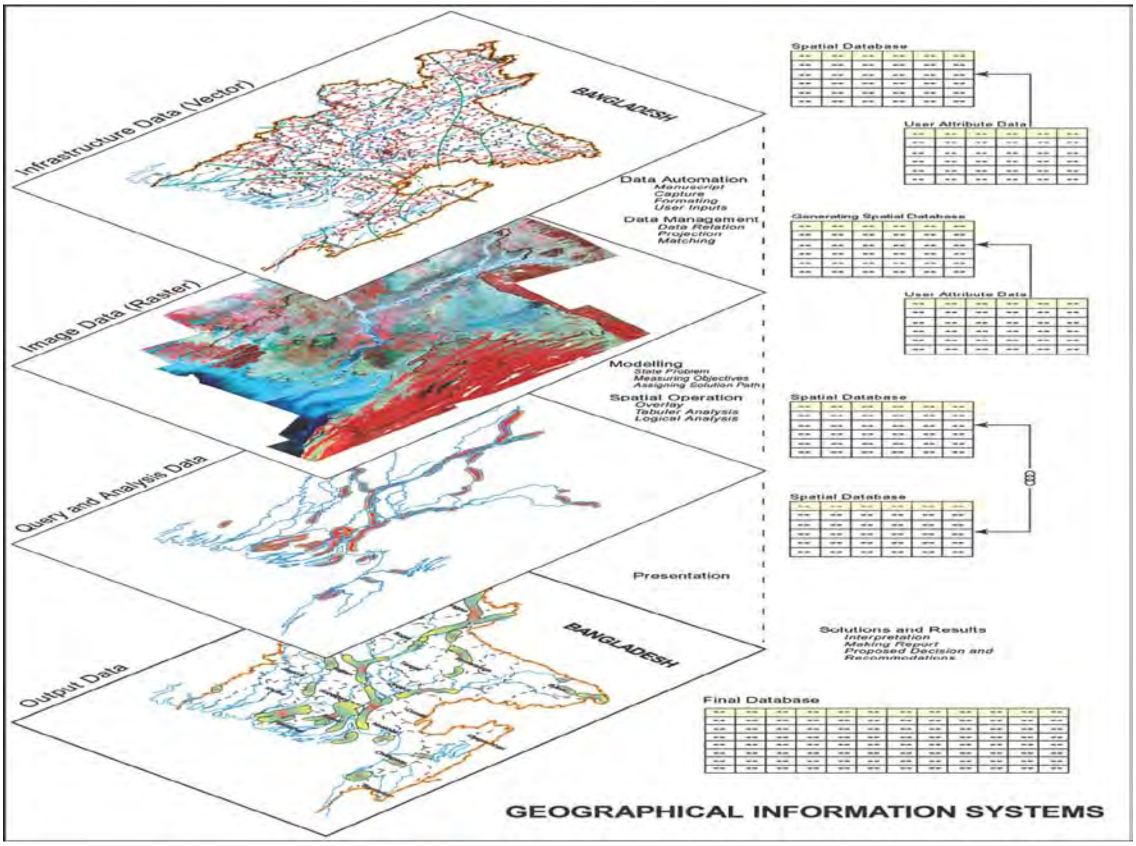



Figure 2.2: A GIS system to show Bangladesh

Remote sensing and Geographical Information Systems (GIS) are powerful tools to derive accurate and timely information on the spatial distribution of land cover changes over large areas [Carlson,T.N.; Azofeifa, S.G.A, Guerschman J.P.; Paruelo, J.M.; Bela, C.D.; Giallorenzi, M.C.; Pacin, F, Rogana, J.; Chen, D, Zsuzsanna, D.; Bartholy, J.; Pongracz, R.; Barcza, Z, 1999]. GIS provides a flexible environment for collecting, storing, displaying and analyzing digital data necessary for change detection (Yomralıo lu, T.,2000; Demers, M. N, 2005; Wu, Q.; Li, H. Q.;Wang, R.S.; Paulussen, J.; He, H.; Wang, M.; Wang, B.H.; Wang, Z, 2006). Remote sensing imagery is the most important data resources of GIS. Satellite imagery is used for recognition of synoptic data of earth's surface (Ulbricht, K.A.; Heckendorf, W.D, 1998, Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced

Thematic Mapper Plus (ETM+) data have been broadly employed in studies towards the determination of land cover since 1972, the starting year of Landsat program, mainly in forest and agricultural areas (Campbell, J.B, 2007) rich archive and spectral resolution of satellite images are the most important reasons for their use.
Satellite Remote sensed data and GIS for land cover and its changes is a key to many diverse applications such as Environment, Forestry, Hydrology, Agriculture and Geology. Natural Resource Management, Planning and Monitoring programs depend on accurate information about the land cover in a region.

Satellite remote sensing is an evolving technology with the potential for contributing to studies for land cover and change detection by making globally comprehensive evaluations of many environmental and human actions possible. These changes, in turn, influence management and policy decision making. Satellite image data enable direct observation of the land surface at repetitive intervals and therefore allow mapping of the extent and monitoring and assessment of: Crop health, Storm Water Runoff, Change detection, Air Quality, Environmental analysis, Energy Savings, Irrigated landscape mapping, Carbon Storage and Avoidance, Yield determination, Soils and Fertility Analysis.

### 2.7 Importance of Land Covers Changes Detection Studies

Land cover studies using remote sensing data have been received immense attention worldwide due to their importance in global change analysis (Cihlar, 2000). Both human-induced and natural land cover changes can influence the global change because of its interaction with terrestrial ecosystem (Houghton, 1994), biodiversity (Sala et al., 2000) and landscape ecology (Reid et al., 2000). In addition, it reflects the human impacts on environment at various temporal and spatial scales (Lopez et al., 2001). Therefore, accurate and up-to-date land use/cover information is essential for environmental planning, to understand the impact on terrestrial ecosystem (Muttitanon and Tripathi, 2005) and to achieve sustainable development (Alphan, 2003). Furthermore, timely and reliable data on land use/cover may facilitate the formation of integrated resource management policies.

Even though most of the developed countries are well equipped and updated with detailed land use/cover information, lack of geospatial database for land use/cover persists in developing countries and may hinder proper development planning. Hence, space-borne remotely sensed data may be particularly useful in developing countries where recent and reliable spatial information is lacking (Dong et al., 1997).

### 2.8 Impact of Land Covers Changes

Studies demonstrated that the transformation of land use/cover either by human activity or natural origin can profoundly impact the hydrological cycle by accelerating volume and rate of surface runoff (Weng, 2001; Shi et al., 2007), mounting flood risk (Nirupama and Simnovic, 2007), degradation of water quality (Xian et al., 2007), and causing erosion (Weng, 2001). Considering these facts, the objectives of this study are to identify the land cover changes and to analyze the impact of land cover changes on livelihood assets in the Haor area of Bangladesh using remote sensing and GIS techniques.

The aim of change detection process is to recognize land cover on digital images that change features of interest between two or more dates ([Muttitanon W.; Tıpathi, N.K, 2005). In this study, change detection comparison (pixel by pixel) technique was applied to the cover maps derived from satellite imagery.

### 2.9 Land Cover Changes and its Impacts on Environment

From Strategic Plan of the US Climate Change Science Program (2004), it is clear evidence that changing land cover has significant impacts on local environmental conditions and economic and social welfare. For example, the water cycle depends heavily on vegetation, surface characteristics, soil properties, and water resources development by humans (e.g., dam construction, irrigation, channeling, and drainage of wetlands) which in turn affects water availability and quality. Land-use and land-cover change, climate variability and change, soil degradation, and other environmental changes all interact to affect natural resources through their effects on ecosystem structure and functioning. In turn, ecological systems may respond unexpectedly when exposed to two or more perturbations.

## 2.10 Land Cover Changes and its Impact on Livelihoods

People live in and around the area depend on the haor for their livelihood. The livelihoods of the haor areas have been highly dependant on the haor resources. But these haors are being degraded recently due to the unregulated harvesting of wetland resources and filling up of water bodies mainly by siltation. A major threat to the haor ecosystem in greater sylhet area is siltation and the subsequent loss of perennial water bodies. The livelihood opportunities are reduced day by day. According to fisheries specialists and scientists, due to siltation in the big rivers and their tributaries, haors and floodplains, the breeding and grazing fields of the native fishes have been affected which consequently affected the fisheries resources dependant livelihoods (IUCN, 2006).

The people of most of the Haors are living in a very poor and distressed condition. The overall livelihood situation is much below compared to the national standard (CEGIS, 2006). The health water and sanitation of the haor area is in an alarming situation. The use of unsafe drinking water at 18% and unsafe sanitation at 63% is very in the haors. The CEGIS study found that around 55% households in the haors are living with more or less deficit round the year. Number of these households is found to be increasing in the whole area due to recurring flood.

There are different categories of livelihoods in the haor area. Land cover dependant livelihood groups are-Farmer (Landless and marginal), Fisherman, Fuel wood collector, Boatman (Majhi), Crab collector, Medicinal plant collector, Women etc

## 2.11 Vegetation Indices

Satellites have historically been used to identify land cover or the sea surface for a particular area at a given point in time. Instruments measure the reflected and emitted radiance from the Earth's surface at different wavelengths bands. Land cover types exhibit distinct characteristics at particular wavelengths, allowing for their spectral separation from other land cover types. To accommodate the study of changes in land cover through time, a surrogate is needed to accurately represent the distinguishing characteristics of green vegetation. The VI accomplishes this by combining the bands that best characterize vegetation into a single measure. In turn, the temporal signal displayed by the VI – or *phenology* – can be characterized and quantified. There is a strong correlation between linear combinations of the red (R) and infrared (NIR) bands and green leaf area and biomass. It can estimate gross primary productivity.

Many vegetation indices have been developed. Some are the basic indices, which are simple combinations of red and NIR like RVI, NDVI, Difference Vegetation Index (DVI), Transformed Difference Vegetation Index (TDVI). The other indices are to minimise soil influences as Perpendicular Vegetation Index (PVI), Weighted Difference Vegetation Index (WDVI), Soil Adjusted Vegetation Index (SAVI), Modified Soil Adjusted Vegetation Index (MSAVI), etc. Some indices are developed to minimize atmospheric noise. There are some indices like Infrared Percentage Vegetation Index (IPVI) to increase the computation speed by eliminating the need of indicating signs as in NDVI. The description of these vegetation indices is based on Gielen *et al.* (2001) and Qi *et al.* (1994).

## 2.12 Normalized Difference Vegetation Index

Tucker first suggested NDVI in 1979 as an index of vegetation health and density (Thenkabail and Gamage et al. 2004). NDVI is defined as:

**NDVI= (NIR-RED)/ (NIR+RED)**

Where,

NDVI = Normalized Difference Vegetation Index

NIR = Near-infrared band of the electromagnetic spectrum

Red = Red band of the electromagnetic spectrum.

NDVI is a good indicator of green biomass, leaf area index, and patterns of production (Thenkabail and Gamage et al. 2004; Wang and Wang et al. 2004). NDVI is the most commonly used vegetation index. It varies from +1 to -1. NDVI value of zero means no green vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves. Various studies have shown that the NDVI index varies linearly with green biomass in semi-arid areas, where crop health is limited by changes in rainfall, although it is sensitive to soil brightness and atmospheric water vapor. Since climate is one of the most important factors affecting vegetation condition, AVHRR- NDVI data have been used to evaluate climatic and environmental changes at regional and global scales (Ji and Peters 2003; Singh, Roy et al. 2003; Li &Lewis et al. 2004). It can be used not only for accurate description of continental land cover, vegetation classification and vegetation vigour but is also effective for monitoring rainfall and drought, estimating net primary production of vegetation, crop growth conditions and crop yields, detecting weather impacts and other events important for agriculture, ecology and economics (Singh &Roy et al. 2003). NDVI has been used successfully to identify stressed and damaged crops and pastures but only in homogenous terrain. In more heterogeneous terrain regions their interpretation becomes more difficult (Vogt et al. 1998; Singh et al.2003). Many studies in the Sahel Zone (Tucker et al 2005), Argentina (Sullivan et al.1998), South Africa (Unganani & Kogan, 2004) and Mediterranean (Vogt et al., 1998), and Senegal (Li. et al., 2004) indicate meaningful direct relationships between NDVI derived from NOAA AVHRR satellites, rainfall and vegetation cover and biomass. This is the simplest form of ratio-based vegetation index calculated through the use of infrared and the Red band of the electromagnetic spectrum. The NDVI, a ratio of near-infrared and red band reflectance is accepted as a surrogate for primary production and has served as a good measure of seasonal vegetation changes, even at coarse scales.

Most anthropogenic changes occur at spatial scales less than that provided by AVHRR. MODIS provides 250m spatial resolution for band 1 (red, 620-670nm) and band 2 (near-infrared, 841-876nm), which are used to generate 250m NDVI land cover change at 8 days, Monthly, Yearly interval. Maximum-value compositing (MVC) provides a method for improving the accuracy of green vegetation monitoring with NDVI. By combining daily reflectance images over a specific time period into a single NDVI image, MVC minimizes cloud effects, reduces view angle effects and mitigates atmospheric water-vapor and aerosol contamination, thus separating the green vegetation land cover type from various other components (clouds, water, soils). This was performed with AVHRR derived products by evaluating each of the individual images on a pixel-by-pixel level, and using only the highest value for each location in the final image. MODIS data is composed of constrained-view angle - maximum value composite (CV-MVC), in which the nearest-to-nadir pixel is selected for inclusion in the output image. The MVC method described above is then utilized in those pixels where the CV-MVC method fails (see http://tbrs.arizona.edu/project/MODIS/compositing.php). Composite imagery provides a temporal and spatial consistency that could not be achieved using previous observation techniques.

# CHAPTER THREE

# OVERVIEW OF THE STUDY AREA

## 3.1 Introduction

Haors are large saucer-shaped flood plain depressions located mostly in north-eastern region of the country covering about 25% of the entire region. There are altogether 411 haors comprising an area of about 8000 km 2 dispersed in the districts of Sunamgonj, Sylhet, Moulvibazar, Hobigonj, Netrokona & Kishoreganj. Haor bowl-shaped large tectonic depression. It receives surface runoff water by rivers and *khals*, and consequently, a haor becomes very extensive water body in the monsoon and dries up mostly in the post-monsoon period. In Bangladesh haors are found mainly in greater Sylhet and greater Mymensingh regions. During monsoon a haor is a vast stretch of turbulent water. The word haor is a corrupt form of the Sanskrit word *Sagar* (SEA). In Sylhet and northeast Mymensingh, the people pronounce the Bangla letter (sa) as (ha), and some times (ga) as (ha). Thus sagar is sounded haor. The haor basin is bounded by the hill ranges of Meghalaya (India) on the north, the hills of Tripura and Mizoram (India) on the south, and the highlands of Manipur (India) on the east. The Surma and Kushiyara in association with other minor hilly streams like Manu, Khowai, Jadhukata, Piyain, Mogra and Mahadao form the dense drainage network of the haors. The rivers are primarily responsible for providing inputs - rainwater and sediment load to the plains including haors. The plains remain flooded for about 7 to 8 months. During the rainy season, the haors turn into a vast inland sea within which the villages appear as islands. Occasional high winds during July to September generate large waves in the haor, which may cause considerable damage to homesteads.

## 3.2. Selection of the Study Area

The Haor area, northeastern part of Bangladesh is taken as study area which is located between latitude 23°59´04.75´´N to 25°12´49´´N and longitude 90°27´22.13´´E to 92°30´10.19´´E (Figure 3.1). The entire Sunamganj district, major portion of Habiganj district, some parts of Sylhet Sadar upazila and Maulvi Bazar district are covered by many haors. In greater Sylhet the most prominent haors are Saneer haor, Hail haor, Hakaluki haor, Dekar haor, Maker haor, Chayer haor, TANGUAR HAOR, and Kawadighi haor.

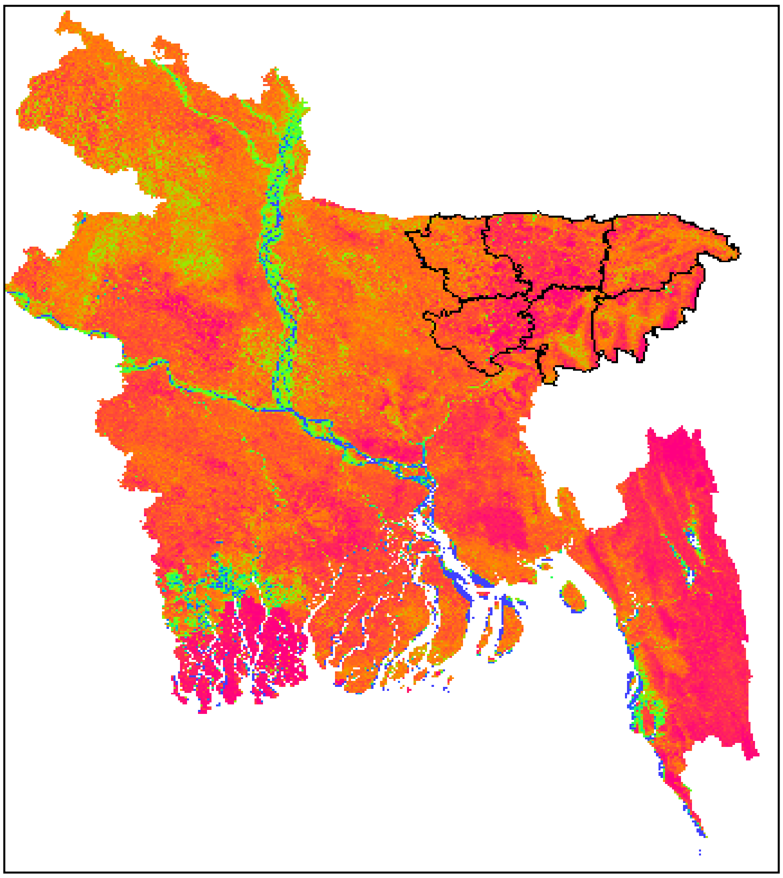


Figure 3.1: Map of Bangladesh showing the Study Area

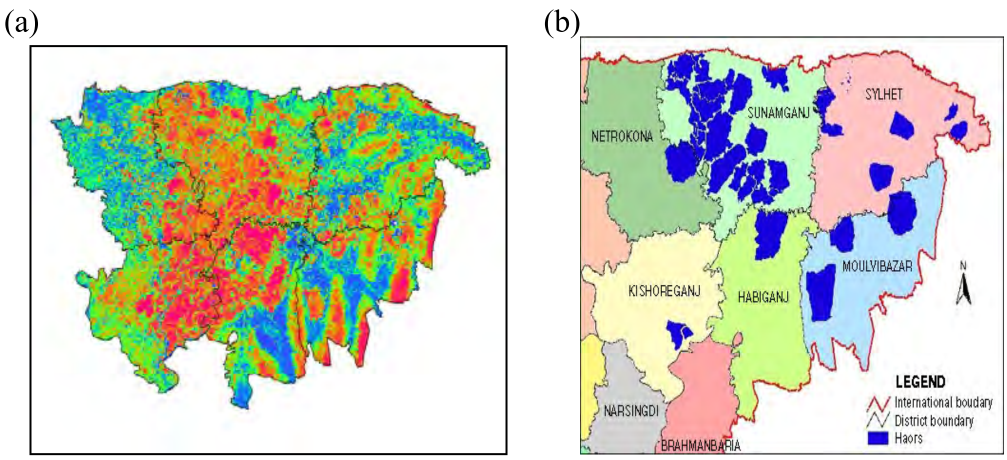



Figure 3.2: Location of the study area

### 3.3 Hakaluki Haor

Hakaluki haor lies between latitude 24°35' N to 24°45' N and longitude 92°00' E to 92°08' E. It is bounded by the Kushiara River as well as a part of the Sonai-Bardal River to the north, by the Fenchuganj-Kulaura Railway to the west as well as to the south, and by the Kulaura-Beanibazar. Road to the east. Hakaluki haor falls (Figure 3.3) under the two administrative districts (Maulvibazar and Sylhet) and five upazilas (Barlekha, Kulaura, Fenchuganj, Golapganj and Juri) (IUCN-Bangladesh, 2006).

Hakaluki haor is a complex ecosystem, containing more than 238 interconnecting beels/Jalmahals (CWBMP 2005). The most important *beel*s are Chatla, Pinlarkona, Dulla, Sakua, Barajalla, Pioula, Balijhuri, Lamba, Tekonia, Haorkhal, Tural, Baghalkuri and Chinaura. The total area of the haor is approximately 18,000 ha, including the area which is completely inundated during monsoon. Of this total area, *beel*s (permanent wetlands) cover an area of 4,635 ha. This 18,000 ha area represents area demarcated as ECA declared by the Government of Bangladesh for Hakaluki haor.

Hakaluki haor is one of the major wetlands of Bangladesh. With a land area of 18,386 hectares, it supports a rich biodiversity and provides direct and indirect livelihood benefits to nearly 190,000 people (CWBMP pro-doc 2000).

Because of the critical conditions of the haor ecology, the government of Bangladesh Declared Hakaluki as an Ecologically Critical Area (ECA) in April 1999. There are 8 ECAs in the country which are considered to be under severe threat. The government has designated these as ECAs to bring them under a management strategy which will ensure their conservation and sustainable use.

According to CNRS-IUCN-Netherlands study report (2001-2), there are 238 beels in Hakaluki haor. Few of them are privately owned, some have disputes with the Government regarding ownership and most of them fall under jalmohals (one or more beels form a jalmohal).

Hakaluki haor is a very important resting place for migratory waterfowls flying in from the north. The most interesting species is the Barheaded Goose, which is now very rare in fresh water wetlands. Other important species include Adjutant Stork, Bear's Pochard, Falcated Teal, Broadbill Sandpiper, Spotted Redshank, Nordmann's Greenshank, Temmiinck's Stint, Steppe Eagle and Osprey.

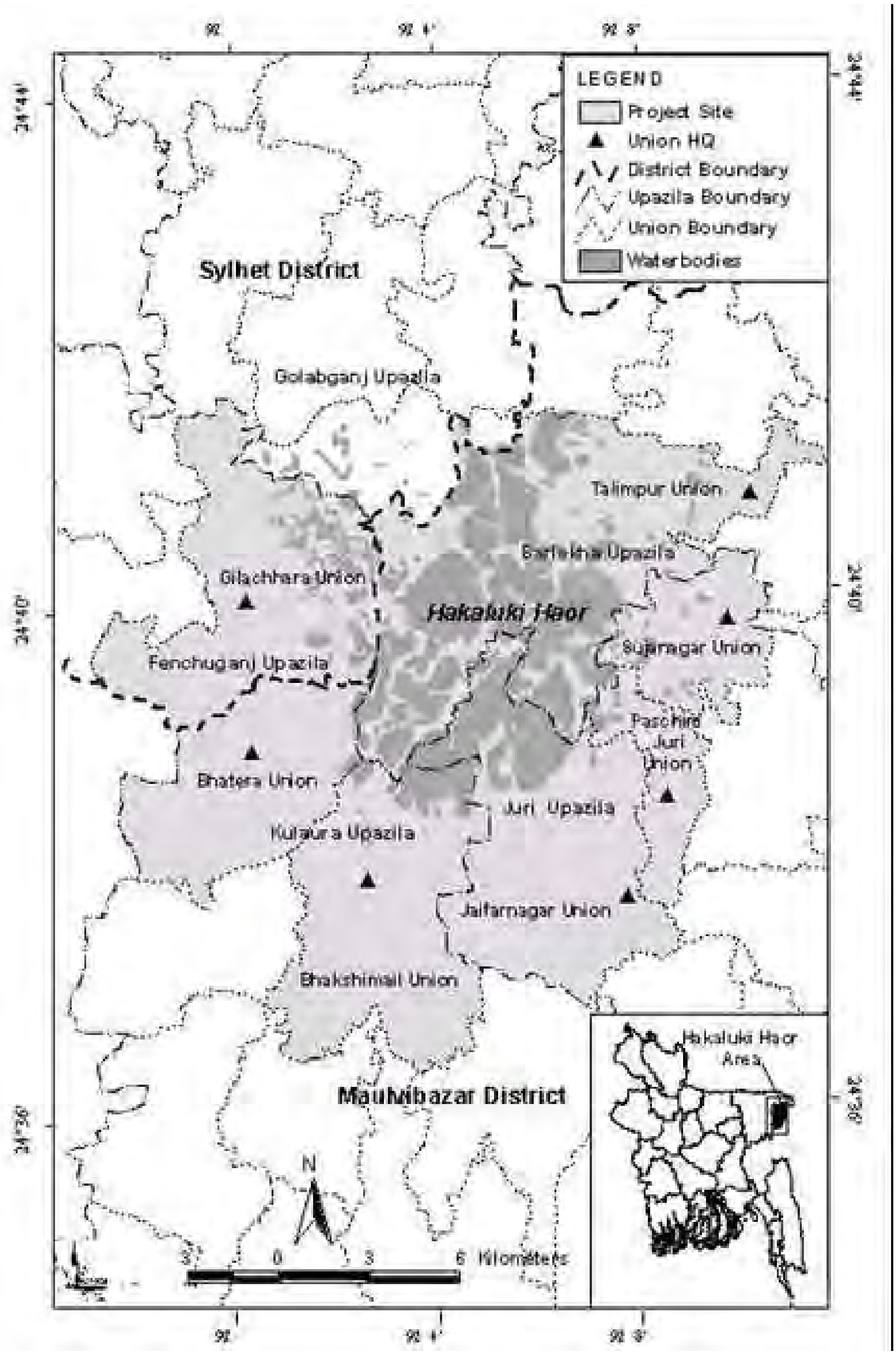



Figure 3.3: Hakaluki haor in Sylhet and Maulvibazar Districts

In a survey conducted under FAP 6 in 1994, 64,000 waterfowl were counted in Haor khal and 15,000 waterfowl were counted in Chatla *beel*. Illegal poaching has been a threat to the waterfowl population (IUCN-Bangladesh, 2006).

Hakaluki haor contained a very dense swamp forest in the past, but deforestation and the lack of conservation practices have virtually destroyed this unique forest in the last two decades. Two small patches of swamp forest remain in the Hakaluki haor. One is in Chatla *beel* another is near the village of Kalikrishnapur. The plants which are common in this type of forest are also found in homestead groves. With the exception of these two swamp forest patches, the vegetation surrounding Hakaluki haor is unique since it includes both swamp forest as well as mixed evergreen rain forest. Hakaluki haor is known as good grazing land. Ecological characteristics, particularly vegetation patterns, differ sharply between the permanent and seasonal water bodies in Hakaluki haor. Thatching material is the most useful natural wetland product of the area. The people in the vicinity use this material in various ways: for example as roofing, wall or wall panel material for their houses and for making mats. The utilization of wetland products is now less intensive, because in recent years the vegetation has decreased considerably (IUCN-Bangladesh, 2006).

### 3.4 Hail Haor

Hail haor is one of the large wetland ecosystems in the northeastern part of Bangladesh located in Moulvibazar district connecting two upazillas namely Sreemongal and Moulvibazar Sadar. There are 64 villages around the close vicinity of the haor in five unions under two upazillas of the district. Being the haor is very rich in having diverse resources system; thousands of households from the villages around the haor have dependence on haor resources for their livelihoods at varying degrees. The haor support a rich diverdity of wildlife including migratory ducks in the winter internationally declared as important bird area.

### 3.5 Hydrological and Physical Values

Near surface sediments in the haor area are substantially thick and non-auriferous. This lithologic condition is reflected in generally low permeability.

### 3.6 Land Tenure

The beels and the levees between the beels are Government owned (khas land) as well as the low lying area other than the beels which are seasonally flooded. These beels are leased out for fishing by the Government through auction at the office of the additional deputy commissioners at Moulvibazar and sylhet. The surrounding area privately owned while some of them are Government khas land leased out to either land less local people or other local villagers for cultivation. The water bodies and land inside the haor are owned by Government (khas land) and leased out every year or every three years for fishing.

### 3.7 Land Use

Mostly fishing, during the winter season when the water level is lower, marginal land of the beels are cultivated with paddy. Apart from it the levees and the fallow land are used for cattle grazing. Most of the surrounding areas are used for rice cultivation with some vegetable growing. Other than the waterway are used for local riverine transportation and for carrying bamboo rafts. The water body is mostly used for fishing Management and extractable of wetland resources which includes thatching materials, animals fodder, wild plant, fruits, food, fuel wood supplement and transport.

### 3.8 Ecological Features

The haor shares most of the ecological features with the other haors in the region. The permanent water bodies support a rich and diverse aquatic habitat comprising unique floral assemblence.

### 3.9 Climate Condition

The climatic factors of the region are sub-tropical monsoon in nature with three prominent seasons, viz. summer, monsoon and winter. Summer begins in April through to June. The monsoon is the rainy season, extending from June to September. Winter is the following season with the peak cold weather in December and January.

#### 3.9.1 Rainfall

The north-eastern of the country is characterised by highest rainfall and relatively low temperature compared to annual average of the country. The average annual rainfall in the region is 4130 mm which is almost double of the country average (BBS) (figure: 3.4).

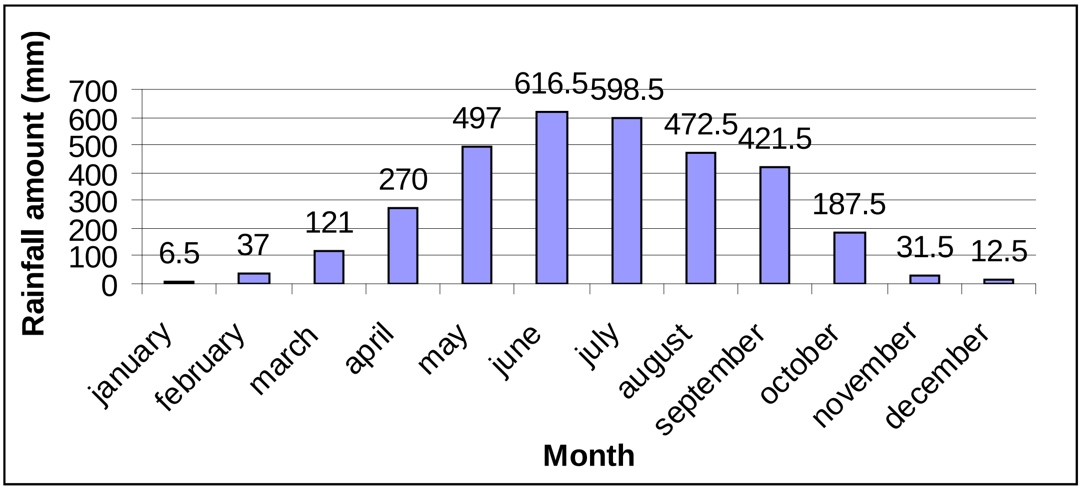



Figure: 3.4 Monthly rainfall trends in the study area of 20 years average

### 3.9.2 Temperature

The average maximum temperature of Sylhet is showing an increasing trend at the rate of 0.039 °C per year. The lowest maximum temperature was recorded in 1977 which was 28.5°C and the highest maximum temperature was recorded in 1998 which was 31.25°C (BBS).

## 3.10 Soil Condition

The haors are of tectonic origin and possibly connected with the rise of Madhupur tract. Beels do not subside but haor basins do. In its original form, the haor basin comprising the floodplains of the Meghna tributaries would have consisted of a rich mosaic of permanent and seasonal lakes and ponds with abundant aquatic vegetation. But through gradual sedimentation, the basin becomes shallower leading to the formation of reeds and sedges. This resulted in providing enough food and shelter for FISH and other aquatic, fauna and attracted the migratory birds which, in their turn, added to the fertility of the water bodies by their excreta promoting rich growth of phytoplankton and macrophytes thus partly contributing to the process of eutrophication.

### 3.11 Agricultural Production

There are three major rice crops in Bangladesh: *Aus*, *Aman* and *Boro*. Of them, *Boro* is the main form of production in the haor area, while *Aus* and transplanted *Aman* are almost universally found on highland and medium highland floodplain ridge soils. *Aus* are widely transplanted in this wet region; elsewhere, sprouted seeds are sown on wet puddle soils. Most such land remains fallow in the *rabi* season. With irrigation, HYV *Boro* is followed by rain fed transplanted *Aman*. On lower land, mixed *Aus* and *Aman* or deepwater Aman are the traditional practices on basin margins, with local *Boro* paddy or grass land (used for dry season cattle grazing) in basin sites. With LLP irrigation, the area under *Boro* paddy — mainly early maturing local varieties — has greatly expanded in the past 30 years, thus considerably reducing the area formerly under grassland and reed swamp. Rabi crops such as vegetable, spices, sweet potato, potato, pulses and mustard are mainly grown on loamy-bank soils.

### 3.12 Natural Resources

The haors are considered the most productive wetland resources of Bangladesh. The basin supports a large variety of wetland bio-diversity and works as natural reservoir as it plays a key role in basin water resources by regulating water flows of the Meghna river system. Also, the haors are noted sanctuaries of both permanent and migratory birds. With the recession of floodwater, a large variety of small fishes, oysters, water snails and bivalves, and pasture spread over the surface attracting a large number of migratory birds. These birds use the haor as temporary resting and roosting ground before moving elsewhere. The Swamp forests, which were once dominant with the flood tolerant tree species like hijal (*Barringtonia acutangula*) and Koroch (*Pongamia pinnata*), have been reduced to a few small patches. The haors are also important fishing grounds of the country. In the past century or so, when the population pressure was less, most of the rim-lands of the haors remained as cultivable wasteland and was used for extensive grazing in the dry season. As population increased, boro cultivation expanded onto these marginal lands leading to a large area being drained. Thus, the very existences of these wetlands are now threatened

The Haors are enriched with various aquatic biodiversities along with 140 species of fish. About 8000 migratory wild birds visit the area annually. In Haor area three major resources viz. land, water & human resource could not be utilized in an integrated way due to its unique geographical as well as complex hydrological characteristics. Some of the important aspects to utilize the resource are to ensure harvesting of principal crop (Boro), enhancement of communication networks, multiple use of water resources with emphasis on fishery, agriculture, cattle farming and employment opportunities for both men & women throughout the year.

### 3.13 Biodiversity of Haor Area

Haor area are characterized by rich aquatic flora, terrestrial habitats, birds and fish habitats, water bodies in the form of perennial beels (marsh/fen/swamp), small and medium canals (variation locally known as *kara, falla, dair* etc.), secondary rivers, seasonally inundated lands, *khandas*, swamp forests housing clusters of *hijal* (*Barringtonia aquatangula*), and *karoch* (*Pongamia pinnata*) trees, *nal khagra* (*Fhragmities karka, chailla ghash* (*Hematheria protensa*) etc.

**Birds:** The haor is an ideal place for the migratory birds. Every winter about 200 types of migratory birds come to this haor and make their temporary habitat here. Once upon a time the zamindars of Sunamganj area used to make cruise into this haor with large *Pansi* boats for hunting birds.

**Fish:** The haor is an important source of fisheries. More than 140 species of fresh water fishes are available here. Among them the notables are *Air*, *Gang Magur*, *Baim*, *Tara Baim*, *Gutum*, *Gulsha*, *Tengra*, *Titna*, *Garia*, *Beti*, *Kakia* etc. In the 1999-2000 fiscal year, government earned Tk 7073184 as revenue only from fisheries of the haor

### 3.14 Haor Goods, Services and Economic Values

The haor system provides a wide range of economic and non-economic benefits to the local people as well as to the people of Bangladesh. These include benefits in terms of fish production, rice production, cattle and buffalo rearing, duck rearing, collection of reeds and grasses, and collection of aquatic and other plants. The haor system also protects the lower floodplains from flash floods occurring in the months of April-May, recharges the water tables, maintains the supply of fish in other lower riparian water bodies, provides habitat for migratory and local waterfowl, and generates important carbon sequestration services. At the same time, the unique haor system is a natural beauty both during the monsoon months and the dry season. In monsoon, its unique physical characteristics make it a huge natural bowl of water and in the dry season it is natural grassland with a horizon nearly 35 km wide, with pockets of *beel*s serving as the resting place for migratory birds. Such a unique natural system, if appropriately marketed, could be a major attraction for tourists. However, as of today, there is little evidence of this. The property rights regime of the haor is complex. Most of the agricultural lands in the haor basin are private land. While the majority of the water bodies are owned by the government and are generally leased out for fishing activities, smaller water bodies are sometimes owned by local villages or by a few families. The banks of the water bodies, which were once tracts of swamp forests, are public land. The cycle of economic activities in the haor region also varies significantly with changes in the seasons. During the monsoon months, most of the land is under water and so fishing is the major economic activity. However, during this time leaseholders have no control over fish, because they are spread over a large area and people are able to catch them freely. During the dry season, a large number of activities take place.. Agricultural land under private ownership is often put under *Boro* rice production. The banks of the wetland provide grazing grounds, and herds of cattle and buffaloes are brought in. Water bodies are more organized and defined, and leaseholders take full control of their fish harvests. Local people collect building materials such as reeds for fences, various plants and fuel wood for personal and commercial use, and sometimes are engaged in hunting and poaching of migratory birds.

### 3.15 Livelihood groups of the haor area

The primary occupation of households living around the haor area is agriculture, closely followed by fishing. Just under half of the populations are engaged in other activities, many of them wetland-based, including manual labourers, boatmen, small traders and remittances from abroad. There are different livelihood groups in the haor area. Primarily identified livelihood groups are-Farmer (Landless and marginal), Fisherman, Fuel wood collector, Boatman (Majhi), Crab collector, Medicinal plant collector, Women (vulnerable group) etc. After FGD we have found that in practical these resource extractors have diversified their livelihood opportunity by extracting different types of resources in responding to decreasing productivity status of Haor area. Taking the interviews, FGD, we have broadly classified the livelihood groups in to four as; Farmer (Landless and Marginal), Fuel wood collector, Fishermen and Boatman.

### 3.16 River systems and Drainage Network

Sunamganj is endowed with an intricate network of river systems. Most of the rivers are considered to be highly infamous for their unpredictable nature, letting loose fury of flood and problem of extensive and regular bank erosion during the rainy season. The majority of the rivers of this region originates in the meghalayan plateau and enters into Bangladesh from a north to northwesterly direction and flows south to southeasterly direction.

The catchment of theses rivers has mostly been deforested and the clearings of the steep slopes have been used for the extension of settlement, agriculture, plantation and communication disrupting the overall hill slope hydrological balance. As a result, during heavy and concentrated rainfall, innumerable landslides are caused transporting huge amount of sediment to the rivers. Most of such landslides have never been treated scientifically with proper protective measures and as such those are in the habit of expanding their territories during monsoon. These often add more and more silt to the rivers, which are incapable of transporting the loads efficiently under existing hydrological conditions, particularly area beyond the foothill zone.

During summer, the observed increment of the size of bars and shoals downstream to the piedmont area proves such a contention. in order to avoid such numerous islands in midst of the channel, the rivers, in their lower reaches, thus attains the significant physical characteristics of braiding which may be attributed to both incompetence and incapacity of the rivers. its means, most of the rivers can transport neither the total amount of debris nor the size of debris that is supplied to it as bed load. As a result, the river bed is rising at some sections in the plains, resulting in the lessening of cross-sectional areas which being incapable of arresting the unusual monsoon discharge and allow water to spill, causing floods.

### 3.17 Strength and Weakness of the Haor Area

The extreme flashy character of the rivers and high rain fall compare to other part of the country in the region causes frequent flash floods in the Haor. To protect the crops in the Haor areas, the erstwhile Zamindars with the participation of the local people used to construct small dykes and appurtenant structures for early flood protection and irrigation. Since 1966, BWDB adopted better technology and completed 46 projects under EIP and SRP in the Sunamgonj, Sylhet, Moulvibazar, Hobigonj, Netrokona and Kishoreganj districts. A total of about 0.29 million hectare cultivable land has been made flash flood free by implementing about 2000 km submersible embankment and ancillary structures.

Sylhet region is highly vulnerable to river flood, flash flood, intensive rainfall, and land slide. The haor area of this region is single cropped and is cultivated only T aman in the kharif season. This crop is damaged almost every alternative year by flash flood. In the recent years, the frequency of flash flood has been increased. Tornado and hailstorm are also two important climate induced disasters for this region which damages crops, houses, trees and even human death. Intensive rainfall causes land slides and erosion in the hillocks area. Soil degradation, due to the sandification of arable land, is also seen as a hazard in this area as well as siltation of river and water bodies that enhance the strength of floods and provoke water logging.

# CHAPTER FOUR
# DATA AND DATA COLLECTION

## 4. 1 Introduction

This chapter gives a brief overview of the data, data type; sources of data collection and finally data collection process. This study has been carried out based on secondary data and field visits.

## 4.2 Category of Data

Spatial and Non spatial data were used in this study. MODIS satellite data acquired in 2000 and 2008 together with other spatial data layers such as soil types hydrology (stream network and water bodies), and topography were used. Meteorological data pertaining to monthly rainfall was collected for a period of 2000 to 2008**.** The categories of data are-

- Hydro-Meteorological data i.e. Temperature data, Monthly rainfall data and Water level data etc.

- Satellite Data i.e. Moderate Resolution Imaging Spectra Radio-meter (MODIS) data like - surface reflectance (500m global Terra data and 250m global Terra data), land surface temperature (1 km Terra data) which is available in MODIS Website (Figure 4.1).

- Field data i.e. livelihoods related data like livelihood groups, livelihood capitals, land cover dependant livelihoods etc.

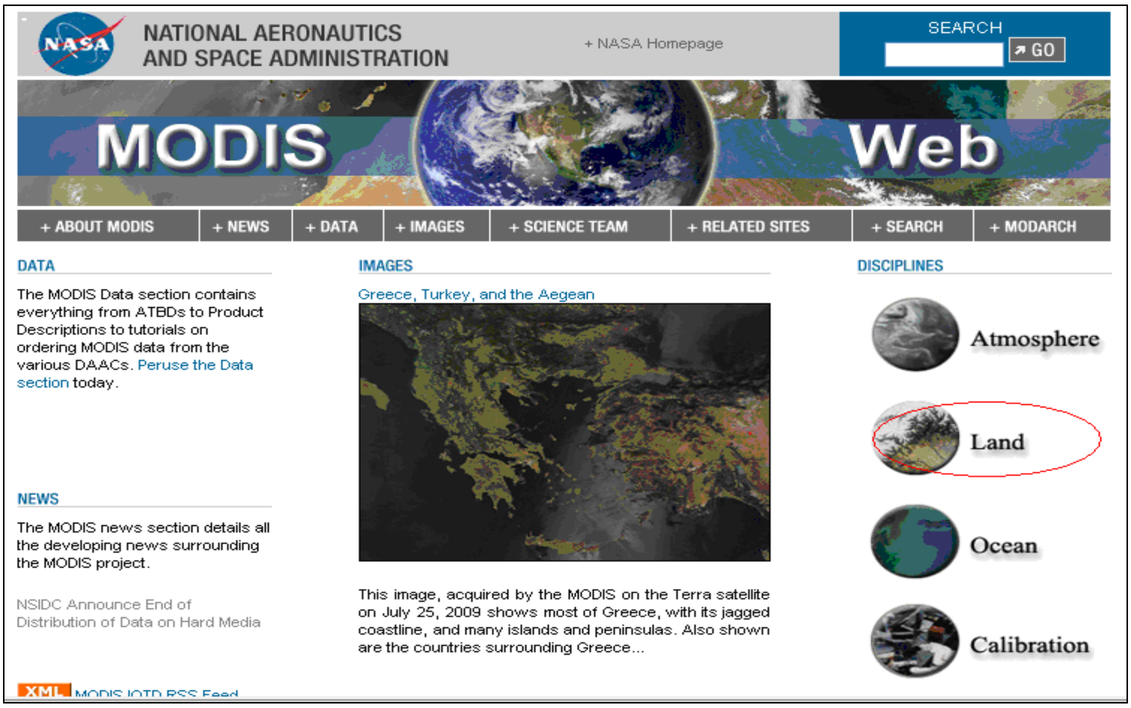



Figure 4.1: MODIS Website for land surface data

## 4.3 Data Acquisition

Data had been acquired mainly from 2 sources, firstly satellite sources and secondly from meteorological department sources. Water level data has been collected from Bangladesh Water Development Board (BWDB). Daily rainfall data were provided from various meteorological stations of Bangladesh Meteorological Department (BMD). Surface reflectance and land surface temperature has been collected from satellite sources i.e. Moderate Resolution Imaging Spectra Radio-meter (MODIS) Website (Figure 4.1), Earth Observing System (EOS) data Gateway (Figure 4.2) and Warehouse Inventory Search Tool (WIST) (Figure 4.3).

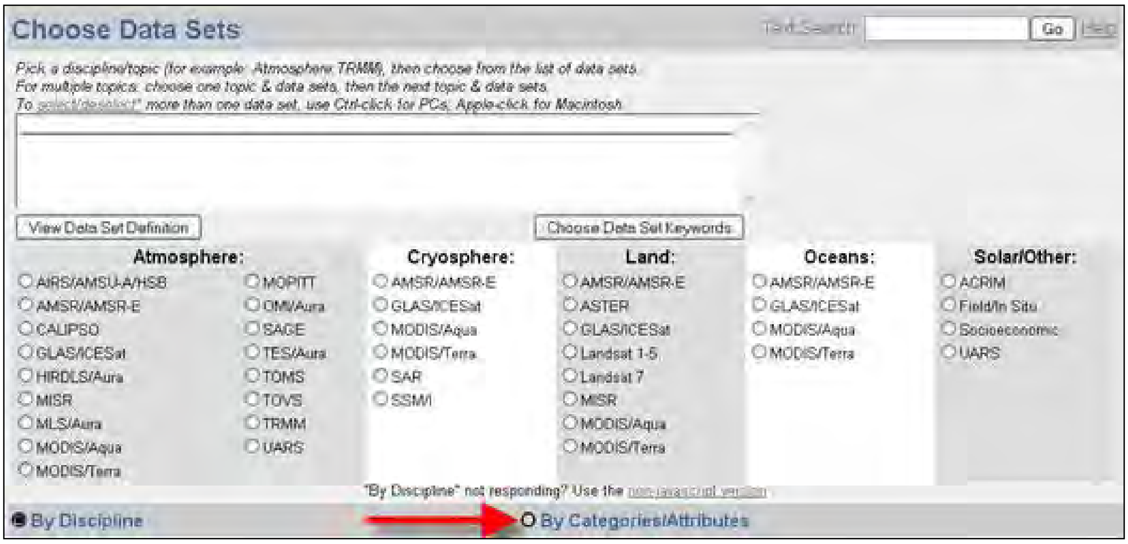


Figure 4.2: Categories of MODIS image in the website

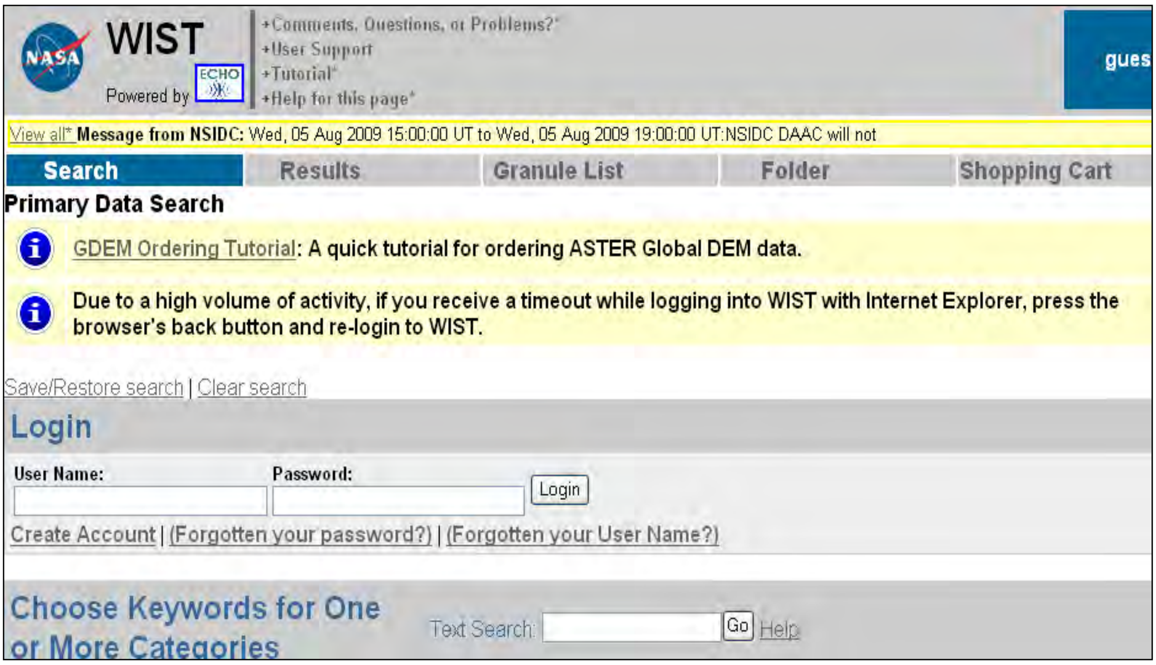


Figure 4.3: Warehouse Inventory Search Tool (WIST) Data search website

### 4.4 Satellite Imagery

This study used MODIS satellite images which are acquired by TERRA instrument. The images can be freely downloaded through the Earth Observing System Data Gateway (EOS, 2006) (Figure 4.2) or by using Warehouse Inventory Search Tool (WIST) (Figure 4.3).

The present study involved an analysis of 8-day composite data of MODIS during 2000 and 2009. The label of this product is "MODIS/TERRA SURFACE REFLECTANCE 8-DAY L3 GLOBAL 500 M SINGRID V005". The spatial resolution of this product is approximately 500 m, and atmospheric correction has already been carried out (Vermote & Vermeulen, 1999). This 8-days average surface reflectance data is delivered as a composite product called MOD09 which took the best surface spectral- reflectance within this period with the least effect of aerosols and other atmospheric ingredients. Satellite images were taken from MODIS TERRA 8-day reflectance (Surface Reflectance 8-Day L3 Global 500m) during the 2000 and 2009. A total of MODIS about 419 images were used. MODIS images were downloaded from the specified grid shown in the Figure 4.4.

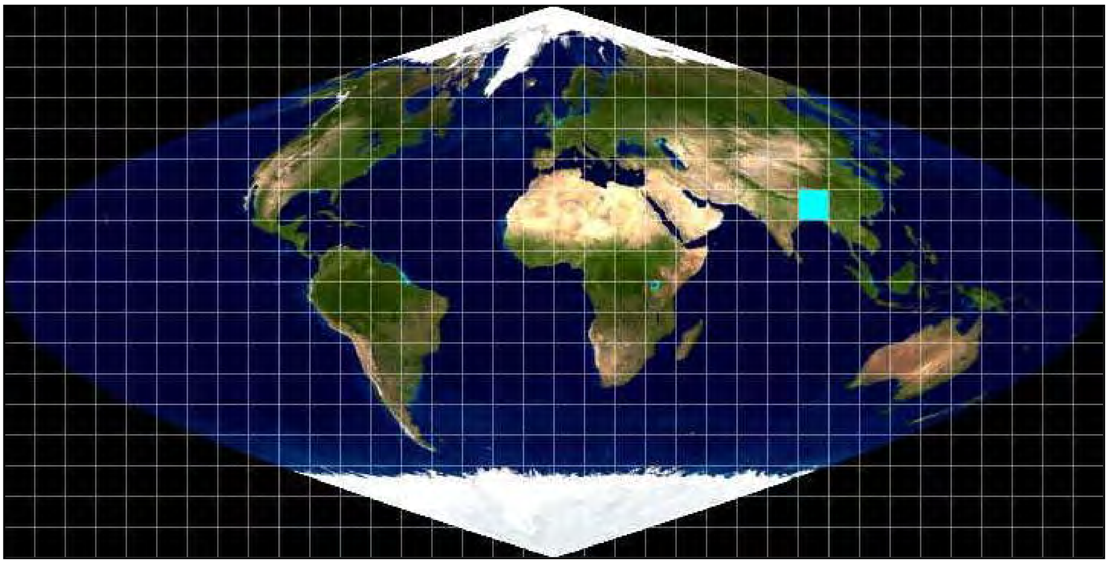


Figure 4.4: MODIS grid all over the world (10 by 10 degree sinusoidal grid) [Source:http://modland.nascom.nasa.gov/developers/bndrytb2.html]

The selected bright portion in the image is the grid of Bangladesh (horizontal row = 26, vertical column = 6).

**4.5 Meteorological Data**

Hydro-Meteorological data like daily temperature, monthly rainfall and Water level data etc were collected from Bangladesh water development Board (BWDB) and Bangladesh Meteorological Department (BMD).

### 4.6 Field Data

Primary data on livelihood assets of the haor area were collected from the selected haor area through FGD and interviews. The study is based on the combination of meteorological data, satellite data and field data. The field data includes livelihood capitals/assets, land cover dependent livelihood groups, livelihood condition and livelihood changes with respect to time.

### 4.7 Satellite Imagery Characteristics

For land use classification, remote sensing techniques plays a crucial tool.The moderate resolution imaging spectroradiometer (MODIS), lunched on NASA's Earth observing system (EOS) Terra satellite on December 18, 1999 provides a comprehensive series of global observations of the Earth's land, ocean, atmosphere and for satellite measurements of global LST in the visible and infrared regions of the spectrum. NASA's EOS Aqua system, a sister satellite to Terra, has already been launched, and it has an early afternoon observation time, crossing the equator at approximately 1:30 PM MODIS is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra's orbit around earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon (Conboy, 2004). At higher temperatures, radiation fluxes are much greater and more representative of surface conditions, therefore it is expected that the afternoon observations allows a significant improvement in drought monitoring. It is comprehensive in that it has a wide spectral range (36 discrete spectral bands ranging from 0.4µm to 14.4µm) and spatial coverage and it takes measurements in spectral regions that have been used in past and current satellite sensors. It provides daylight reflection and day/night emission imaging for all points on earth at least once every two days. Satellite data used for study is surface reflectance and the product name is MOD11A2 and MOD09Q1 respectively. These two products have been downloaded from EOS data gate way for the period of July to December from 2000 to 2008. This time series represents the monsoon season. All this data is 8 days composite basis and the naming of processed intermediate image has been done according to the Julian day (Table 4.1).

Table 4.1 Julian date calendars for leap year and non-leap year

**Year**
2004

Gives the Julian Dates for 0:00 UT (GMT) for Gregorian Calendar years > 1901

**Julian Date Calendar**

*Year: 2004* *Leap Year?* **Yes**

*To calculate the Julian Date, add the day-of-year to:* **2453004.5**

| Day | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1 | 32 | 61 | 92 | 122 | 153 | 183 | 214 | 245 | 275 | 306 | 336 |
| **2** | 2 | 33 | 62 | 93 | 123 | 154 | 184 | 215 | 246 | 276 | 307 | 337 |
| **3** | 3 | 34 | 63 | 94 | 124 | 155 | 185 | 216 | 247 | 277 | 308 | 338 |
| **4** | 4 | 35 | 64 | 95 | 125 | 156 | 186 | 217 | 248 | 278 | 309 | 339 |
| **5** | 5 | 36 | 65 | 96 | 126 | 157 | 187 | 218 | 249 | 279 | 310 | 340 |
| **6** | 6 | 37 | 66 | 97 | 127 | 158 | 188 | 219 | 250 | 280 | 311 | 341 |
| **7** | 7 | 38 | 67 | 98 | 128 | 159 | 189 | 220 | 251 | 281 | 312 | 342 |
| **8** | 8 | 39 | 68 | 99 | 129 | 160 | 190 | 221 | 252 | 282 | 313 | 343 |
| **9** | 9 | 40 | 69 | 100 | 130 | 161 | 191 | 222 | 253 | 283 | 314 | 344 |
| **10** | 10 | 41 | 70 | 101 | 131 | 162 | 192 | 223 | 254 | 284 | 315 | 345 |
| **11** | 11 | 42 | 71 | 102 | 132 | 163 | 193 | 224 | 255 | 285 | 316 | 346 |
| **12** | 12 | 43 | 72 | 103 | 133 | 164 | 194 | 225 | 256 | 286 | 317 | 347 |
| **13** | 13 | 44 | 73 | 104 | 134 | 165 | 195 | 226 | 257 | 287 | 318 | 348 |
| **14** | 14 | 45 | 74 | 105 | 135 | 166 | 196 | 227 | 258 | 288 | 319 | 349 |
| **15** | 15 | 46 | 75 | 106 | 136 | 167 | 197 | 228 | 259 | 289 | 320 | 350 |
| **16** | 16 | 47 | 76 | 107 | 137 | 168 | 198 | 229 | 260 | 290 | 321 | 351 |
| **17** | 17 | 48 | 77 | 108 | 138 | 169 | 199 | 230 | 261 | 291 | 322 | 352 |
| **18** | 18 | 49 | 78 | 109 | 139 | 170 | 200 | 231 | 262 | 292 | 323 | 353 |
| **19** | 19 | 50 | 79 | 110 | 140 | 171 | 201 | 232 | 263 | 293 | 324 | 354 |
| **20** | 20 | 51 | 80 | 111 | 141 | 172 | 202 | 233 | 264 | 294 | 325 | 355 |
| **21** | 21 | 52 | 81 | 112 | 142 | 173 | 203 | 234 | 265 | 295 | 326 | 356 |
| **22** | 22 | 53 | 82 | 113 | 143 | 174 | 204 | 235 | 266 | 296 | 327 | 357 |
| **23** | 23 | 54 | 83 | 114 | 144 | 175 | 205 | 236 | 267 | 297 | 328 | 358 |
| **24** | 24 | 55 | 84 | 115 | 145 | 176 | 206 | 237 | 268 | 298 | 329 | 359 |
| **25** | 25 | 56 | 85 | 116 | 146 | 177 | 207 | 238 | 269 | 299 | 330 | 360 |
| **26** | 26 | 57 | 86 | 117 | 147 | 178 | 208 | 239 | 270 | 300 | 331 | 361 |
| **27** | 27 | 58 | 87 | 118 | 148 | 179 | 209 | 240 | 271 | 301 | 332 | 362 |
| **28** | 28 | 59 | 88 | 119 | 149 | 180 | 210 | 241 | 272 | 302 | 333 | 363 |
| **29** | 29 | 60 | 89 | 120 | 150 | 181 | 211 | 242 | 273 | 303 | 334 | 364 |
| **30** | 30 | | 90 | 121 | 151 | 182 | 212 | 243 | 274 | 304 | 335 | 365 |
| **31** | 31 | | 91 | | 152 | | 213 | 244 | | 305 | | 366 |

**Julian Calendar – Non-Leap Year**

| Day | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 32 | 60 | 91 | 121 | 152 | 182 | 213 | 244 | 274 | 305 | 335 | 1 |
| 2 | 2 | 33 | 61 | 92 | 122 | 153 | 183 | 214 | 245 | 275 | 306 | 336 | 2 |
| 3 | 3 | 34 | 62 | 93 | 123 | 154 | 184 | 215 | 246 | 276 | 307 | 337 | 3 |
| 4 | 4 | 35 | 63 | 94 | 124 | 155 | 185 | 216 | 247 | 277 | 308 | 338 | 4 |
| 5 | 5 | 36 | 64 | 95 | 125 | 156 | 186 | 217 | 248 | 278 | 309 | 339 | 5 |
| 6 | 6 | 37 | 65 | 96 | 126 | 157 | 187 | 218 | 249 | 279 | 310 | 340 | 6 |
| 7 | 7 | 38 | 66 | 97 | 127 | 158 | 188 | 219 | 250 | 280 | 311 | 341 | 7 |
| 8 | 8 | 39 | 67 | 98 | 128 | 159 | 189 | 220 | 251 | 281 | 312 | 342 | 8 |
| 9 | 9 | 40 | 68 | 99 | 129 | 160 | 190 | 221 | 252 | 282 | 313 | 343 | 9 |
| 10 | 10 | 41 | 69 | 100 | 130 | 161 | 191 | 222 | 253 | 283 | 314 | 344 | 10 |
| 11 | 11 | 42 | 70 | 101 | 131 | 162 | 192 | 223 | 254 | 284 | 315 | 345 | 11 |
| 12 | 12 | 43 | 71 | 102 | 132 | 163 | 193 | 224 | 255 | 285 | 316 | 346 | 12 |
| 13 | 13 | 44 | 72 | 103 | 133 | 164 | 194 | 225 | 256 | 286 | 317 | 347 | 13 |
| 14 | 14 | 45 | 73 | 104 | 134 | 165 | 195 | 226 | 257 | 287 | 318 | 348 | 14 |
| 15 | 15 | 46 | 74 | 105 | 135 | 166 | 196 | 227 | 258 | 288 | 319 | 349 | 15 |
| 16 | 16 | 47 | 75 | 106 | 136 | 167 | 197 | 228 | 259 | 289 | 320 | 350 | 16 |
| 17 | 17 | 48 | 76 | 107 | 137 | 168 | 198 | 229 | 260 | 290 | 321 | 351 | 17 |
| 18 | 18 | 49 | 77 | 108 | 138 | 169 | 199 | 230 | 261 | 291 | 322 | 352 | 18 |
| 19 | 19 | 50 | 78 | 109 | 139 | 170 | 200 | 231 | 262 | 292 | 323 | 353 | 19 |
| 20 | 20 | 51 | 79 | 110 | 140 | 171 | 201 | 232 | 263 | 293 | 324 | 354 | 20 |
| 21 | 21 | 52 | 80 | 111 | 141 | 172 | 202 | 233 | 264 | 294 | 325 | 355 | 21 |
| 22 | 22 | 53 | 81 | 112 | 142 | 173 | 203 | 234 | 265 | 295 | 326 | 356 | 22 |
| 23 | 23 | 54 | 82 | 113 | 143 | 174 | 204 | 235 | 266 | 296 | 327 | 357 | 23 |
| 24 | 24 | 55 | 83 | 114 | 144 | 175 | 205 | 236 | 267 | 297 | 328 | 358 | 24 |
| 25 | 25 | 56 | 84 | 115 | 145 | 176 | 206 | 237 | 268 | 298 | 329 | 359 | 25 |
| 26 | 26 | 57 | 85 | 116 | 146 | 177 | 207 | 238 | 269 | 299 | 330 | 360 | 26 |
| 27 | 27 | 58 | 86 | 117 | 147 | 178 | 208 | 239 | 270 | 300 | 331 | 361 | 27 |
| 28 | 28 | 59 | 87 | 118 | 148 | 179 | 209 | 240 | 271 | 301 | 332 | 362 | 28 |
| 29 | 29 | | 88 | 119 | 149 | 180 | 210 | 241 | 272 | 302 | 333 | 363 | 29 |
| 30 | 30 | | 89 | 120 | 150 | 181 | 211 | 242 | 273 | 303 | 334 | 364 | 30 |
| 31 | 31 | | 90 | | 151 | | 212 | 243 | | 304 | | 365 | 31 |

## 4.8 MODIS Images

MODIS has 36 bands, which bands number 1 and 2 aggregated in 250 meter measure spectral range from 620 nm to 876 nm , bands 3 through 7 aggregated in 500 meter measure spectral range of the 459 nm to 2155 nm and bands 8 through 36 in 1 km resolution measure spectral range of the 405 nm to14.385µm.

Table 4.2: Description of MODIS spectral bands

| Reflected Solar Bands | | | Emissive Bands |
|---|---|---|---|
| *Aggregated 250 m* | *Aggregated 500 m* | *1 km reflective solar bands* | *1 km thermal bands* |
| Band 1 (620-670 nm) | Band 3 (459-479 nm) | Band 8 (405-420 nm) | Band 20 (3.660-3.840 µm) |
| Band 2 (841-876 nm) | Band 4 (545-565 nm) | Band 9 (438-448 nm) | Band 21 (3.929-3.989 µm) |
| | Band 5 (1230-1250 nm) | Band 10 (483-493 nm) | Band 22 (3.939-3.989 µm) |
| | Band 6 (1628-1652 nm) | Band 11 (526-536 nm) | Band 23 (4.020-4.080 µm) |
| | Band 7 (2105-2155 nm) | Band 12 (546-556 nm) | Band 24 (4.433-4.498 µm) |
| | | Band 13L (662-672 nm) | Band 25 (4.482-4.549 µm) |
| | | Band 13H (662-672 nm) | Band 27 (6.535-6.895 µm) |
| | | Band 14L (673-683 nm) | Band 28 (7.175-7.475 µm) |
| | | Band 14H (673-683 nm) | Band 29 (8.400-8.700 µm) |
| | | Band 15 (743-753 nm) | Band 30 (9.580-9.880 µm) |
| | | Band 16 (862-877 nm) | Band 31 (10.780-11.280 µm) |
| | | Band 17 (890-920 nm) | Band 32 (11.770-12.270 µm) |
| | | Band 18 (931-941 nm) | Band 33 (13.185-13.485 µm) |
| | | Band 19 (915-965 nm) | Band 34 (13.485-13.785 µm) |
| | | Band 26 (1.360-1.390 µm) | Band 35 (13.785-14.085 µm) |
| | | | Band 36 (14.085-14.385 µm) |

## 4.9 MODIS product characterization

3.9.1 MODIS/Terra Surface Reflectance 8-Day L3 Global 250m SIN Grid V005

3.9.2 MODIS/Terra Land Surface Temperature/Emissivity 8-Day L3 Global 1km SIN Grid V005

### 4.9.1 MODIS/Terra Surface Reflectance 8-Day L3 Global 250m SIN Grid V005 (MOD09Q1)

The surface reflectance product is the input for product generation for several of the land products: Vegetation Indices (VIs), BRDF, Thermal Anomalies, Land cover, Snow/Ice

Cover, and LAI/Fpar. It is an estimate of the surface spectral reflectance for each band as it would have been measured at ground level if there were no atmospheric scattering or absorption. This product is a composite using eight consecutive daily 250 m images. The "best" observation during each eight day period, for every cell in the image, is retained. This helps reduce or eliminate clouds from a scene. The file contains the same spectral information as the daily file listed above, centered at 645 nm and 858 nm. There is one additional band of data for quality control. It has three layers and the layer 1 and 2 has been used for NDVI computation. It is an example of the MODIS Level 3 surface reflectance product at 250m resolution.

### 4.9.2 MODIS/Terra Land Surface Temperature/Emissivity 8-Day L3 Global 1km SIN Grid V005 (MOD11A2)

MODIS Land Surface Temperature and Emissivity (LST/E) products provide per-pixel temperature and emissivity values. LST is one of the key parameters in the physics of land surface processes, combining surface-atmosphere interactions and the energy fluxes between the atmosphere and the ground. The moderate resolution imaging spectroradiometer (MODIS) land surface temperature/emissivity product is created, using multiple methods. For land surfaces with high and stable emissivities, a view-angle dependent, split-window algorithm provides calculation of temperature to the nearest Kelvin. For land cover types with variable emissivity, surface temperature is calculated from daytime and night time observations in seven MODIS thermal infrared (TIR) bands using a statistical regression approach, a least-squares fit approach, or both. These MOD11A2 data are provided every 8 days as a gridded level-3 product in the Sinusoidal projection. It has twelve layers.

# CHAPTER FIVE

# METHODOLOGY

## 5.1 Introduction

This study has been carried out based on secondary data and field visits.

## 5.2 Methods of Pre-processing of Satellite Data

Integrated Land and Water Information System (ILWIS 3.4) software was used for image processing and spatial analysis. Using software MODIS Re-projection Tool (MRT) images were geo-referenced.

There are seven steps of pre-processing of Satellite data. These are-

- Conversion of HDF format to tif format
- Reprojection
- Subset
- Multification factor
- NDVI computed from model maker
- Inherited cloud problem with NDVI
- Layer stacking

### 5.2.1 Conversion of HDF format to “tif” format

The original MODIS data are provided in the Hierarchical Data Format (HDF-EOS). HDF is a multi-object file format for sharing scientific data in multi-platform distributed environments. Terra MODIS images are not geo-referenced and provided in a rectangular gird. All Terra MODIS images downloaded in raw format were geo-referenced using the software MODIS Re-projection Tools (MRT) is shown in figure 3.3. This HDF-EOS format image is exported to “tif” format using MRT tool.

### 5.2.2 Re-projection of raw images through geo-referencing and MODIS reprojection tool (MRT)

Terra MODIS images files are presented as Geo-TIF format. Geo-TIF formatted images are geo referenced to WGS-84 Coordinate system. A geo-referenced image of surface reflectance 0.25km (250m) resolution after carrying out processing with MODIS MRT software. MRT is a software tool that re-projects MODIS level-2G, level-3, and level-4 land data products. The MRT currently supports MODIS land products in the integerized Sinusoidal and Sinusoidal projections. After exporting all images it is subjected to reprojection. Version three MODIS data use the Integerized Sinusoidal projection and Version five MODIS data use the more common Sinusoidal projection with the WGS84 datum. MODIS surface reflectance image is in sinusoidal projection and WGS84 datum. Output image information for surface reflectance data given below-

INPUT FILENAME

D:\MODIS_SR_DATA\MODIS_SR_250\SR_2008_250\MOD09Q1.A2008217.h26v06.005.2008236130455.hdf

SPECTRAL_SUBSET= (1 1 0)

SPATIAL_SUBSET_TYPE= INPUT_LAT_LONG

SPATIAL_SUBSET_UL_CORNER= (26.8 87.8)

SPATIAL_SUBSET_LR_CORNER= (20.5 92.8)

RESAMPLING_TYPE=NEAREST NEIGHBOR

OUTPUT_PROJECTION_TYPE=GEO

DATUM=WGS84

### 5.2.3 Subset

Using layer of Bangladesh administrative boundary, subset area corresponds to Bangladesh has been done for all the images. study area were selected and imported to the integrated land and water information system(ILWIS) which is PC-based GIS and Remote sensing software, developed by ITC, Netherlands.

### 5.2.4 Multification Factor

Multification factor is different for land surface temperature as well as for surface reflectance. All the surface reflectance images have been multiplied by scale factor 0.0001 in model maker.

### 5.2.5 NDVI Computed from Model Maker:

Normalized difference vegetation index has been computed using two bands of surface reflectance image. In Surface reflectance image band 1 represents red and band 2 represents near infrared (wavelength).Mathematically it can be written as-

NDVI= (NIR-R)/ (NIR+R) that is (band2-band1)/ (band2+band1)

### 5.2.6 Inherited Cloud Problem with NDVI

The presence of clouds in satellite images is a significant obstacle to land surface studies. Undetected clouds distort the real reflectivity of the land surface and consequently develop into an additional source of error. Clouds in satellite images must thus be precisely identified prior to any further analysis. The total number of NDVI images processed is around four hundred for the period from 2000 to 2008 and out of these some images are cloudy.

### 5.2.7 Layer Stacking

After processing above steps, all the images are stacked.

## 5.3 Methods of Post-processing of Satellite Data Analysis

Five main methods of post-processing of satellite data analysis were adopted in this study. These are

- MODIS derived vegetation index: NDVI
- Development of a Classification Scheme Based on NDVI value
- Land cover category detection (Vegetation cover, mixed land cover and water bodies)
- Flash flood timing determination
- Calculation of the Area in square kilometers of the resulting land cover types for each study year and subsequently comparing the results.

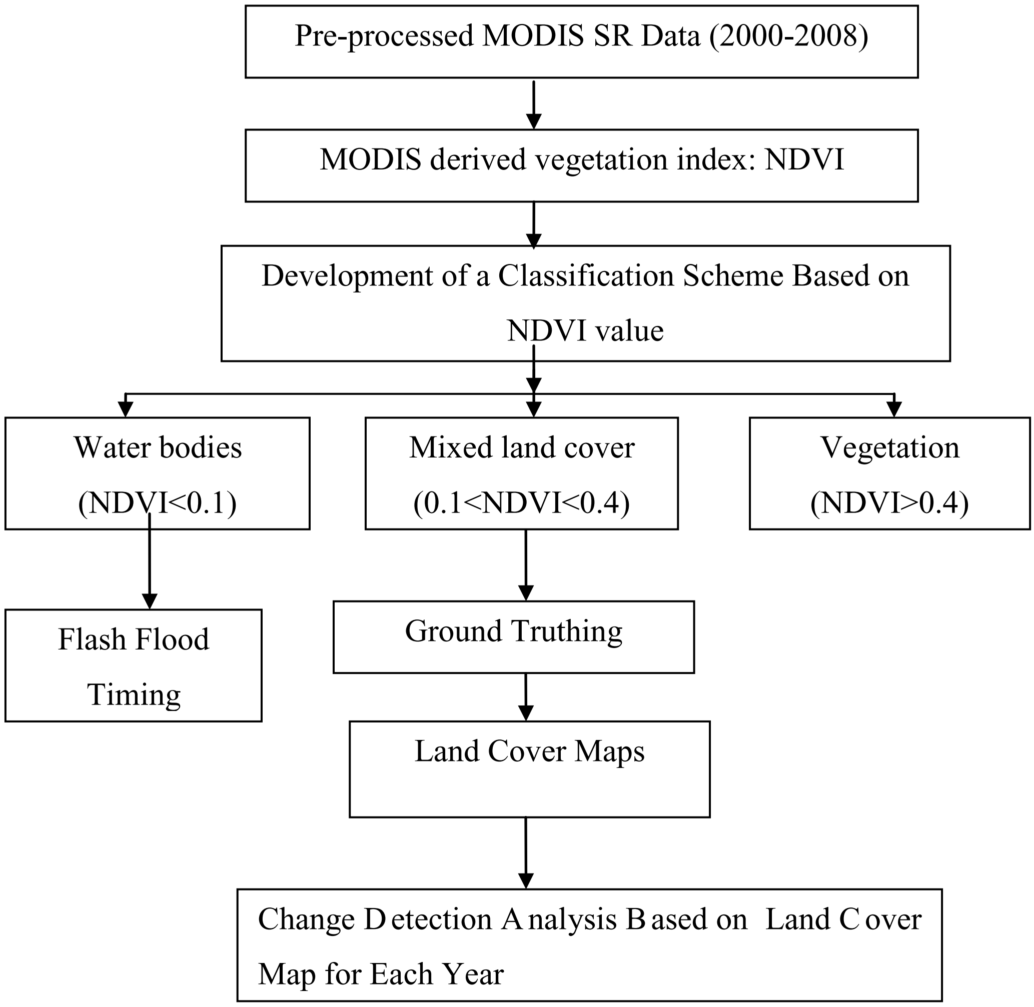



Figure 5.1: Post-processing of satellite MODIS data.

### 5.3.1 Normalized Difference Vegetation Index

It is a measure of the amount and vigour of vegetation at the surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigour and amounts of vegetation. The reason NDVI is related to vegetation is that healthy vegetation reflects very well in the near infrared part of the spectrum. For MODIS surface reflectance 250m resolution images, NDVI is universally defined as

$$NDVI = (\text{band } 2 - \text{band } 1) / (\text{band } 2 + \text{band } 1)$$

To derive the seasonal pattern of NDVI for 2000-2008, firstly, average NDVI for each year was computed by using following expression:

Average NDVIy = (NDVI1 + NDVI2 + ---------+NDVI5)/ 5

Where, NDVIy is NDVI for y year and NDVI1, NDVI2……….NDVI5 stands for NDVI of particular months in that year.

Mean NDVI for 9 years was then computed by using following expression

Mean NDVI = (Avg. NDVIy1+ Avg. NDVIy2+……………..+ Avg. NDVIy9)/ 9

Where, Average NDVIy1……….. Average NDVIy9 stands for the yearly average NDVI value for 9 years.

### 5.3.2 Development of a Classification Scheme Based on NDVI Value

Based on the priori knowledge of the study area for over 9 years, a brief reconnaissance survey with additional information from previous research in the study area NDVI (Normalized difference vegetation index), a classification scheme was developed for the study area. The classification scheme developed gives a rather broad classification where the land cover was identified by two digits after decimal of NDVI value. Three separable land cover types have been identified, that is, water bodies, vegetation, and mixed (bare soil/grassland).

Table 5.1: land cover classification scheme

| CODE | Land cover categories | NDVI value |
|---|---|---|
| 1 | Water body | $<0.1$ |
| 2 | mixed | $0.1<NDVI<0.4$ |
| 3 | vegetation | $>0.4$ |

### 5.3.5 Area Calculation

After counting NDVI value, pixel value was calculated based on NDVI value. Here one pixel represents 0.059 sq. km. Total area of each land cover was calculated multiplying total pixel by 0.059 sq. km.

## 5.4 Outline of the Methodology

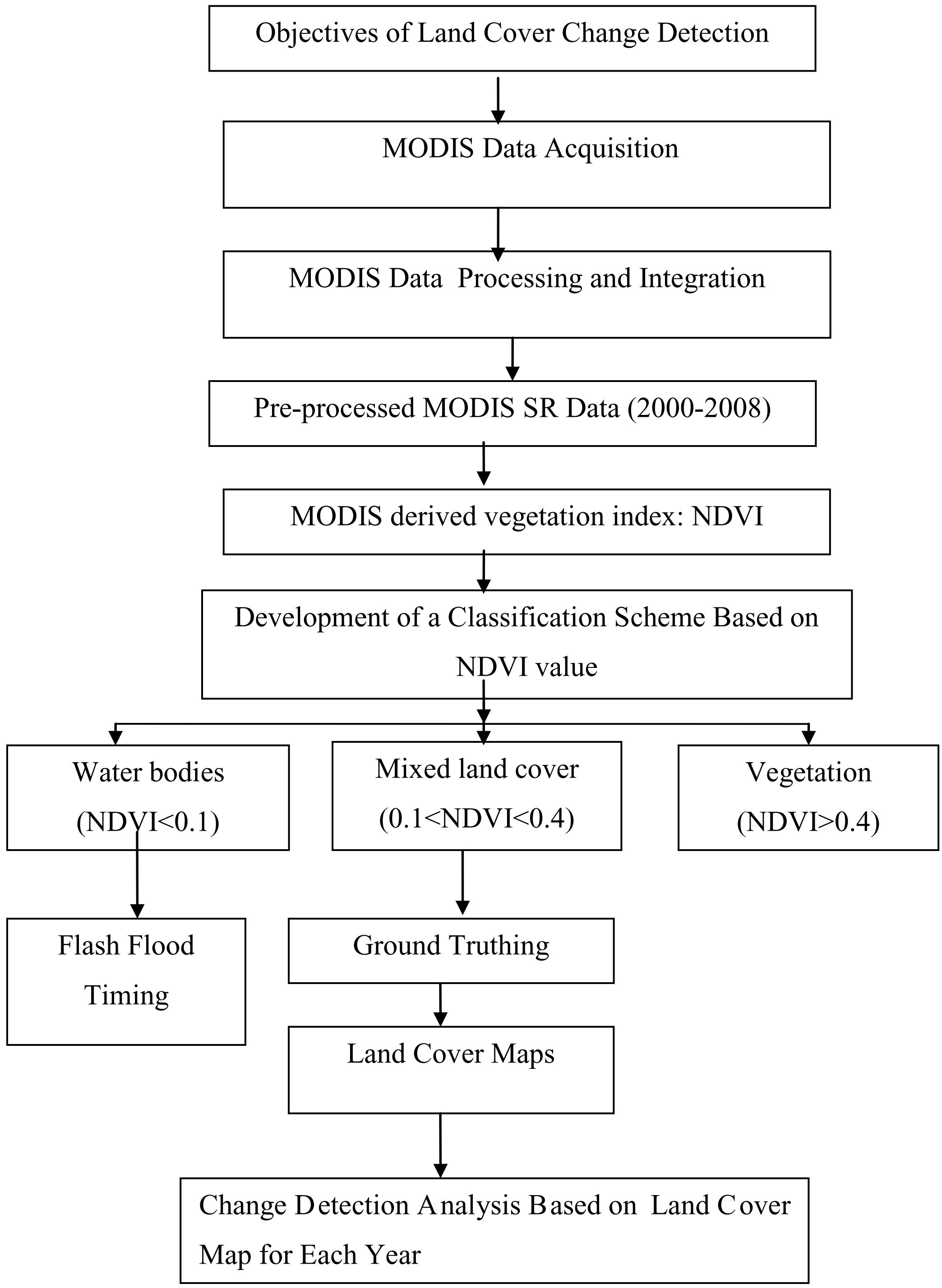



Figure 5.2 Schematic presentation of Methodology

### 5.5 Identifying Livelihood Group

Primarily the livelihood groups were identified through literature review. Then the preliminary identifications were refined and verified through field visit and Focus Group Discussion (FGD) of the study area. A focus group is a form of qualitative research in which a group of livelihoods are asked about their perceptions, opinions, beliefs and attitudes towards haor resources and haor area. Questions are asked in an interactive group setting where participants are free to talk with other group members. There are five livelihood groups that is farmer, boatman, fuel wood collector, fisherman and women are selected for focus group discussion in this study.

### 5.6 Software Used

Basically, the following Remote sensing and GIS packages have been used to perform the MODIS data processing and analysis. i.e.

- ILWIS 3.6-This was used for the development of land use land cover classes and subsequently for change detection analysis of the study area.
- Arc GIS 9.2- This was also used to compliment the display and processing of the data
- MODIS Reprojection Tool (MRT)
- Microsoft Excel for arrangement of data and producing different graphs.
- Microsoft word was used basically for the presentation of the research.

# CHAPTER SIX
# LIVELIHOODS IN THE HAOR AREA

## 6.1 Introduction

This chapter presents the livelihoods of the haor area. The following section outlines the background of livelihoods, sustainable livelihood, sustainable livelihood approach, sustainable livelihood assets/ capitals, livelihoods strategy, land cover dependant livelihoods, impacts on livelihood assets due to land cover changes.

## 6.2 Background on Livelihood

Conceptually, “livelihoods” connote the means, activities, entitlements and assets by which people make a living. Assets, in this particular context, are defined as not only natural/biological (i.e., land, water, common-property resources, flora, fauna), but also social (i.e., community, family, social networks, participation, empowerment, human (i.e., knowledge, creation by skills) and physical (i.e., roads, markets, clinics, schools, bridges). Livelihoods consist of the capabilities, assets – both material and social resources – and activities required for a means of living (FAO, 2005).

## 6.3 Sustainable Livelihood

The International Institute for Sustainable Development (IISD) defines sustainable livelihoods as being “concerned with people's capacities to generate and maintain their means of living, enhance their well-being, and that of future generations”

The definition used by the UK's Department of Foreign and International Development (DFID) incorporates these sentiments.
'A livelihood comprises the capabilities, assets (including both material and social resources), and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base' (Chambers, and Conway, 1992).

A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, and provide net benefits to other livelihoods locally and more widely, both now and in the future, while not undermining the natural resource base (FAO, 2005).

### 6.4 Sustainable Livelihood Approach

FAO has a broad mandate to assist people to achieve food security, which is facilitated by the use of an approach that focuses on the need to understand and promote sustainable livelihoods. The Sustainable Livelihoods Approach (SLA) is based on understanding people's assets, capacities and their livelihood activities. It goes beyond sectoral analyses and therefore better reflects people's realities. This makes it more useful for planning holistic programmes and actions that support rehabilitation and recovery after disasters

The SLA builds on five crucial concepts linked and assessed by using a set of equally important working principles.

Table 6.1: Five crucial concepts of SLA

| **Key concepts (5)** | **Key principles (7)** |
|---|---|
| Livelihood assets | People-centred |
| Vulnerability context | Sustainability-focused |
| Institutional context | Holistic |
| Livelihood strategies | Partnership-based implementation |
| Livelihood outcomes | Links the micro with the macro |
| | Dynamic |
| | Builds on strengths |

### 6.5 Sustainable Livelihood Capitals or Assets

Capitals are considered to be stocks of different types of assets that can be used directly or indirectly to generate livelihoods. They can give rise to a flow of output, possibly becoming depleted as a consequence, or may be accumulated as a surplus to be invested in future productive activities.

People and their access to assets are at the heart of livelihoods approaches. In the original DFID framework, 5 categories of capital or assets are identified, although subsequent adaptations have added others, such as political assets (power and capacity to influence decisions).

Based on the five types of assets identified by the sustainable livelihood framework, five assets are identified:

**Natural assets:** consists of land, water and biological resources such as trees, pasture, and biodiversity. The productivity of these resources may be degraded or improved by human management**.** Natural resources such as land, soil, water, forests and fisheries.

**Financial assets:** Consists of stocks of money or other savings in liquid form. In this sense it does not includes financial assets only but should also include easily disposable assets such as livestock, which in other senses may be considered as natural assets. It includes **i**ncome levels, variability over time, and distribution within society of financial savings, access to credit, and debt levels. Financial resources including savings, credit, and income from employment, trade and remittances.

**Physical assets:** It includes infrastructure such as roads, irrigation works, water & sanitation, schools, ICT; and producer goods, electricity, tools, reticulated equipment and housing.

**Human assets:** is constituted by the quantity and quality of labour available. At household level, therefore, it is determined by household size, but also by education, skills, and health of household members**.** E.g. skills, knowledge, health and ability to work.

**Social assets:** Any assets such as rights or claims that are derived from membership of a group. This includes the ability to call on friends or kin for help in times of need, support from trade or professional associations (e.g. framers' associations) and political claims on chiefs or politicians to provide assistance (Carney, 1998*) .e.g.* social resources, including informal networks, membership of formalized groups and relationships of trust that facilitate co-operation

Assets can be destroyed or created as a result of the trends, shocks and seasonal changes in the vulnerability context within which people live. Policies, institutions and processes can have a great influence on access to assets - creating them, determining access, and influencing rates of asset accumulation. Those with more assets are more likely to have greater livelihood options with which to pursue their goals and reduce poverty.

Livelihood assets refer to the resource base of the community, and different categories of households, and are often represented as a pentagon in the SLA framework.

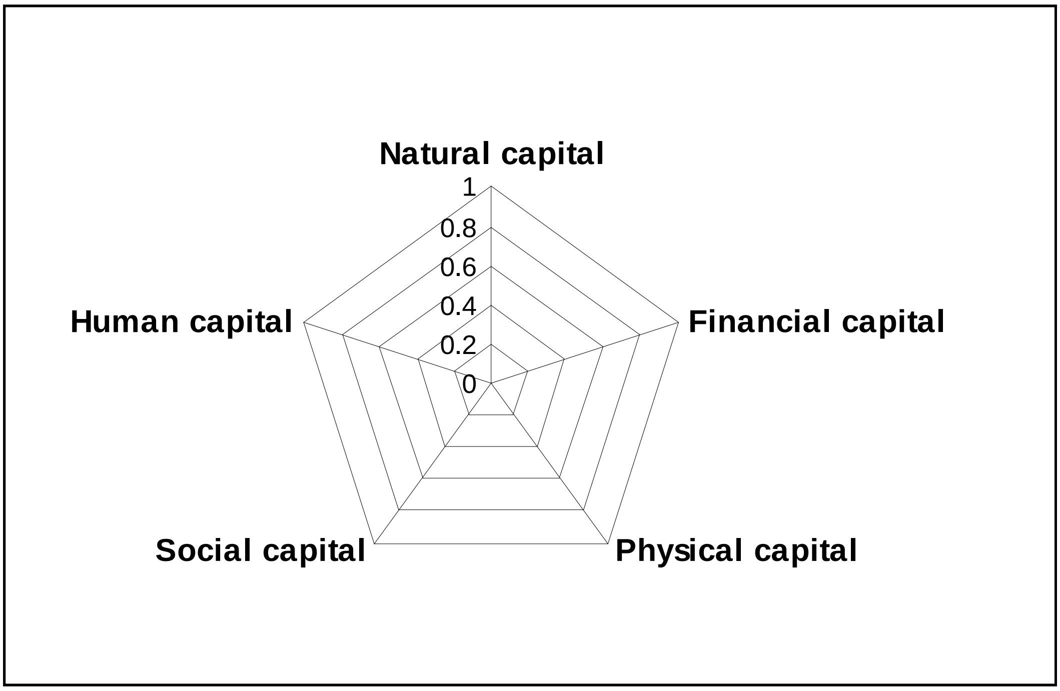



Figure 6.1: livelihood pentagon

**6.6 Identifying Land Cover Dependent Livelihoods Group of Haor area**

Primarily we identified 8 livelihood groups which were;

1) Farmer (Landless and marginal)
2) Fisherman
3) labour
4) Fuel wood collector
5) Boatman (Majhi)
6) Crab collector
7) Medicinal plant collector
8) Women (vulnerable group) etc.

After field observation and FGD we have found that in practical these resource extractors have diversified their livelihood opportunity by extracting different types of resources in responding to decreasing productivity status of Haor area.

Taking the interviews, FGD, Household survey, we have broadly classified the livelihood groups in to five as;

1) Farmer (Landless and Marginal)
2) Labour
3) Fishermen
4) Boatman and
5) Women.

### 6.7 Livelihood Assets

In this study, livelihood has been defined in the notion of five Assets following the sustainable livelihood framework. Livelihood Assets have been categorized in to five groups as; natural, physical, financial, social and human. For all of the livelihood groups, Haor is the vital assets but recognized differently. Social and physical assets play important role to increase livelihood resilience. The livelihood assets were identified through FGD.

### 6.8 Livelihood Assets Profile of Haor Area

A summary analysis for the study area using the assets polygon is presented in Figure 6.2

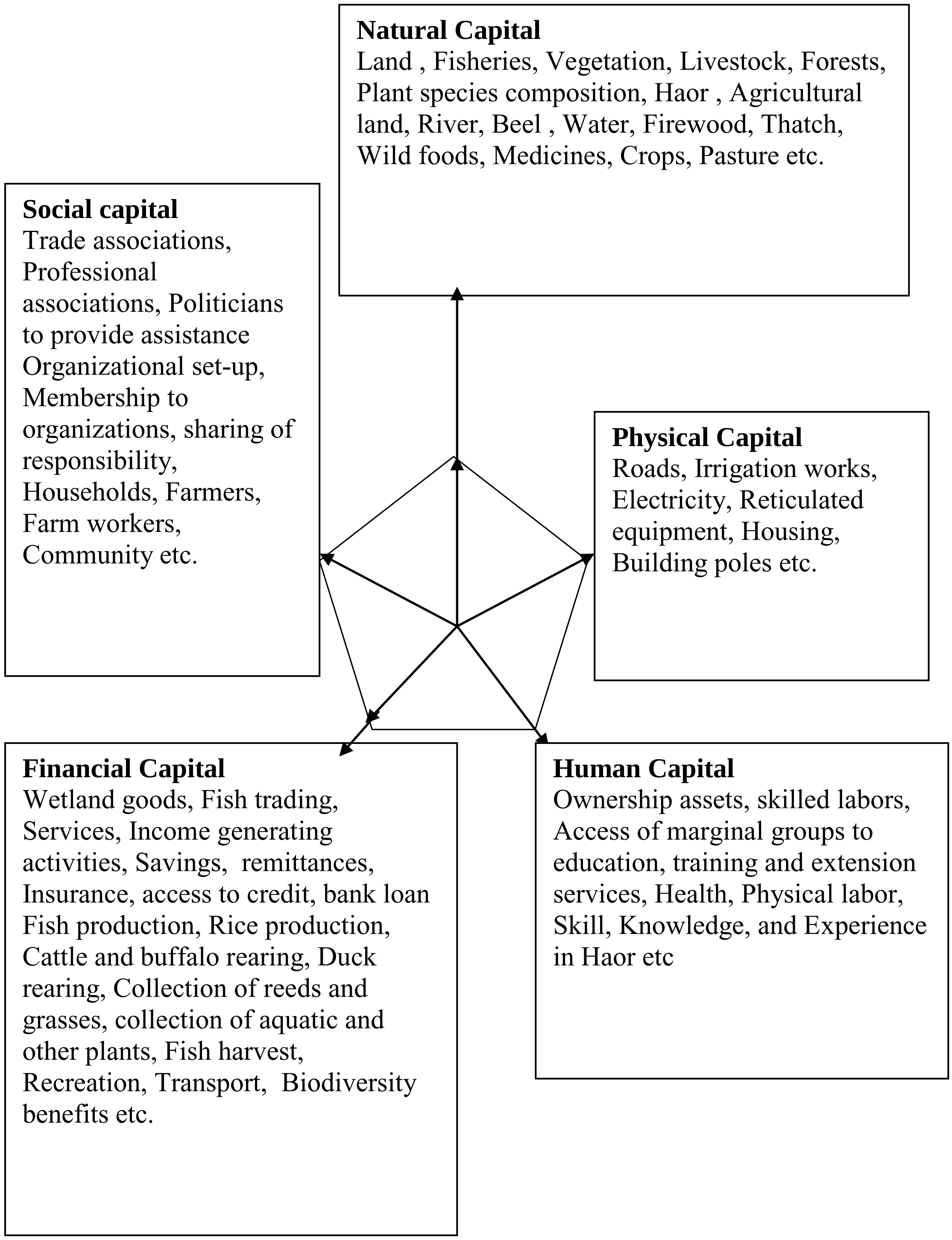



Figure 6.2: Livelihood Assets polygon for the study area (Haor area in Bangladesh)

**CHAPTER SEVEN**

**RESULTS AND DISCUSSIONS**

## 7.1 Introduction

The objective of this study forms the basis of all the analysis carried out in this chapter. The results are presented inform of maps, charts and statistical tables. They include the static, change and projected land cover of each class.

## 7.2 Normalized Difference Vegetation Index (NDVI)

NDVI provides a measure of the amount and vigor of vegetation at the land surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of vegetation. So, the normalized difference vegetation index (NDVI) provides us with an indication of how much green vegetation exists at a particular place on the ground.

As we know that whether NDVI value is maximum, vegetation is maximum and water bodies is minimum. Studies have shown that the NDVI value is minimum in 2004, 2000 and 2002 is about 0.32, 0.34 and 0.35 respectively whereas in 2003 and 2006, the NDVI value is maximum (Figure 7.1). The previous study shows that mostly affected flash flood year is 2002 and 2004 which this analysis provides the water bodies values is maximum in this same year.

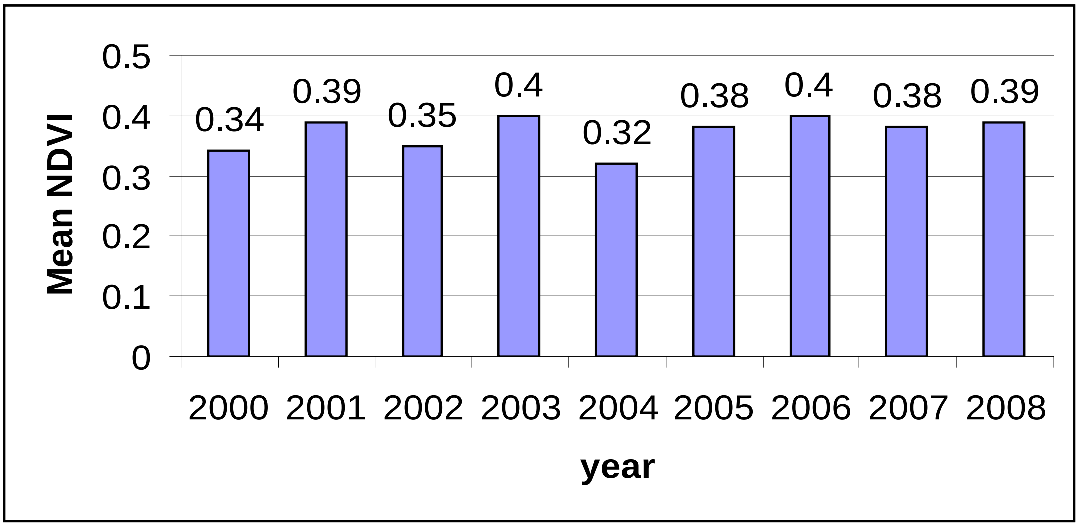



Figure 7.1: NDVI change pattern of the study area from 2000 to 2008

### 7.3 Land Covers Change Patterns in the Dry Seasons and Wet Seasons from 2000 to 2008

Analysis revealed that in the dry season, the vegetation cover area is maximum in the haor area where as water bodies are minimum or low (Figure 7.2). In the wet season, (figure 7.3 ) the vegetation cover is decreasing trends where as the water bodies is increasing trends. The pixel number of vegetation cover during dry season is more or less constant with minimum difference. On the other hand, in wet season, the number of pixel is fluctuated with a downward trend. In 2002, the vegetation cover area is highest in dry season whereas in wet season it is the lowest. Similarly Mixed land cover and water body has drastic difference in change pattern during dry and wet season.

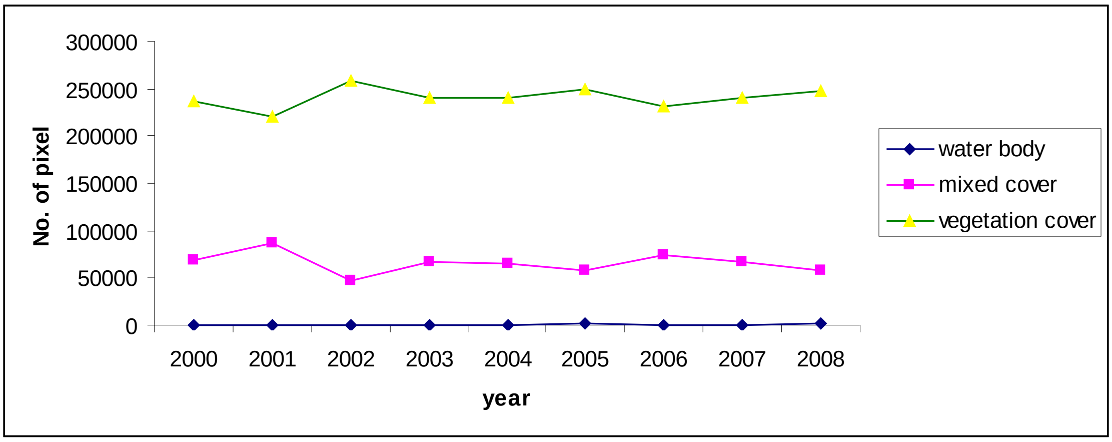



Figure 7.2: Land cover changes in Dry season (February) from 2000 to 2008

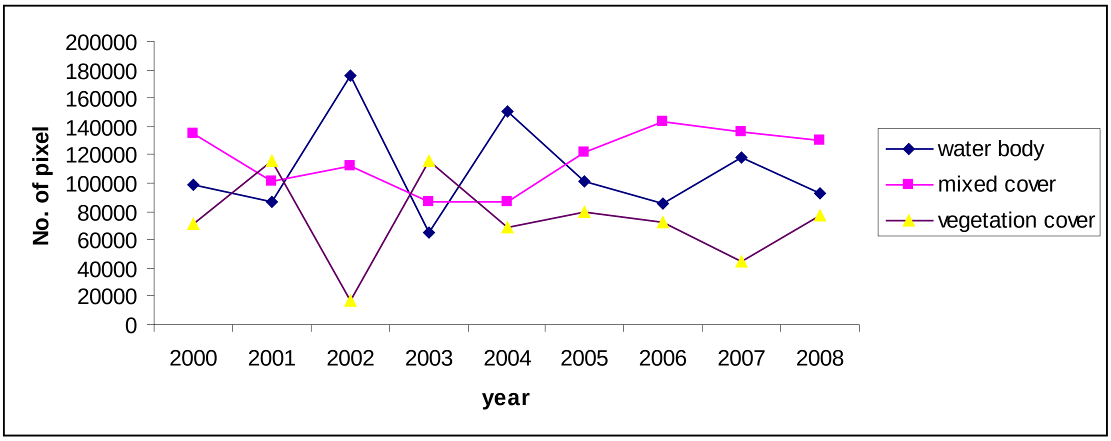
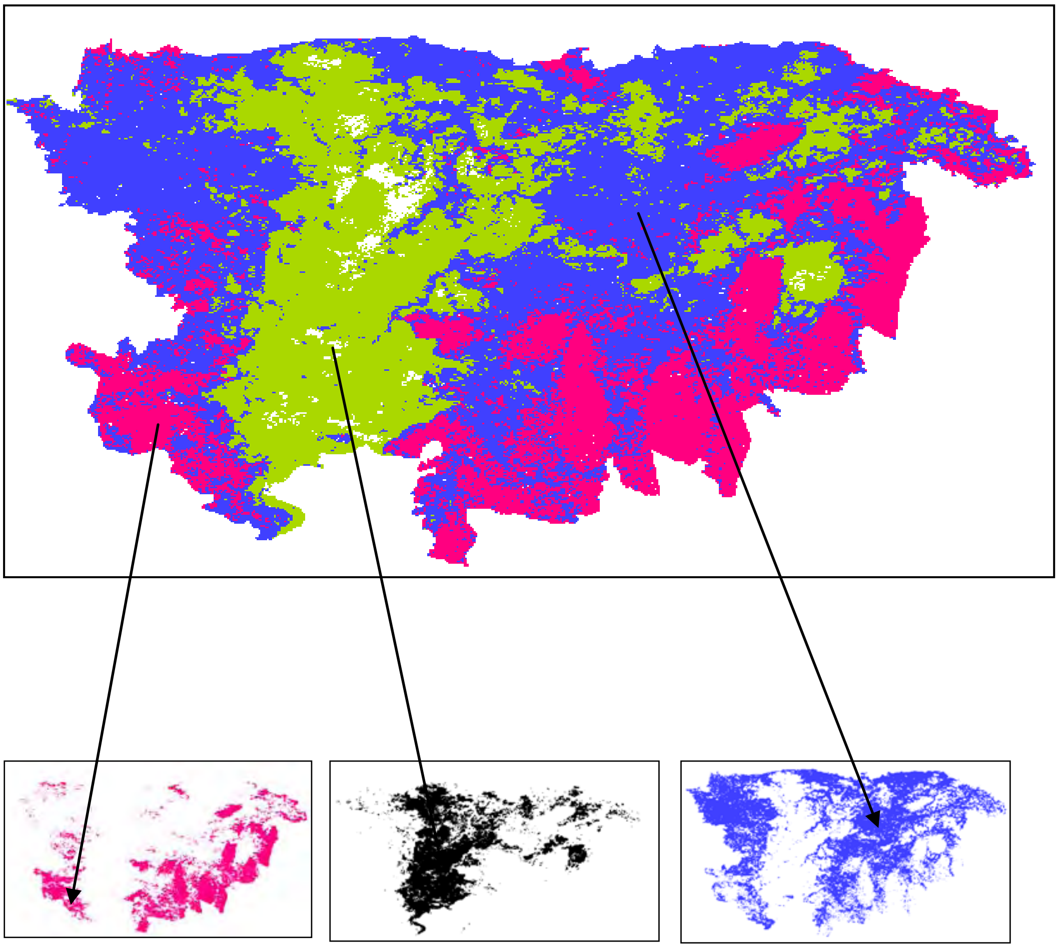



Figure 7.3: Land cover changes in Wet Season (July) from 2000 to 2008

## 7.4 Extraction of Land Covers Categories from Original NDVI Images

Due to moderate resolution sensor of MODIS/TERRA, a pixel can be composed of various mixture types of land surface (Figure 7.4). If the NDVI value is less then 0.1 it's found to be water pixel. If NDVI value is greater than 0.4, it's consider as vegetative land cover. And in between 0.1 and 0.4, it's identified as mixed land cover type.



**Vegetation July, 2006** **waterbody_july, 2006** **Mixed_july, 2006**

Figure 7.4: Extraction of different land cover (water bodies, vegetation and mixed land cover) from NDVI original images

## 7.5 Land Cover Change Patterns on the Basis of Pixel Information of MODIS Images from 2000 to 2008

The monthly change of pattern in vegetation cover is similar except in 2000, 2002 and 2004 (Figure 7.5). Water body remains at zero level from January to March and then starts to rise and again goes downward from August. Mostly it is highest in June and July (Figure 7.6). The mixed land cover area is highest in December and January and starts to goes downward from January to April and then again starts to rise upward from April to September (Figure 7.7).

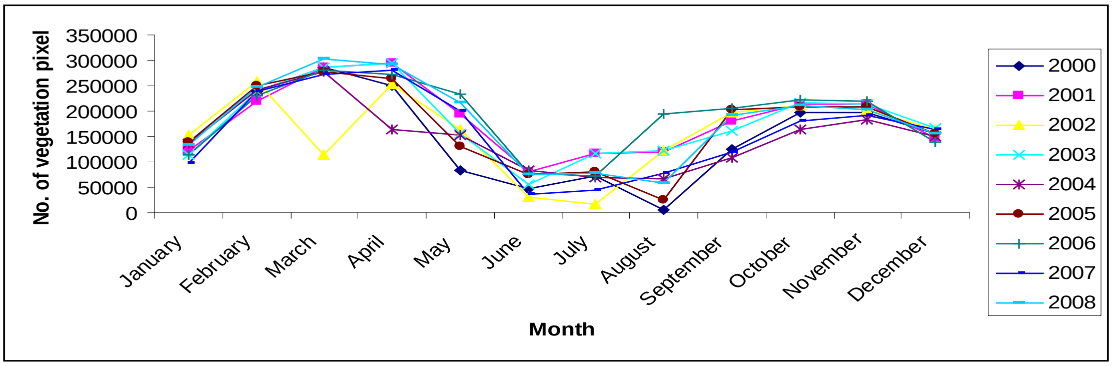



Figure 7.5: Monthly vegetation change of the Haor area from 2000 to 2008

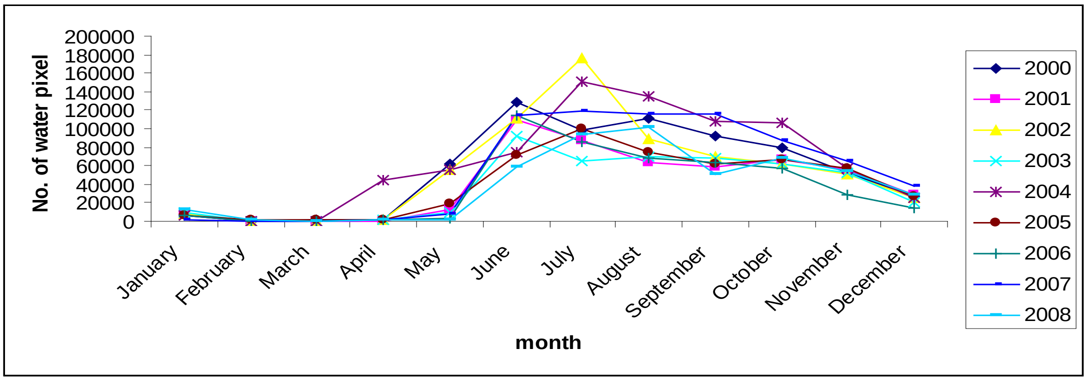



Figure 7.6: Monthly water body changes of the Haor area from 2000 to 2008

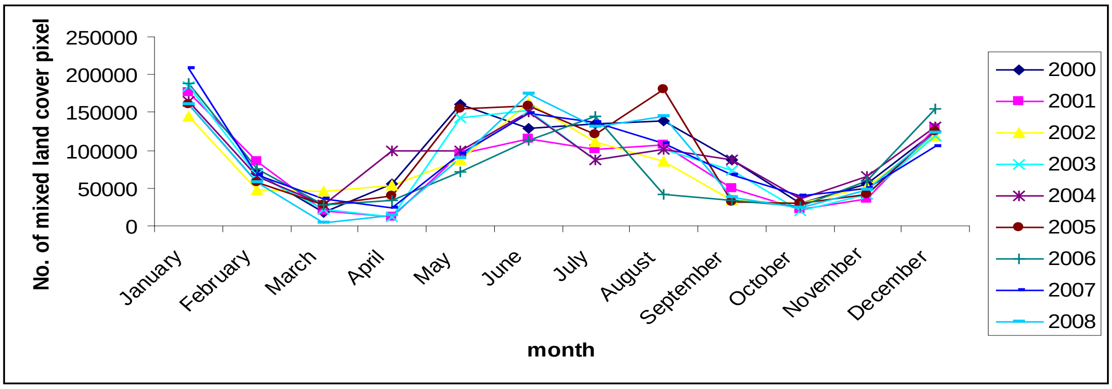
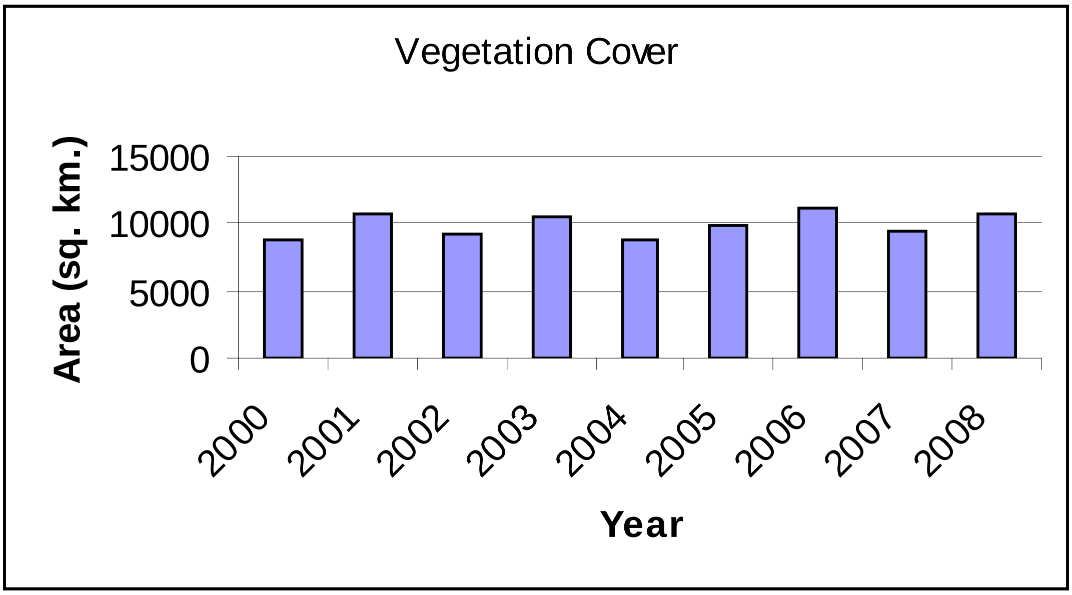



Figure 7.7: Monthly mixed land cover changes of the Haor area from 2000 to 2008

### 7.6 Vegetation Cover Changes of the Haor Area



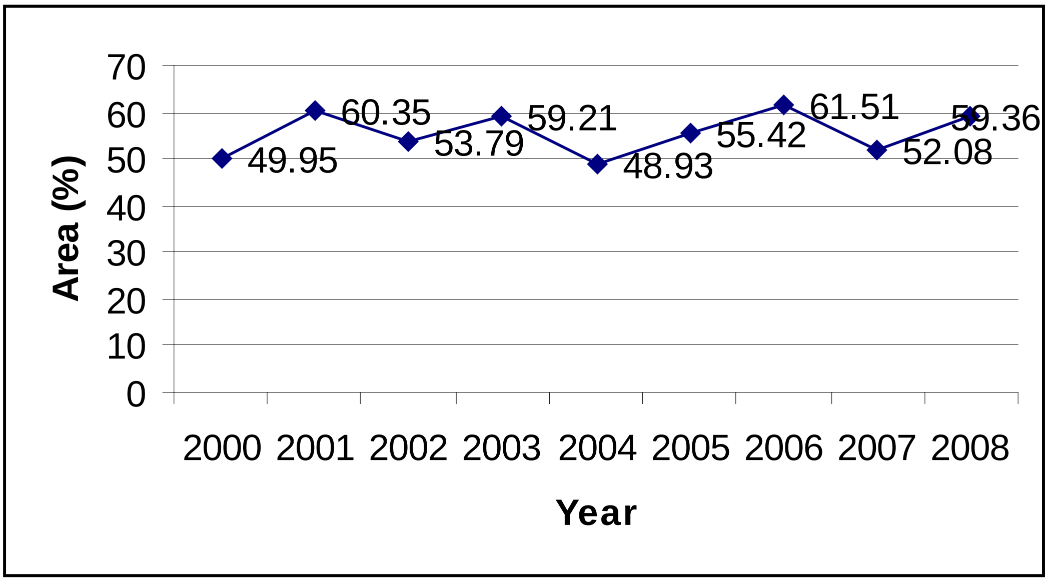




Figure 7.8: Vegetation Cover changes of the Haor Area from 2000 to 2008

It is found that land cover in the study area has been changed since 2000. Analysis revealed that the vegetative cover area has increased to about 8.35% compared to the 2000 vegetative cover areas whereas in 2000 (8880.892 sq. km.) and 2008 (10635.64 sq. km) (Figure 7.8).

### 7.7 Water Bodies Changes of the Haor Area

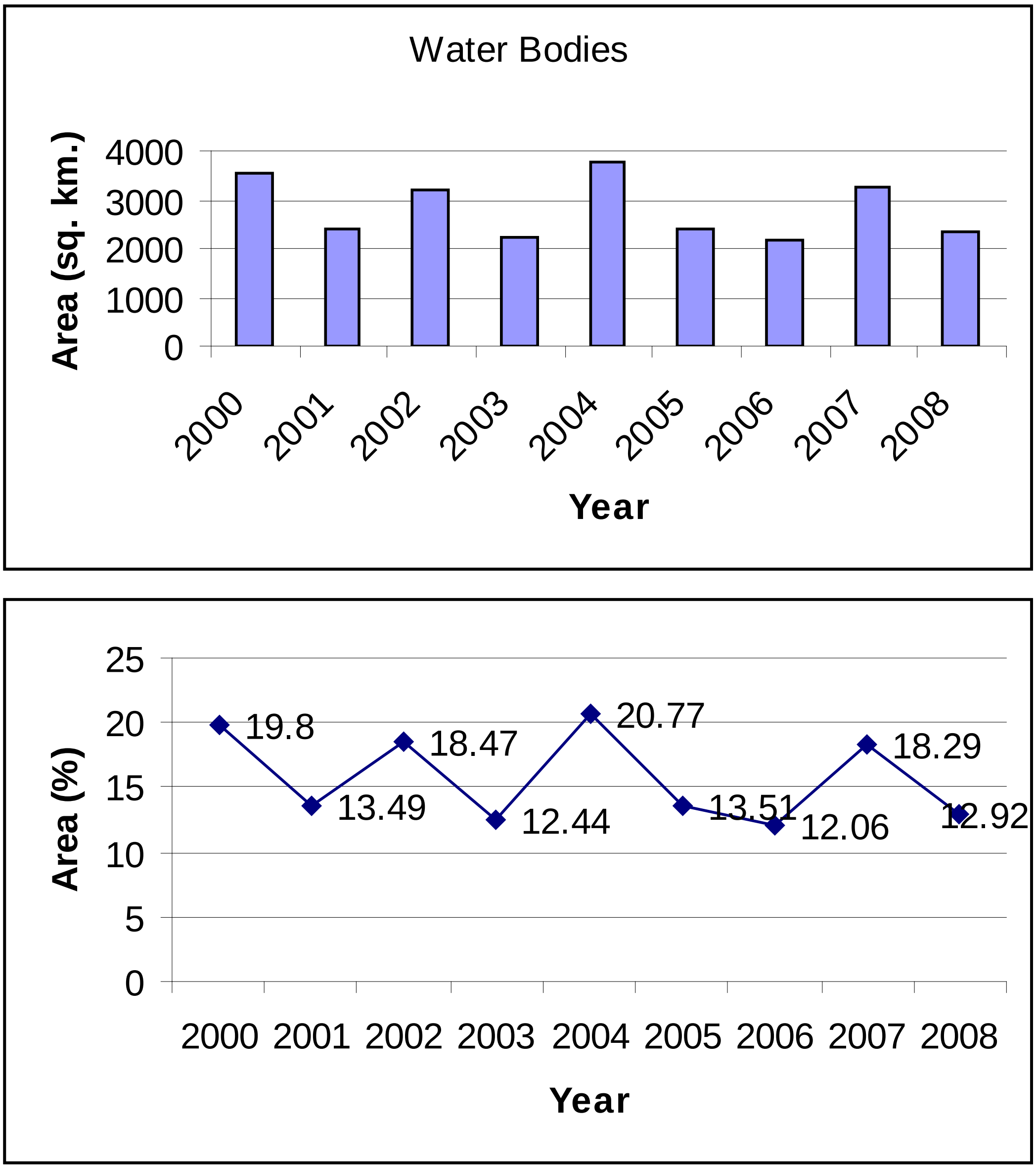



Figure 7.9: Water Bodies Changes of the Haor Area from 2000 to 2008

From the analysis of the water bodies' images, it was found that the water bodies has been reduced greatly and converted to other land cover areas (figure 7.9). In 2000.the water bodies are is about 19.8% of total land cover of haor area which is decreasing about 6.88% in 2008.

### 7.8 Mixed land Cover Changes of the Haor Area

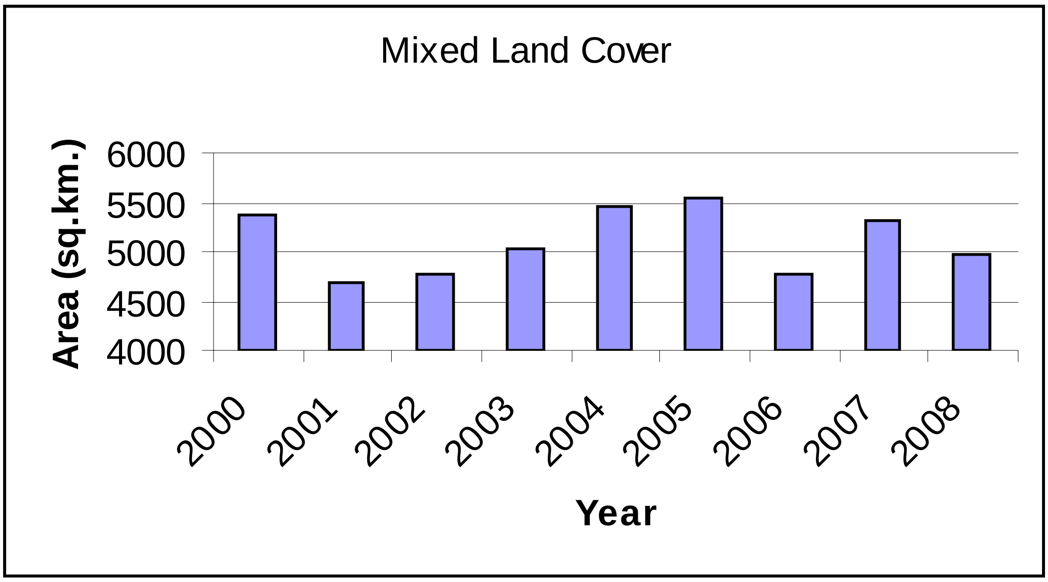



Figure 7.10: Mixed Land Cover Changes of the Haor Area from 2000 to 2008 (sq. km.)

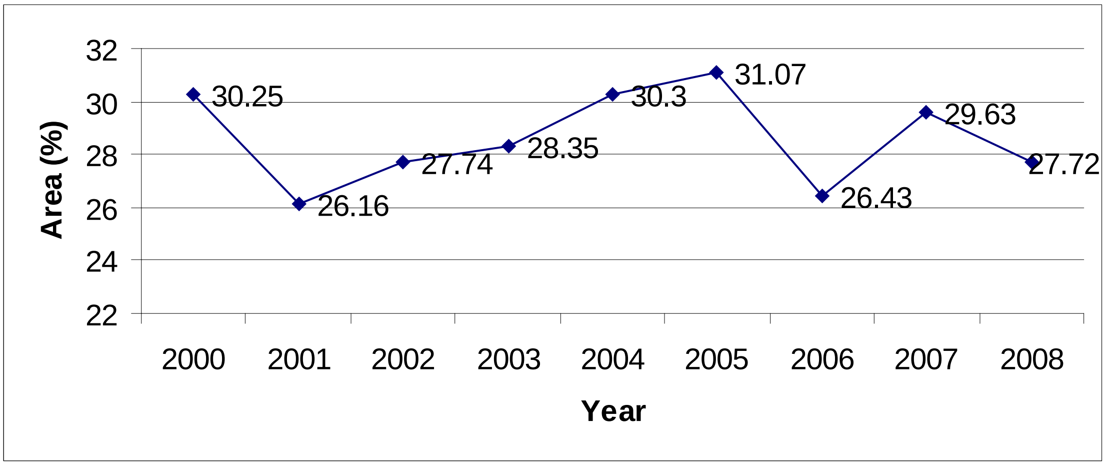



Figure 7.11: Mixed Land Cover Changes of the Haor Area from 2000 to 2008 (%)

Analysis revealed that the change pattern of mixed land cover is somewhat unchanged except 2001 and 2006 (Figure 7.10). It is almost same in 2001 and 2006. From 2001 to 2005, the percentage area of mixed land cover increases (Figure 7.11).

### 7.9 Land Cover Change Pattern of Study Area from 2000 to 2008

The figure 7.12 shows that land cover change has a regular pattern. Every year after the vegetation cover is increasing only in 2006 instead of decreasing it has increased. Then when the vegetation cover increases, the water body rises. For example when in 2001, the vegetation cover rises from 8880.892 sq. km to 10782.09 sq. km, the water bodies decrease from 3519.784 sq. km to 2410.312 sq. km. on the other hand, the changes of mixed land cover is almost negligible. Also in 2006, the vegetation cover is 11106.27 sq. km, the highest when the water body is 2176.75 sq. km, the lowest. The change in mixed land cover does not very much from year to year. the highest difference is 4 % which oc curred i n 2001 a nd 2006. In 2002, 20 03 a nd 2005 t he c hange i s a lmost negligible that is only 1% increases (Table 7.1).

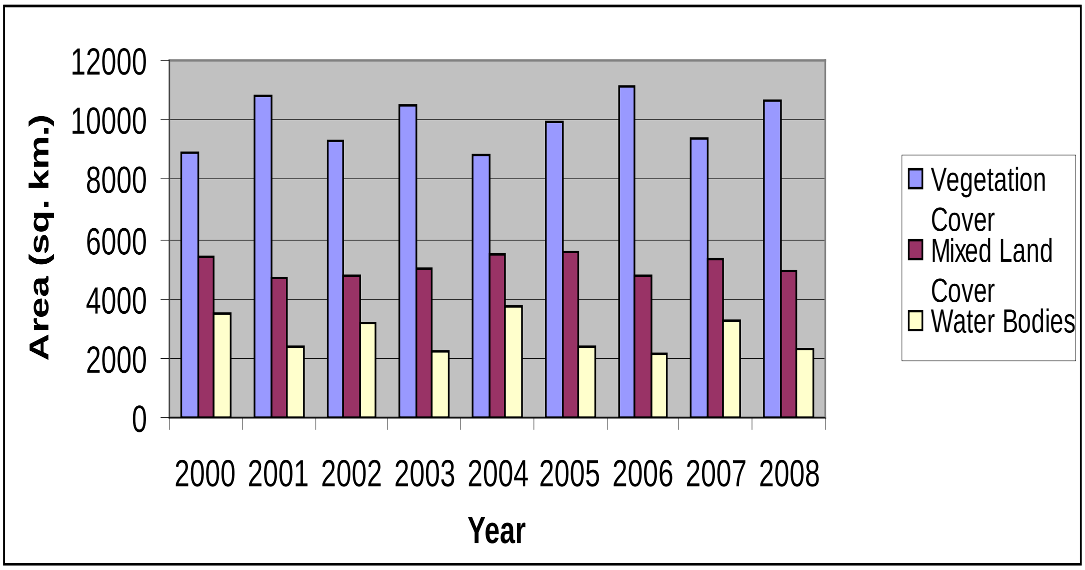



Figure 7.12: Land Cover Change patterns of the Haor Area from 2000 to 2008

The ve getation c over changes i ts a rea t hough r egularly as de scribed e arlier but t he difference i s not iceable. F or i nstance, the area of ve getation cover i ncreases 11% i n 2001 f rom t hat of 200 0. M oreover i n 2004, t hough t he di fference i s 11% i t ha s decreased from t hat of previous year (Table 7. 1). t he w ater bodi es also ha s r egular changes though in 2006 the change is really negligible that is 1% , whereas in 2007 and 2008, the differences of change remains equal by getting increased by 6% and lowered by 6% (Table 7.1).

.

**Table 7.1** Area and Percentage of Land Cover types from 2000 to 2008

| Land Cover Categories | **Year from 2000-2008** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | |
| | Area (sq. km) | % | Area (sq. km) | % | Area (sq. km) | % | Area (sq. km) | % | Area (sq. km) | % | Area (sq. km) | % | Area (sq. km) | % | Area (sq. km) | % | Area (sq. km) | % |
| Vegetation Cover | 8880.892 | 49.95 | 10782.09 | 60.35 | 9274.027 | 53.79 | 10503.3 | 59.21 | 8834.754 | 48.93 | 9909.038 | 55.42 | 11106.27 | 61.51 | 9352.609 | 52.08 | 10635.64 | 59.36 |
| Mixed Land Cover | 5379.148 | 30.25 | 4673.985 | 26.16 | 4782.791 | 27.74 | 5029.495 | 28.35 | 5470.613 | 30.30 | 5555.307 | 31.07 | 4772.461 | 26.43 | 5321.161 | 29.63 | 4966.418 | 27.72 |
| Water bodies | 3519.784 | 19.80 | 2410.312 | 13.49 | 3184.707 | 18.47 | 2206.876 | 12.44 | 3750.871 | 20.77 | 2414.851 | 13.51 | 2176.751 | 12.06 | 3283.605 | 18.29 | 2315.253 | 12.92 |
| Total | 17779.82 | 100 | 17866.39 | 100 | 17241.52 | 100 | 17739.67 | 100 | 18056.24 | 100 | 17879.2 | 100 | 18055.48 | 100 | 17957.38 | 100 | 17917.31 | 100 |

### 7.10 Flash Flood of the Haor Area

### 7.10.1 Introduction

A flood, which is caused by heavy or excessive rainfall in a short period of time over a relatively small upstream area, is referred to as flash flood. In flash flood, water level rises and falls quite rapidly with little or no advance warning. typically, flash flood occurs in area where the upstream basin topography is relatively steep and the concentration time of the basin is relatively short. In Bangladesh, flash floods generally occur in the north-east.. But devastating and extended flash flood is a recurrent phenomenon for the north-eastern haor region of Bangladesh. The extreme flashy character of the hilly rivers and sudden excessive rainfall in the region causes frequent flash floods. In the haor area, flash flood comes from the very steep uplands adjacent to the region in Meghalaya hills in India causing immense damage to the standing crops and properties. Flash flood occurs in this area almost every year. Intensity differs from year to year and intra basin locations. In most cases, flood water comes into the haor very early in the monsoon and farmers do not get sufficient time to harvest the standing boro crops. For reducing the flash flood risk, the flash flood timing is very important. This is help to the community peoples to take appropriate measures against devastating flash flood. Flash flood timing is very important which is finding out from the consecutive 8-days MODIS images between 2000 and 2008.

### 7.10.2 Flash Flood Timing from MODIS Images Analysis

Flash flood is a common phenomenon in Haor. It has been reported that theses floods occur quite frequently, sometimes in years in a row and on other occasions intermittently. Satellite images have been analyzed to find out the flash flood timing (Appendix XVII).

### 7.10.3 Flash Flood Timing Analysis

To identify the flash flood timing in the study area MODIS images are used. The images are taken with 8 days interval from 2000 to 2009. Now, by calculating the water pixel of theses images the flow of flash flood in and out of the study area has been found. For example, the image taken on 22nd April of 2000 shows negligible amount of water pixel which shows that the flood has yet not occurred (Appendix XVII). But the very next image taken after 8days shows abundant amount of water pixel determining the period of flash flood. However, the next MODIS image taken after 8 days interval on 8th May, the water has flowed away from the study area which is determined by the counting of number of water pixel of the image.

Table 7.2: Flash Flood damages of the haor area

| Year | Extent of damage | Households | |
|---|---|---|---|
| | | affected | Not affected |
| 2000 | 70% | | |
| 2001 | 75% | | |
| 2002 | 70% | 40.25% | 59.75% |
| 2003 | 20% | 0.75% | 99.25% |
| 2004 | 90% | 99.75% | 0.25% |
| 2005 | 15% | 25.00% | 75.00% |
| 2006 | | 10.25% | 89.75% |
| 2007 | | 51.50% | 48.50% |

From the Table 7.3, in 2000 the flash flood enters into the study area on 30th April and exit water from the study area on 8th May. It becomes totally devastating if the flood hits haor area in early April. Analysis explored that the flash flood damages are maximum in 2000, 2002, and 2004 and in these year the flash flood has occurred in the hair area in April and also become the duration of the flash flood was maximum. The extent of flash flood damages is maximum in 2004 (90%), 2002(70%) and 2000(70%) (Table 7.2).

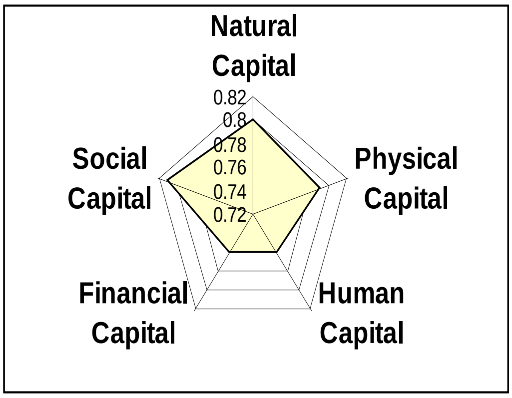
Table 7.3: Flash Flood Timing of the haor area

| Year | **Flood water enter the Haor** (Source: community response and DAE sunamganj) | **8-days interval MODIS images analysis** | | **Duration of the flash Flood** |
|---|---|---|---|---|
| | | Flash flood water enter(starting date) | Flash F lood water ex it (ending date) | |
| 2000 | 28April-30 April | 2000121(30, April) | 2000129(08, May) | 9-days |
| 2001 | 27 pril-30 April | 2001121-2001129 (01-09,May) | 2001137(17, May) | 12-days |
| 2002 | 14 April-18 April | 2002105(15, April) | 2002113(23, April) | I weeks (7-days) |
| 2003 | 27 May-30 May | 2003145-153 (25,May-2,june) | Mingle w ith normal flood | Mingle with normal flood |
| 2004 | 13 April-15 April | 2004105 ( 14, April) | 2004121(30, April) | 17-days |
| 2005 | 22 May-25 May | 2005137 ( 17, May) | 2005153 ( 02, June) | 17-days |
| 2006 | | 2006153 ( 02, June) | Mingle w ith normal flood | Mingle with normal flood |
| 2007 | | 2007153 ( 02 June) | Mingle w ith normal flood | Mingle with normal flood |
| 2008 | | 2008153 ( 01, June) | 2008161 ( 09, June) | 1 Weeks |

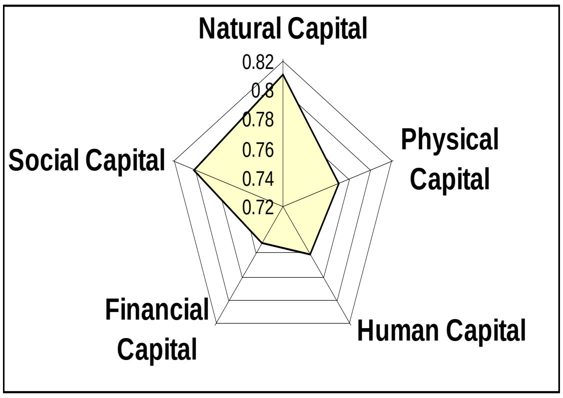
## 7.11 Livelihoods of the haor area

### 7.11.1 Livelihood pentagon of five groups of the haor area

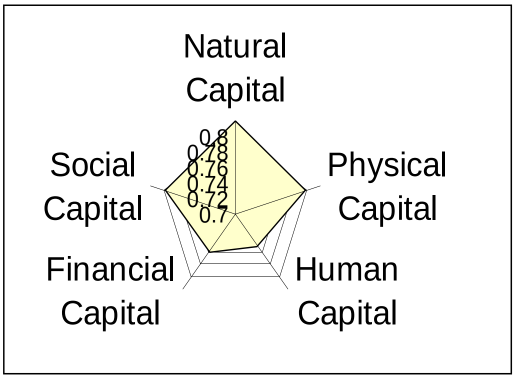
From the analysis of the capitals (Appendix XIX) of each group in a frame to indicate the accessibility of the groups to the livelihood assets, the livelihood pentagons of are illustrated below-



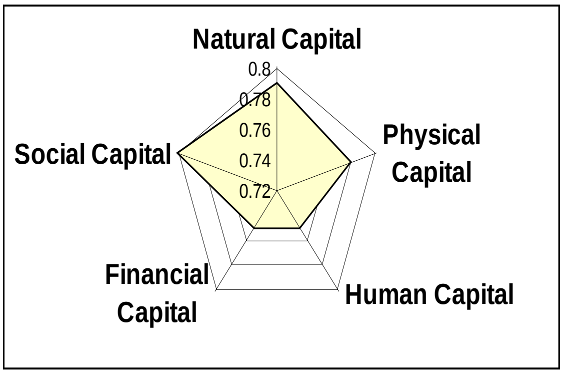

**Farmer groups**



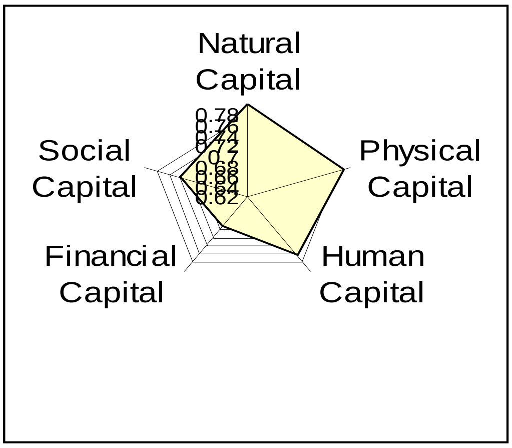

**Laborer group**




**Fisherman group**




**Boatman group**




**Women group**

Figure 7.13: Livelihood pentagon change pattern before land cover changes

### 7.11.2 Impact of Land Cover Changes on Livelihood Assets

Land cover is likely to change the productivity of Haor area that will affect livelihood assets of Farmer, Boatman; Fisherman, Raw material collector etc. Different livelihood assets are likely to be impacted in different ways. The livelihoods dependent on haor area are affected due to land cover changes by different ways. The impacts or problems are identified by FGD and interviews. This information of problems is generated from each focus group belonging to different areas. The identified Problems of different livelihood groups of haor area due to land cover changes are –

1. food insecurity
2. depletion of fish stock
3. homes and homestead lands are threatened by erosion
4. degradation of aquatic tress, vegetation
5. lack of employment opportunities
6. shortage of sanitary latrines
7. lack of access to formal education
8. shortage of water
9. problems of agricultural activities
10. shortage of medical facilities
11. poor transportation-communication networks
12. shortage of fire wood
13. problems of dairy farming
14. problems of poultry farming
15. silt deposits on rivers, canals, beels, and other water bodies

Other problems are

1. poor people lack access to community lands
2. large and rapid growing population
3. shortage of fruits and vegetables
4. shortage of cremation grounds of Hindus
5. lack of postal communications
6. lack of educational institutions
7. shortage of space to construct places of worship
8. problems of construct dams

9. shortage of electricity
10. shortage of milk

### 7.11.3 Impact on Natural Assets

Land cover changes are likely to affect the productivity of the Haor area. Land cover changes cause change in fish composition. These changes in productivity ultimately affect other livelihood assets. Over the last 9 years the natural capital has changed significantly due to land cover changes in the haor area.

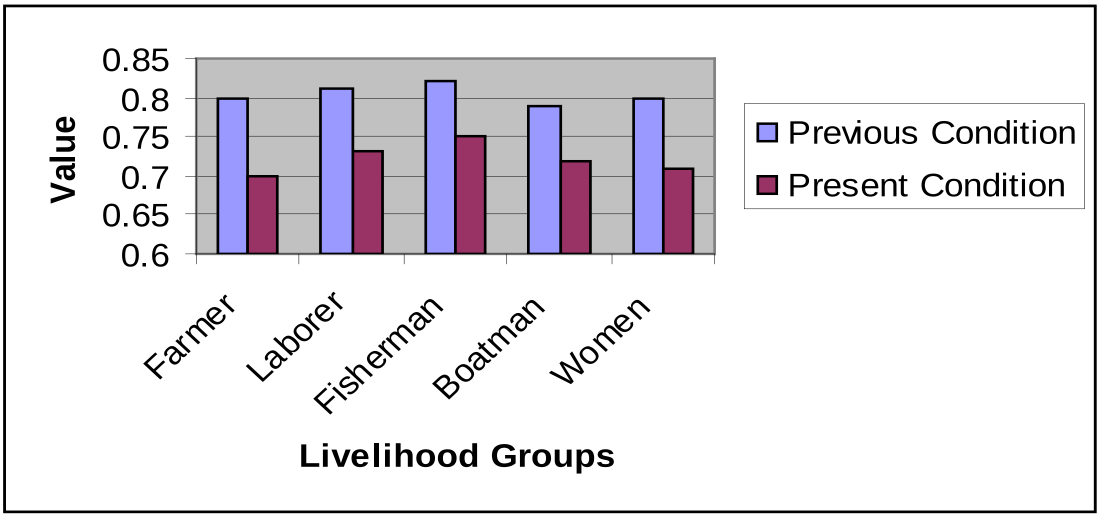



Figure 7.14: Impacts on livelihood groups due to natural assets change

### 7.11.4 Impact on Physical Assets

Land cover changes affect the physical resources. Construction of Roads, irrigation works, electricity, drainage, reticulated equipment, Housing, Building poles etc in physical assets which improve the life style of livelihood groups that will make vulnerable to other disaster.

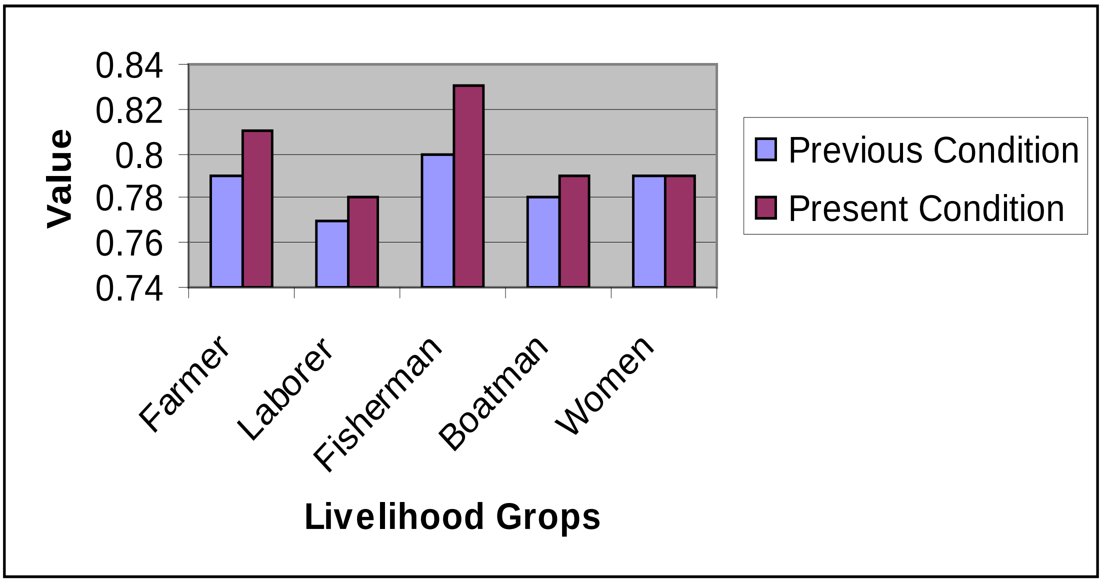



Figure 7.15: Impacts on livelihood groups due to physical assets change

#### 7.11.5 Impact on human assets

Reduction of income opportunity due to the lake of haor resources will force people to switch livelihoods. Local people reported that already some of them migrated to the cities for seeking income opportunities.

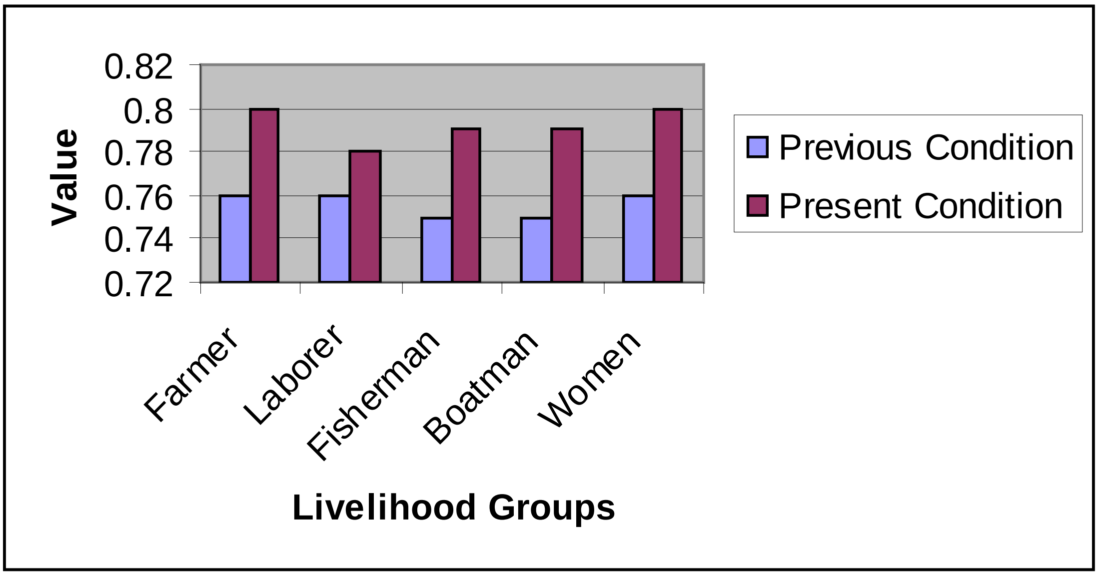



Figure 7.16: Impacts on livelihood groups due to human assets change

This migration of experienced manpower will cause shortage of skilled labor for harvesting of haor resources. Unskilled person have no knowledge on how to harvest haor resources in sustainable manner. Involving unskilled person will make the harvesting system unsustainable which will affect haor sustainability. Impact on haor sustainability will also affect other livelihood assets.

### 7.11.6 Impact on Financial Assets

Production of natural resources from the haor area has been reduced day by day. It is explicitly showed that amount of the extracted fish catch has been reduced significantly.

But alternatives job facilities has been increased in the haor area over the last 9 years period of time Thus the livelihoods dependent on haor area are affected due to land cover changes.

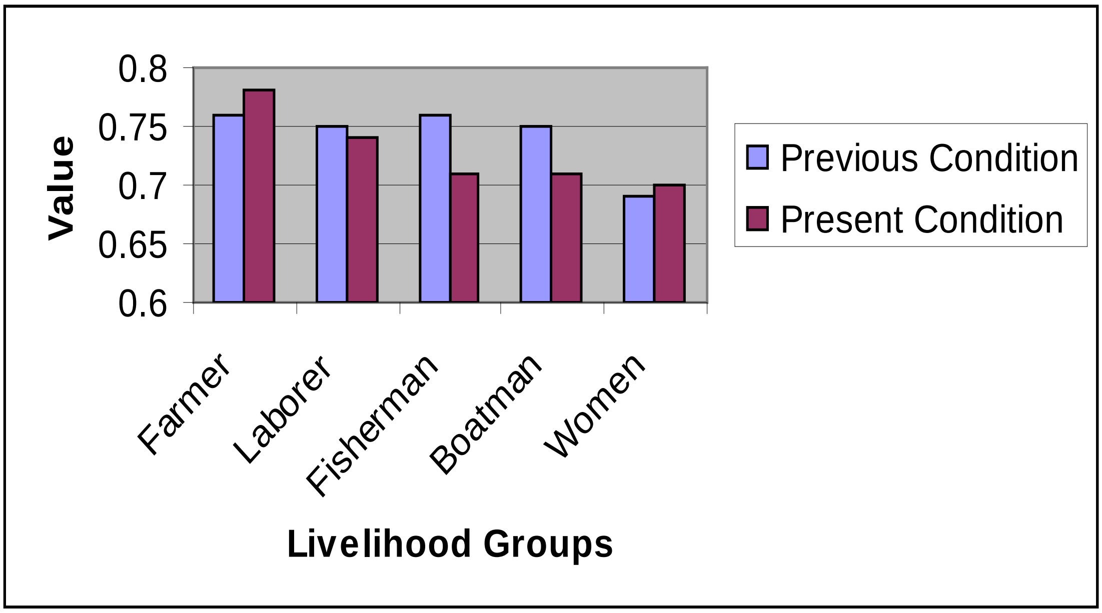



Figure 7.17: Impacts on livelihood groups due to financial assets change

### 7.11.7 Impact on Social Assets

Social assets filter the risk. Social assets are most important for enhancing livelihood resilience. Social assets are institutions, safety nets, social networks, policies, rules and regulations etc. which are related and co-acting with other livelihood assets. Community based haor management, alternative income opportunities, credit systems, government supported assistantship programs are acting as resilient measures of livelihood of haor area. Effectiveness and function of other livelihood assets especially physical, human and financial assets depend on function of social assets.

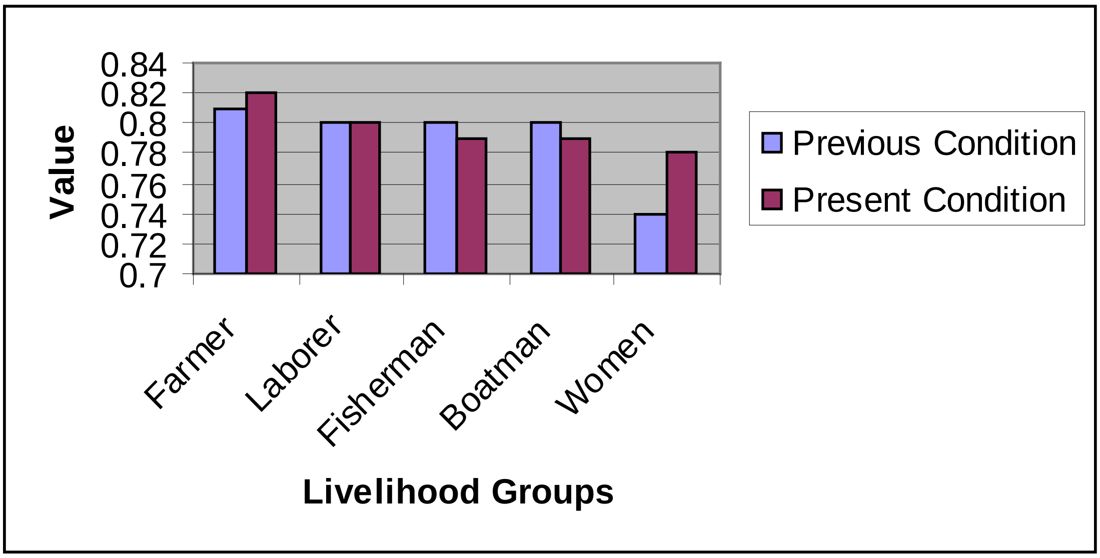


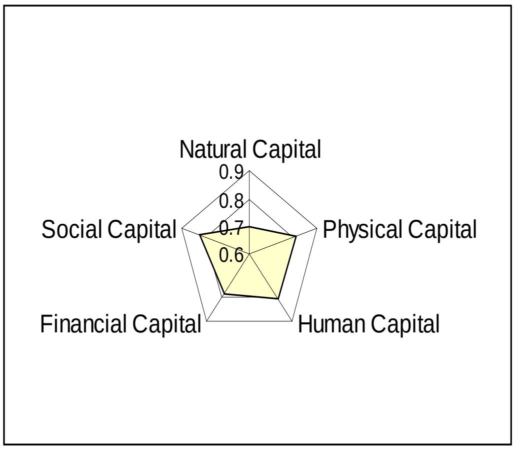

Figure 7.18: Impacts on livelihood groups due to social assets change

### 7.11.8 Impact on Gender specially Women and children

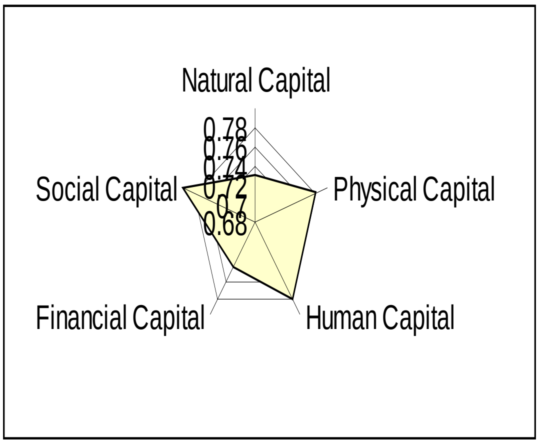
Land cover changes affect the underprivileged people specially women and children in the Haor area. Women faces different kind of problems i.e. Food insecurity, scarcity of fire-wood, lack of cattle rearing facilities, poultry farming, access to safe latrines and sanitation facilities, degradation of common resources. Food scarcity leads to malnutrition, especially for women and children. This cause anxiety and leads to high infant mortality rate. People's sufferings are aggravated due to inadequate health-care facilities. Women and children are especially vulnerable. They become susceptible to diseases. As a result child and maternal mortality rates are high in the haor area.

### 7.11.9 Livelihood Pentagon of Five Groups of the Haor Area Due to Land Covers Changes

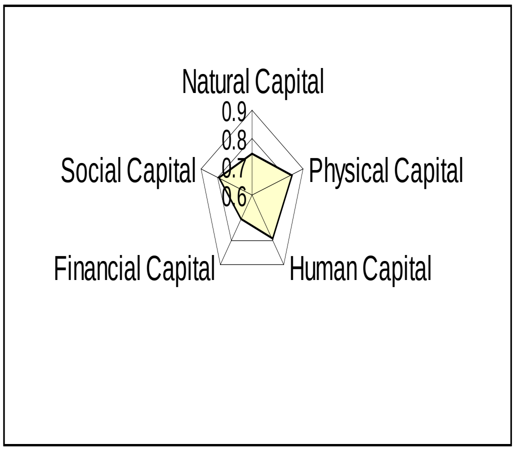
From the analysis of the capitals (Appendix XIX) of each group in a frame to indicate the accessibility of the groups to the livelihood assets, the livelihood pentagons of are illustrated below-



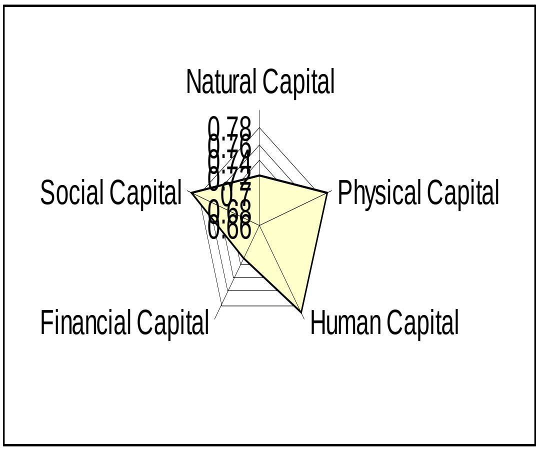

**Farmers group**



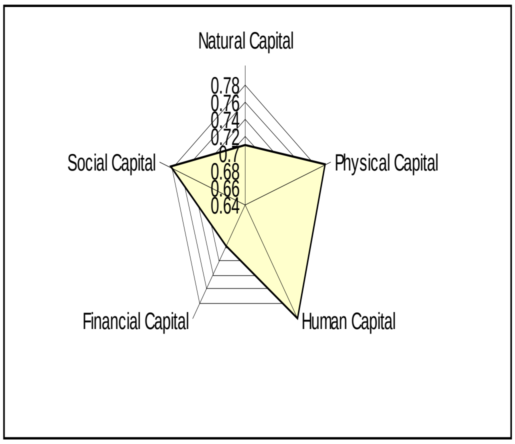

**Laborer group**




**Fisherman Group**




**Boatman Group**




**Women Group**

Figure 7.19: Livelihood pentagon change pattern due to land cover changes

### 7.11.10 Impact on Livelihood Group Due to Land Covers Changes of Haor Area

Land Cover Changes have different impacts on Farmer and Laborer groups. In Farmer groups, after the change their physical, human, financial and social capitals have increased except natural capital (Figure 7.20). On the other hand, in the case of laborer group, physical, human have increased whereas natural capital and financial capital decreased due to land cover changes of the study area. There are no changes occurred in social capital (Figure 7.21).

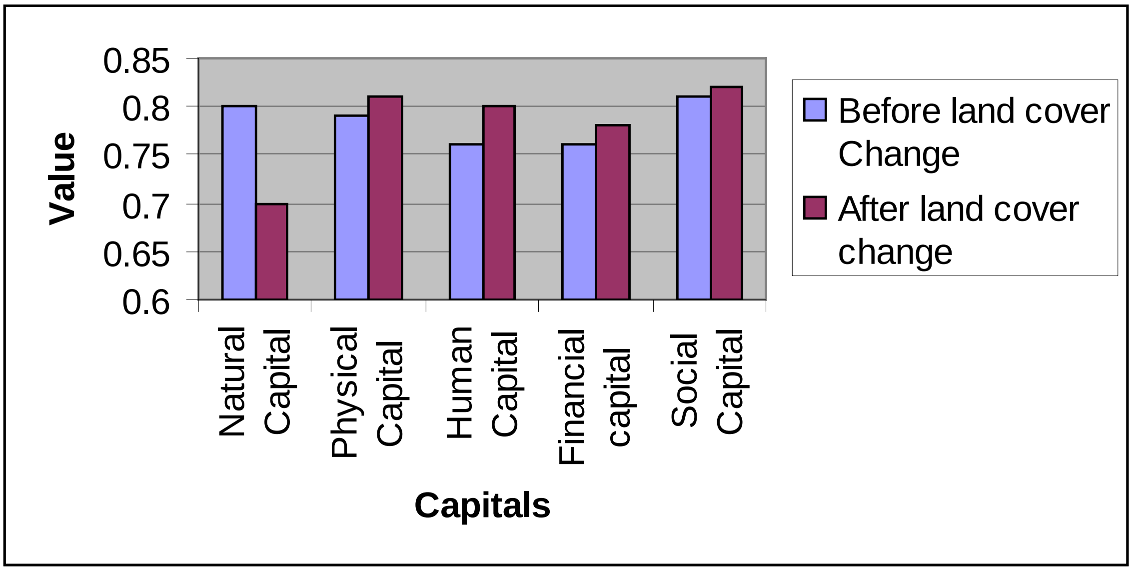



Figure 7.20: Impacts on livelihood capitals of Farmers Group

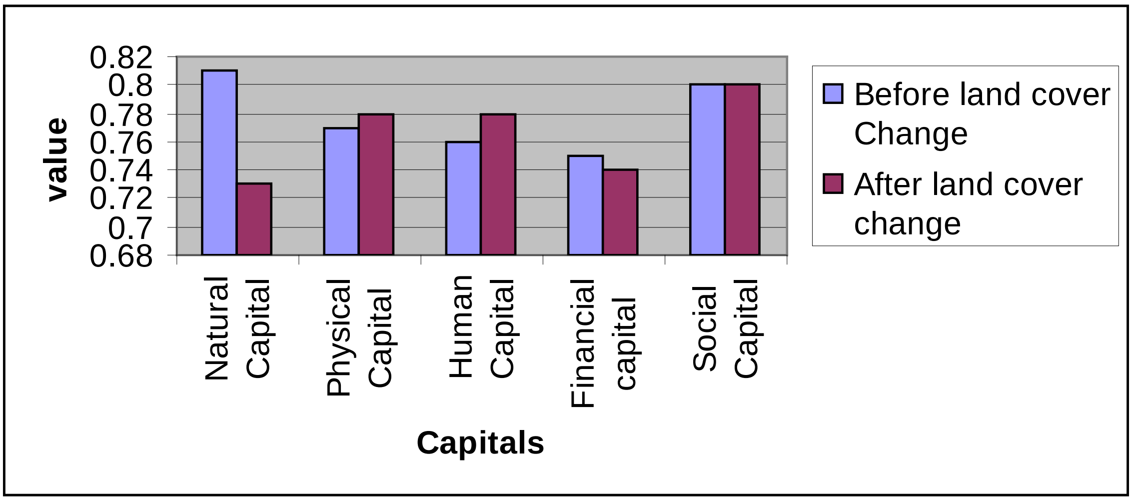



Figure 7.21: Impacts on livelihood capitals of laborer Group

Land Cover Changes of the haor area have different impacts on haor dependant livelihood groups like fisherman and boatman groups. In fisherman groups, after the change their physical, human, financial and social capitals have increased except natural capital (Figure 7.22). On the other hand, in the case of boatman group, natural, financial and social capitals have increased whereas physical and human capitals have decreased due to land cover changes of the haor area (Figure 7.23).

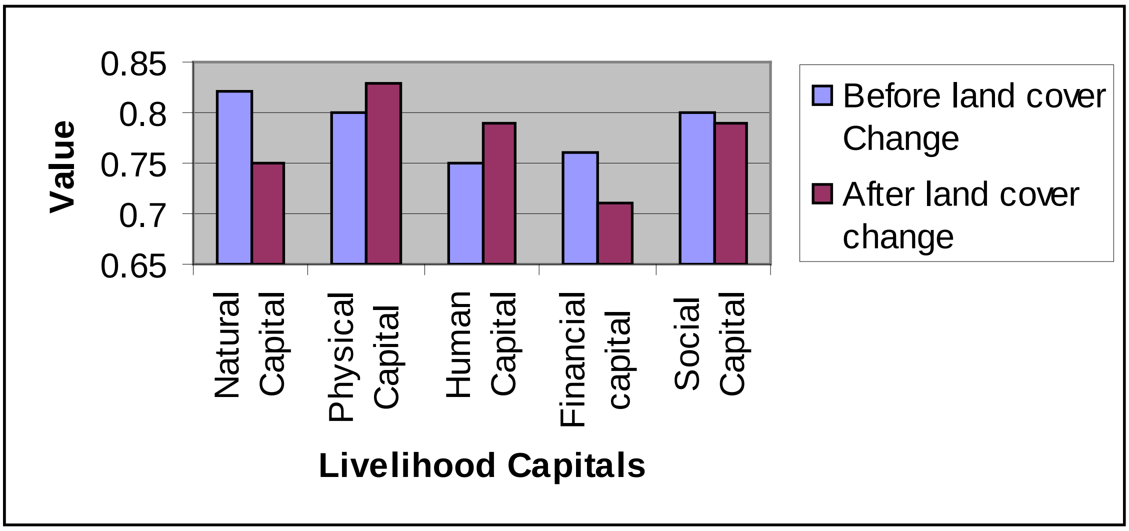



Figure 7.22: Impacts on livelihood capitals of Fisherman Group

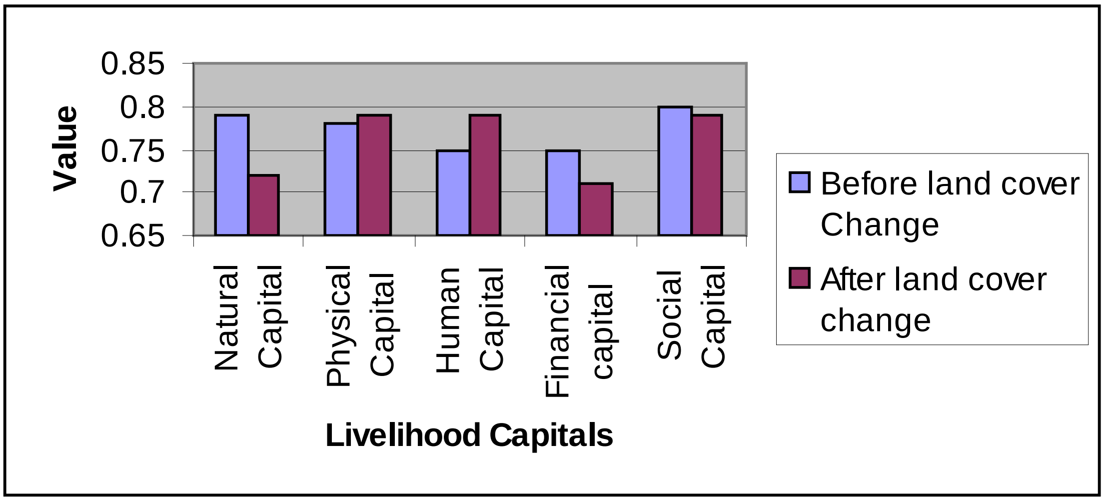



Figure 7.23: Impacts on livelihood capitals of Boatman Group

Land cover changes affect women group in the Haor area. Women faces different kind of problems i.e. Food insecurity, scarcity of fire-wood, lack of cattle rearing facilities, poultry farming, access to safe latrines and sanitation facilities, degradation of common resources. After the land cover changes, the natural capital of the women group is decreased whereas the others capital have increased (Figure 7.24).

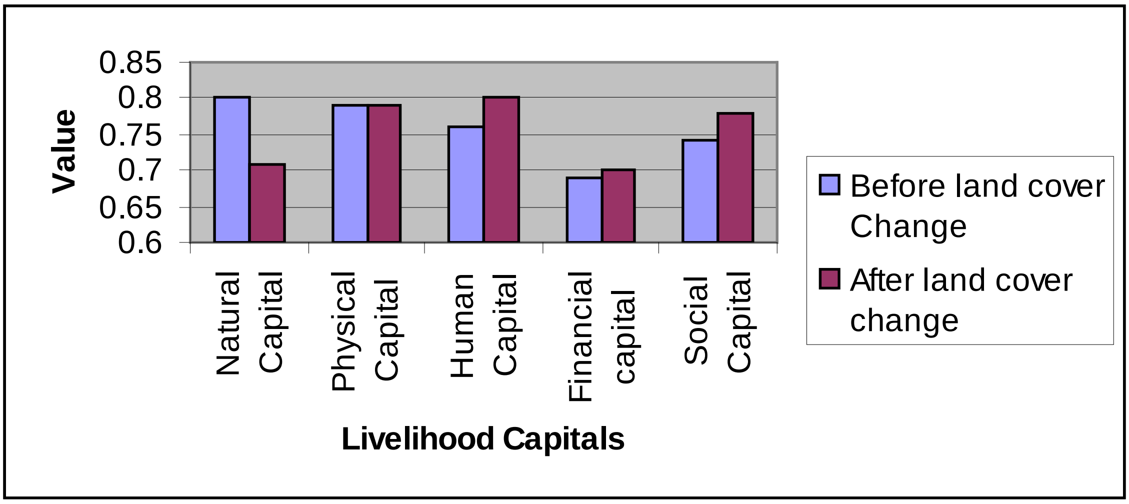



Figure 7.24: Impacts on livelihood capitals of Women Group

# CHAPTER EIGHT

# CONCLUSIONS AND RECOMMENDATIONS

## 8.1 Conclusions

MODIS TERRA satellite data and the methodology adopted were found to be useful for the assessment and monitoring of land cover status and dynamics at small scales. They provide a broad view of land cover change over Haor area between 2000 and 2008 and give an immediate measure of the nature, extent and rates change. However, it was not possible to discriminate smaller and sporadic changes with the 500m resolution MODIS data. While small scale studies show the rational pattern, large-scale studies are needed to investigate what is causing such changes in land cover. Hence, studies using remote sensing need to be followed up by more specific and detailed investigation in the field. In the haor area, vegetation land cover, mixed land cover and water bodies were discerned with the MODIS TERRA data.

Analysis revealed that the vegetation cover increased from 8880.89 km$^2$ to 10782.09 km$^2$ from 2000 to 2001 after that there was a slight decreased in 2002 and then it increased in 2003, and this was followed by slight decreased in 2004. On the other hand from 2004, there was an upward trend of vegetation cover with a minute decreased in 2007 but in 2008 it reached to 10635.64 km$^2$. The vegetation cover had a very slight increment during the study period. It was 8880.89 km$^2$ in 2000 but 10635.64 km$^2$ in 2008 .The change pattern of mixed land cover is somewhat unchanged except 2001 and 2006. In contrast, the other land cover category i.e. water bodies has been reduced greatly and converted to other land cover areas.

This research also demonstrates the flash flood timing, flash flood of starting and ending date and duration of the flash flood. Studies showed that most of flash flood hit to the haor area in the month of April to June. It becomes totally devastating if the flood hits haor area in early April. Analysis reveals that the flash flood damages are maximum in 2000, 2002, 2004 and in these years the flash flood has been occurred in the haor area in April and also because the duration of the flash flood was maximum.

It has been found that the land cover changes are affected the productivity of the haor area. Fish production is hampered due to the declining trend of water bodies of the haor area. Over the last 9 years the natural capital has been reduced significantly due to land cover changes in the haor area which ultimately affects the haor resources dependent livelihood groups. On the other hand, the other capitals are changed positively due to the improvement of physical capital, Social capital and financial capital. In the context of livelihood dimension, change in productivity and risk is somewhat negative but equity and sustainability is positively promoted on livelihood groups and capitals. The access of farmers group, laborer group, fisherman group boatman group and women groups to livelihood capital i.e. physical capital, human capital, social capital and financial capital is about moderately increased where as the natural capital is decreased. Analysis revealed that, the access of the most vulnerable group i.e. women to livelihood capital i.e. natural capital, physical capital, human capital, social capital and financial capital was about 0.80, 0.79, 0.76, 0.69 and 0.74 in 2000 whereas 0.71, 0.79, 0.80, 0.70 and 0.78 in 2008 respectively. The impacts of land cover changes to the livelihood groups of the haor area is positive trend except the natural capital.

## 8.2 Recommendations

Based on the experience gained during the course of this study, the following recommendations are made:

The study has been carried out for 9 years MODIS TERRA satellite data. The research results should be verified conducting more research studies considering more than 20 years MODIS TERRA data in the haor area. The research results could be tuned more accurately, if remote sensing image of higher resolution for the study area could be used. The field visit is conducted in some of the selected areas, but not the whole area of the haor regions. The results of livelihood analysis could be more accurate, if the field visit was done on the whole area.

The research could be done smoothly if limitations of time, fund, and sophisticated equipment could be managed in a better way. Yet the research has been carried out as accurately as possible encountering all these limitations.

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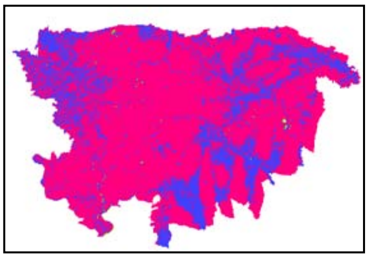
**APPENDIX I: Spatial changes of Monthly NDVI Plot of Haor area from 2000 to 2008**

a) Spatial changes of Monthly NDVI Plot of Haor area during January to December of 2000



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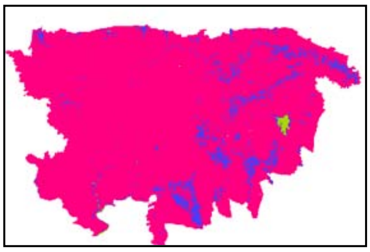

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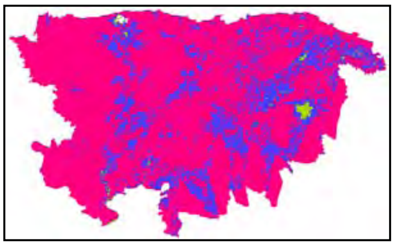

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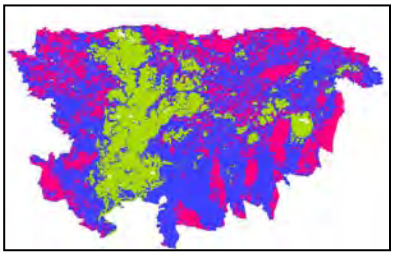

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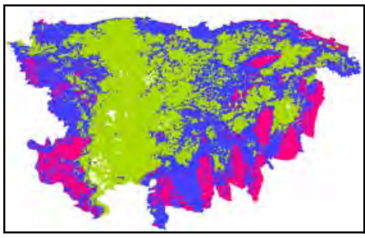

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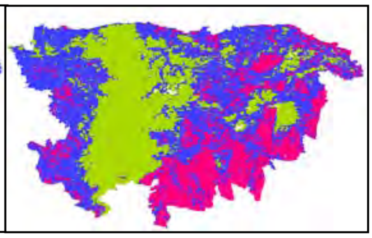

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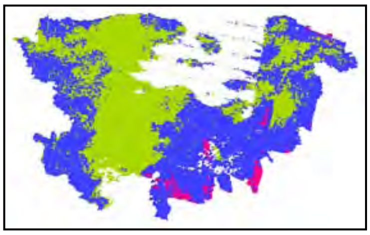

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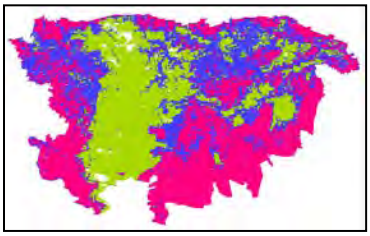

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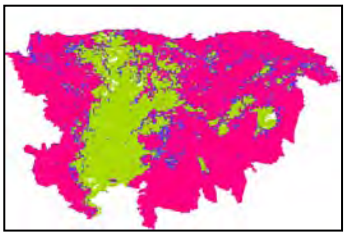

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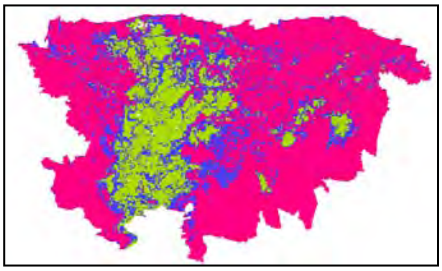

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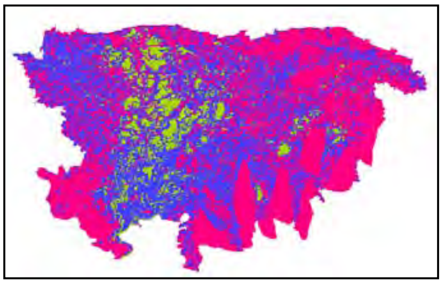
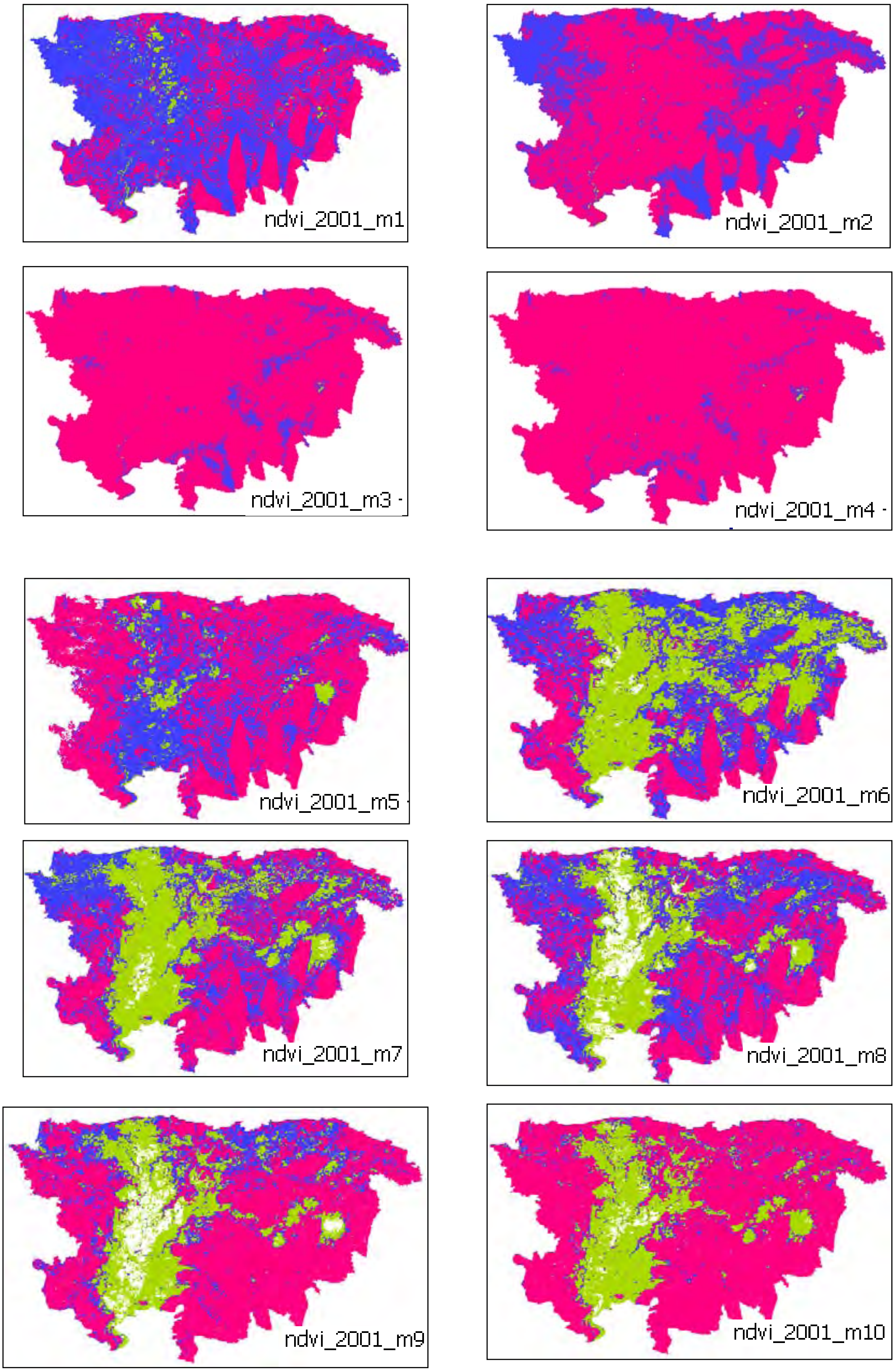
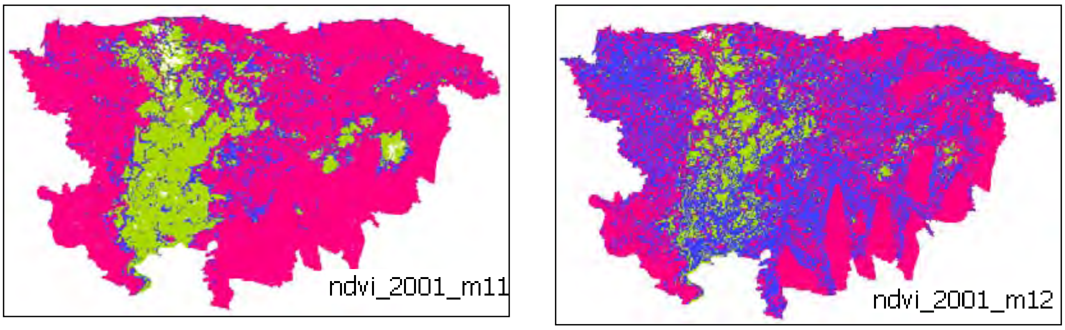


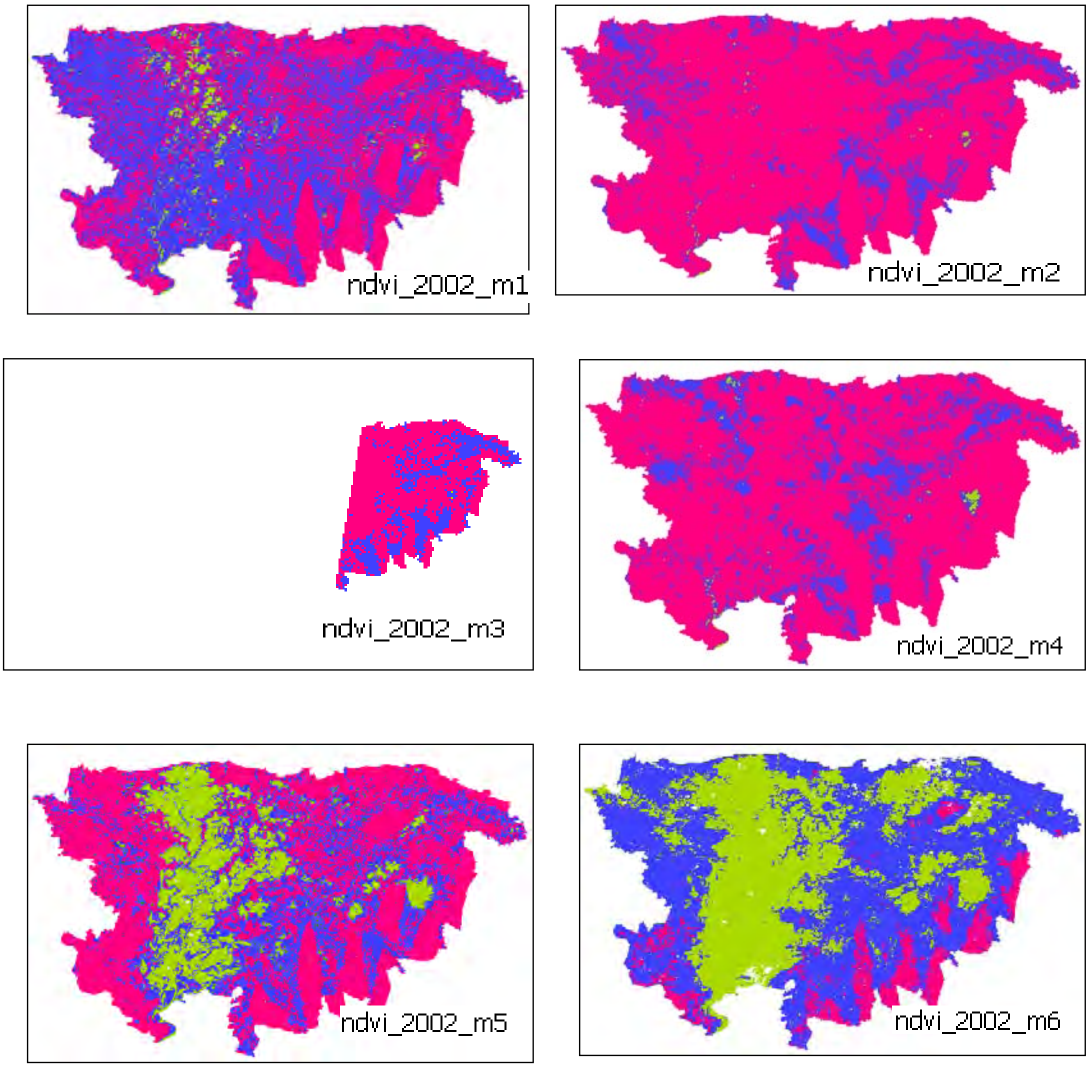
**December 2000**

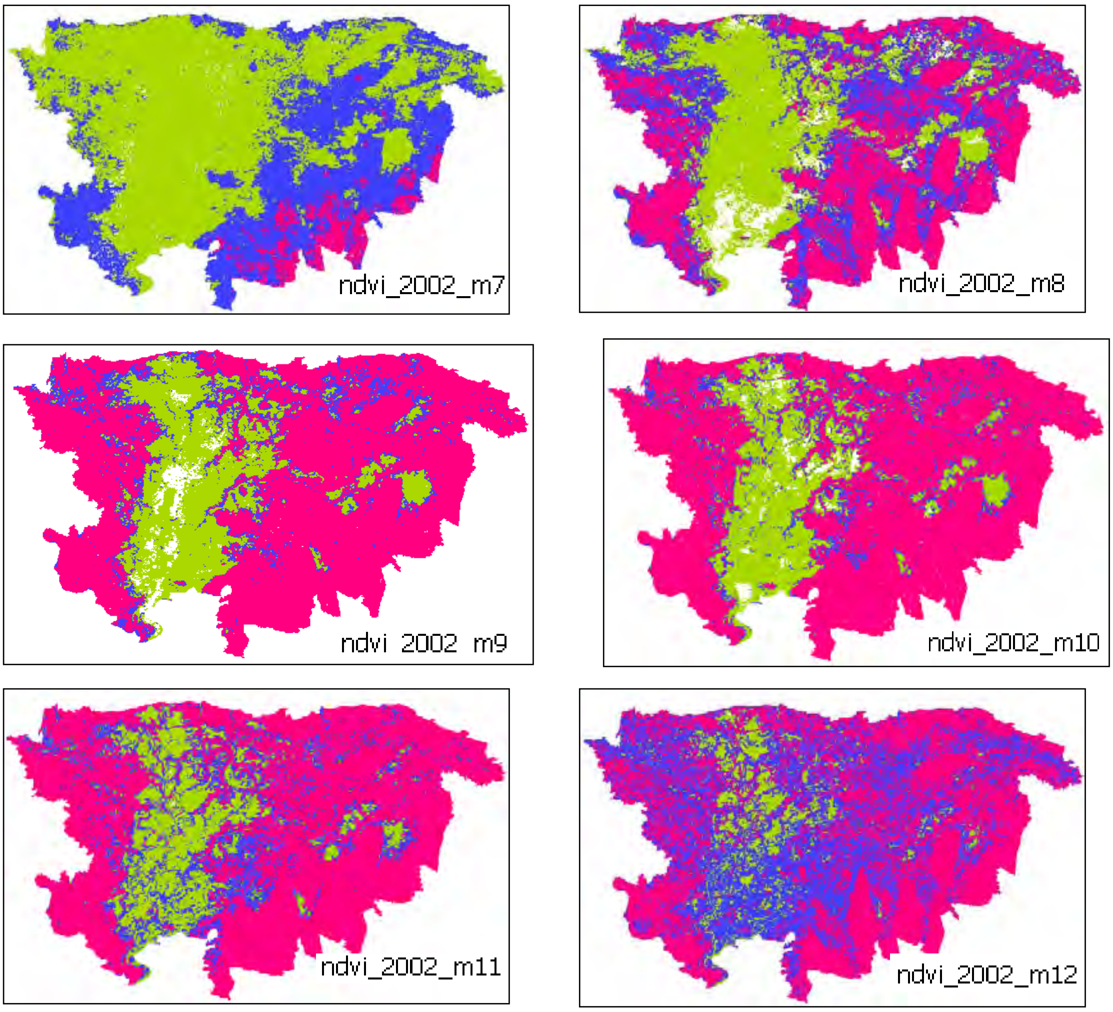
b) Spatial changes of Monthly NDVI of haor area during January and December of 2001 (m1, m2, m3 ...indicates month of January, February, March ...)



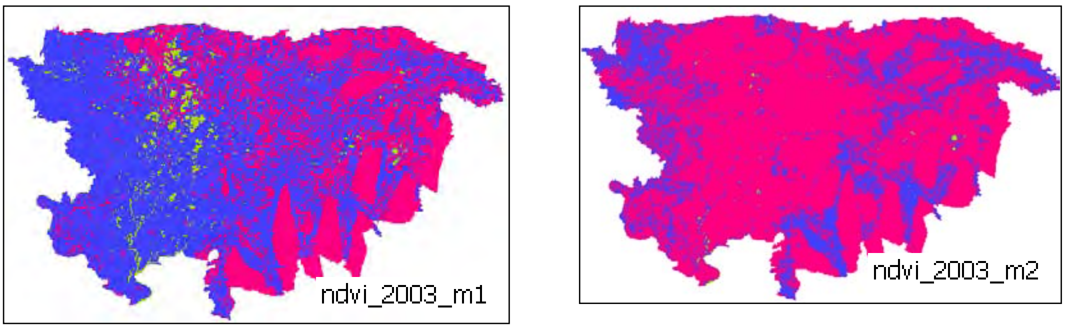


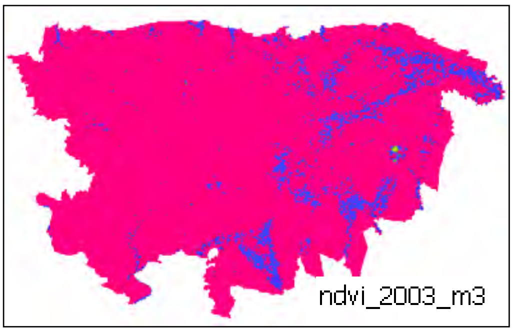

c) Spatial changes of Monthly NDVI of haor area during January and December of 2002






d) Spatial changes of Monthly NDVI of haor area during January and December of 2003

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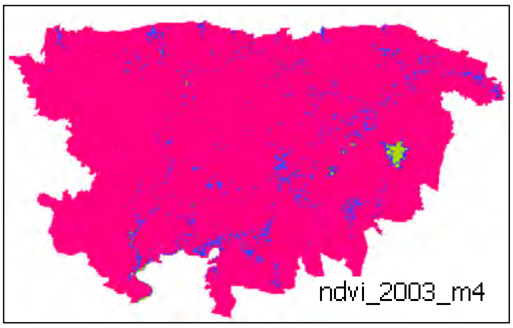
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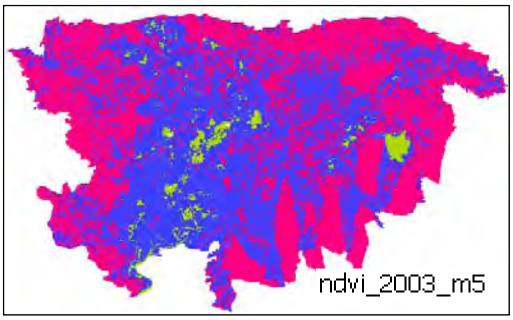
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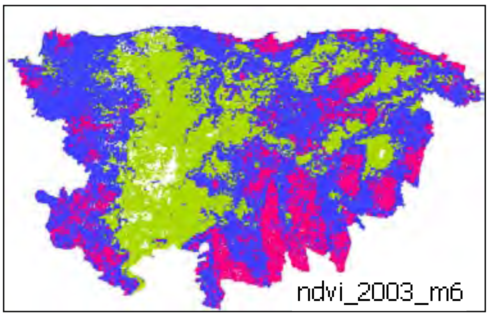
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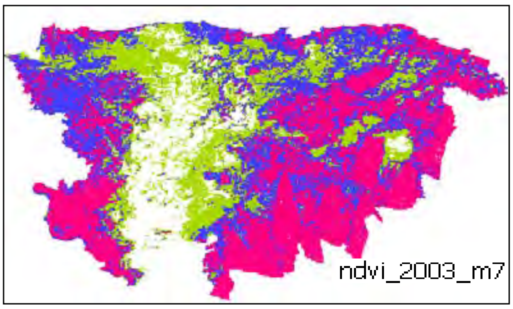
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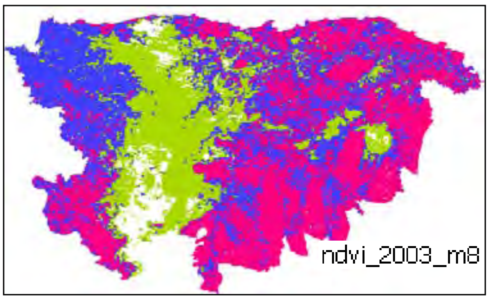
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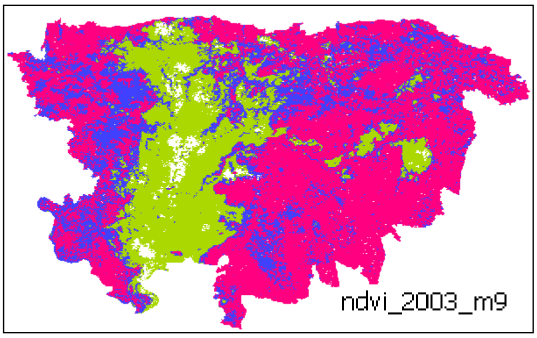
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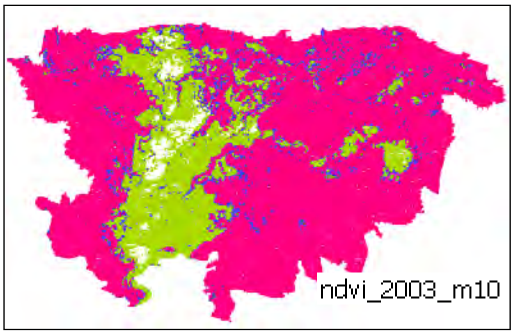
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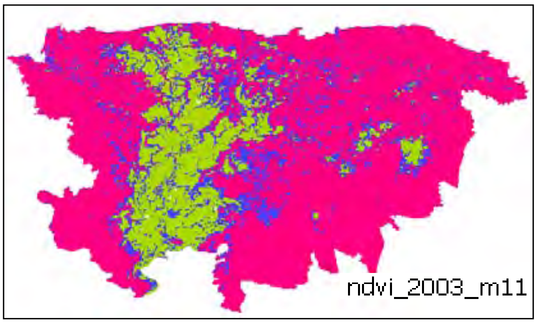
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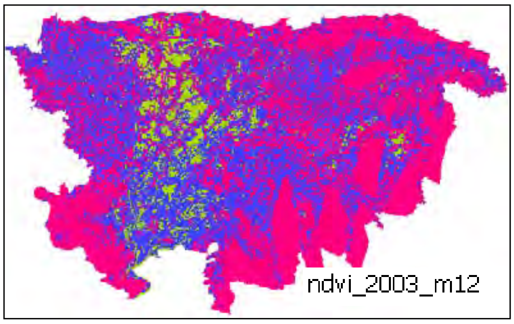
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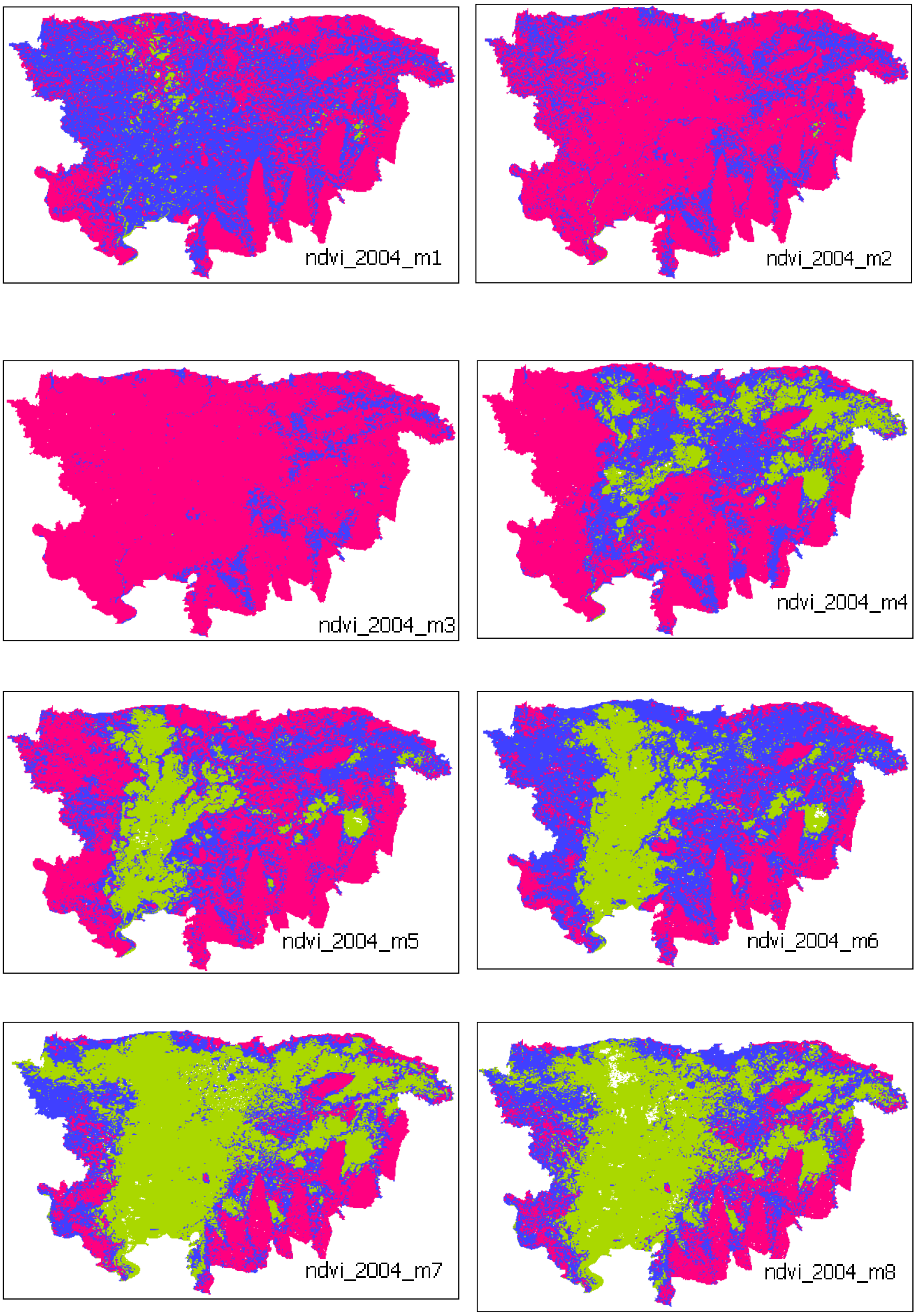
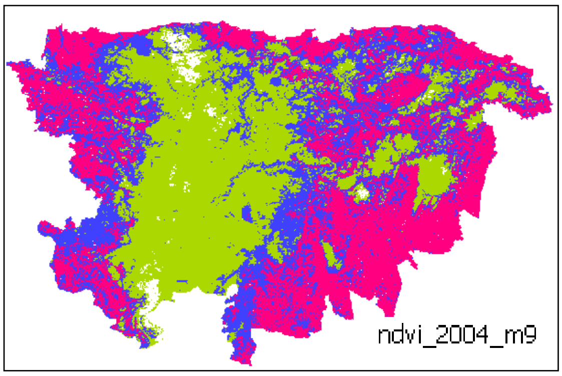
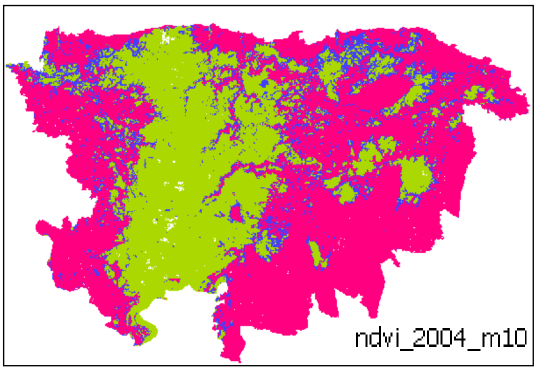
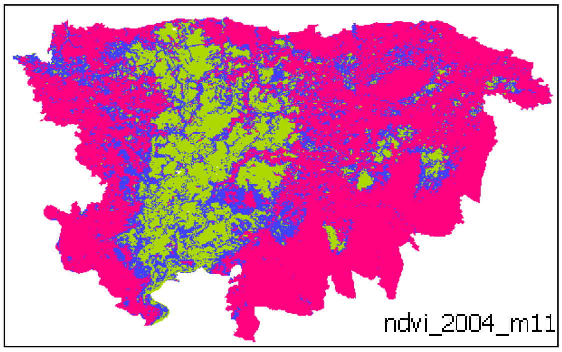
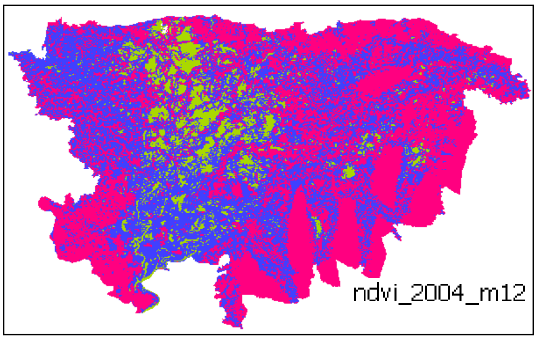
e) Spatial changes of Monthly NDVI of haor area during January and December of 2004



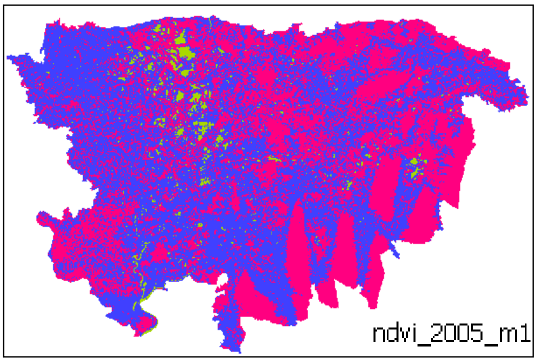


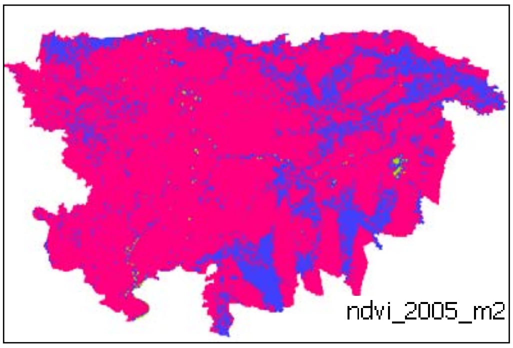


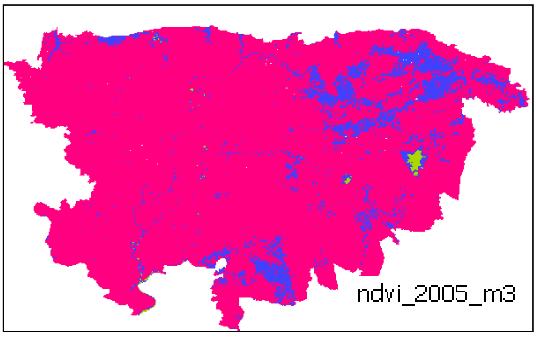





f) Spatial changes of Monthly NDVI of haor area during January and December of 2005



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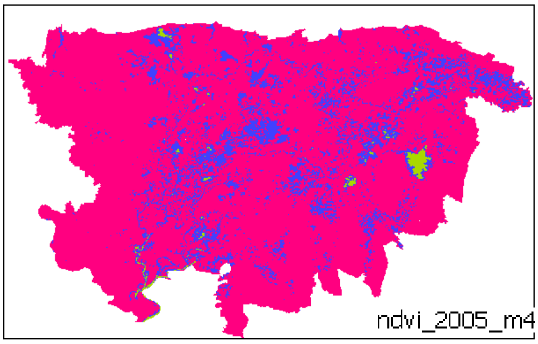
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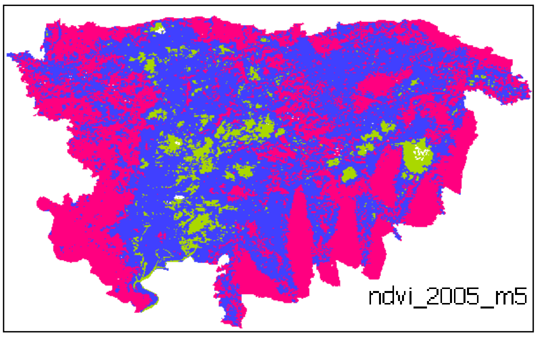
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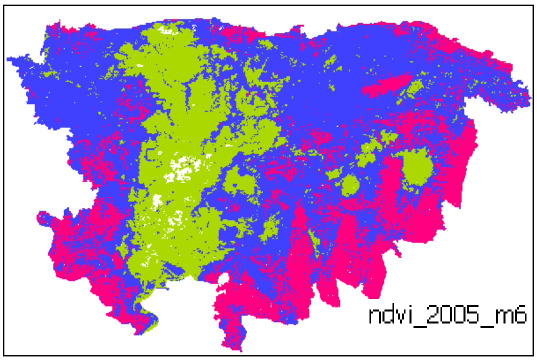
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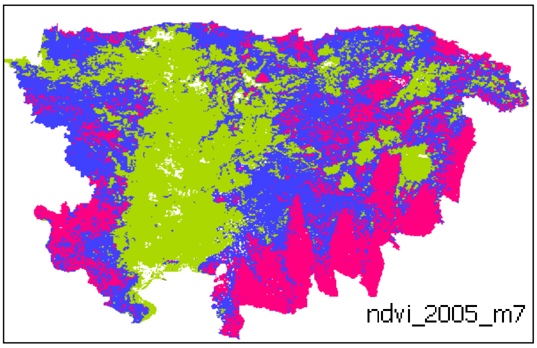
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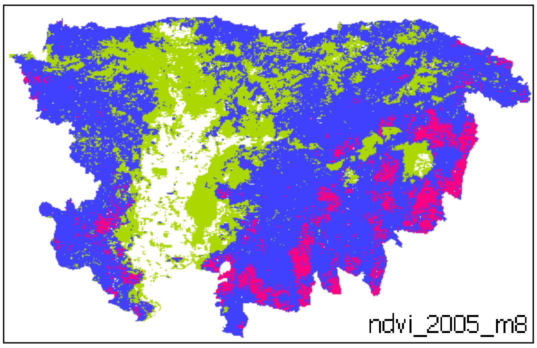
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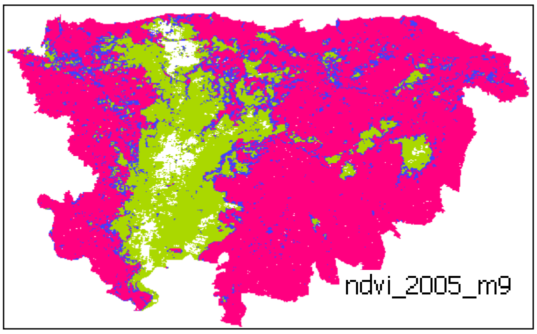
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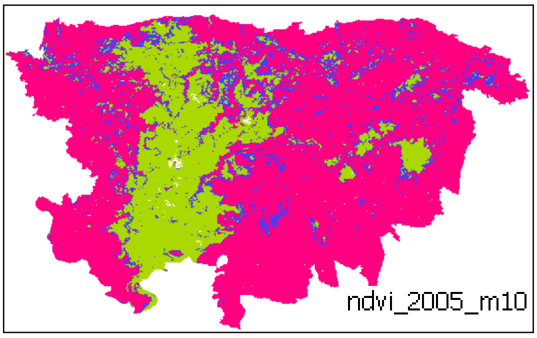
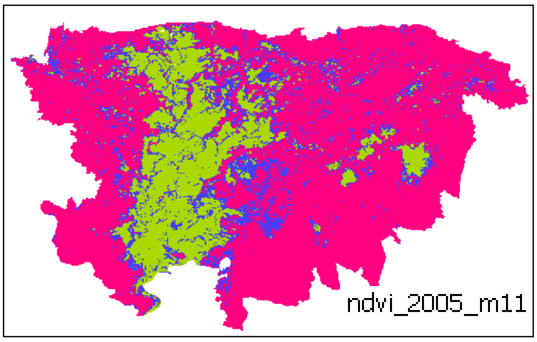
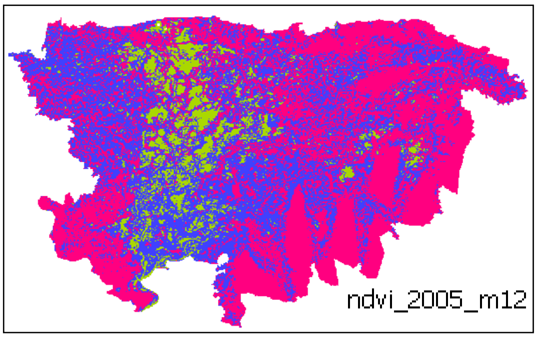
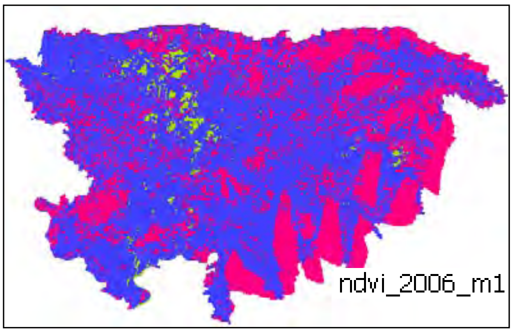
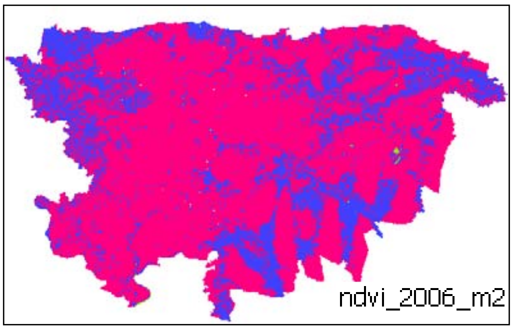

ndvi_2005_m10

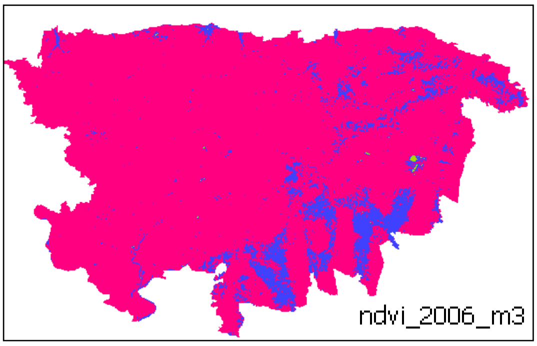


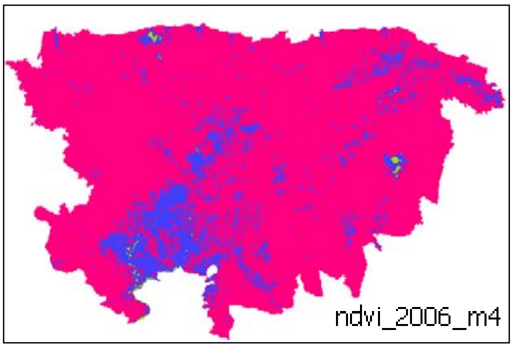



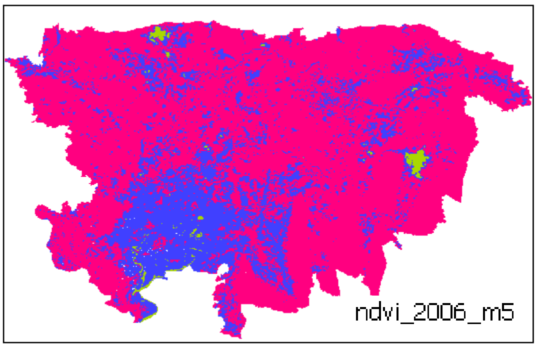

g) Spatial changes of Monthly NDVI of haor area during January and December of 2006

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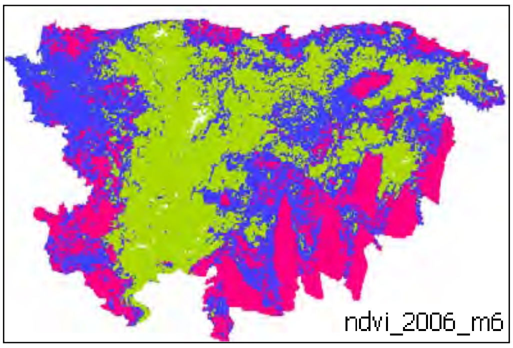
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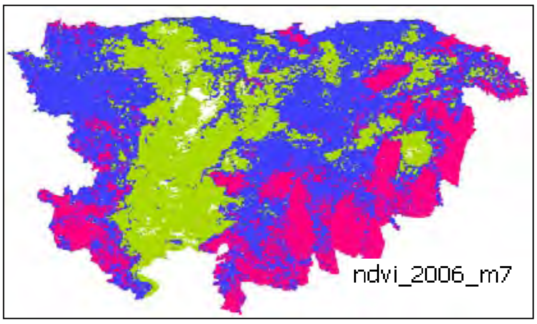
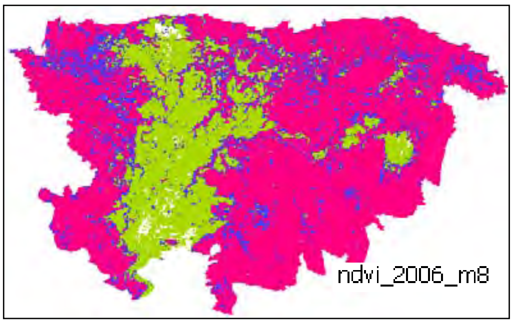
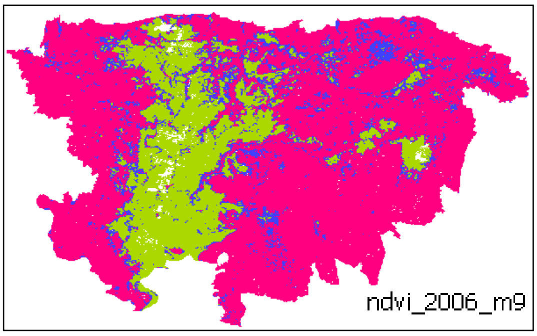
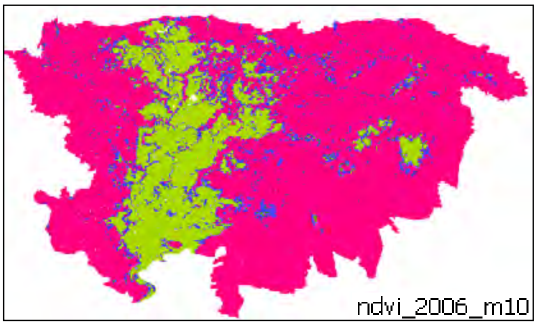
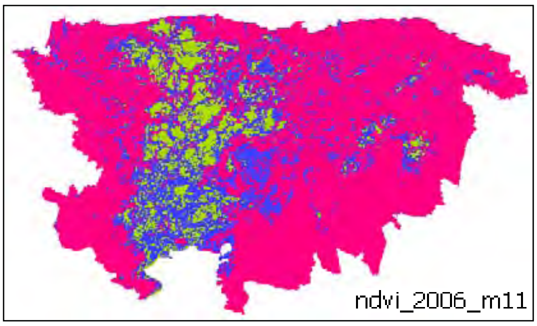
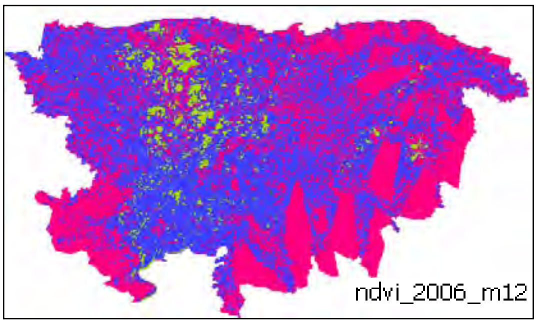
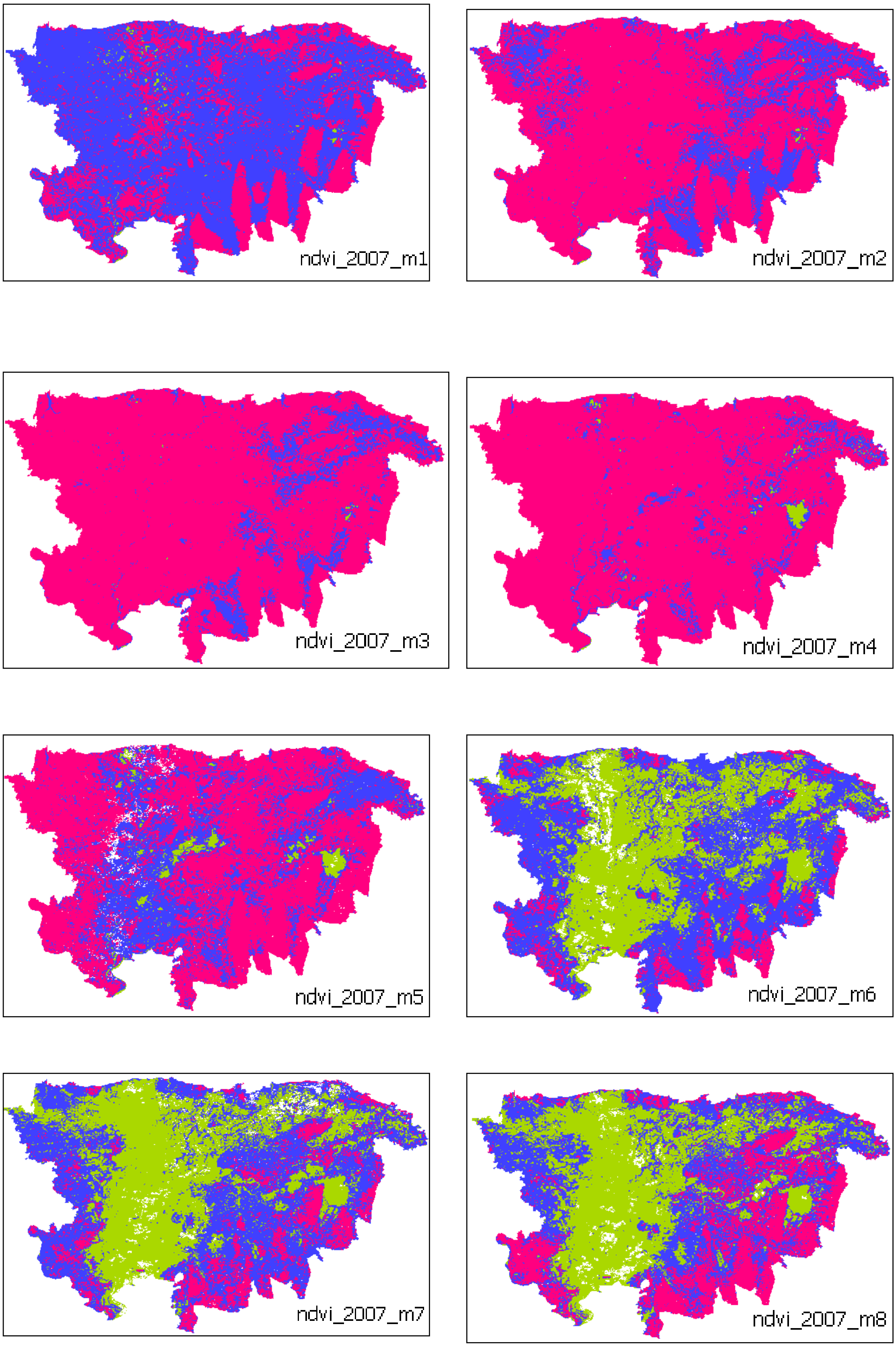
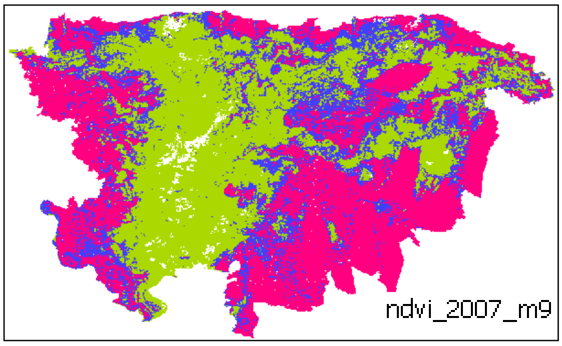
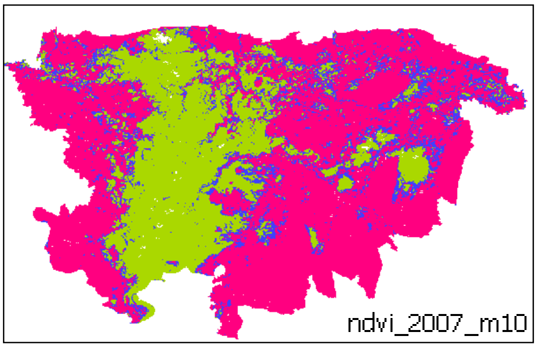
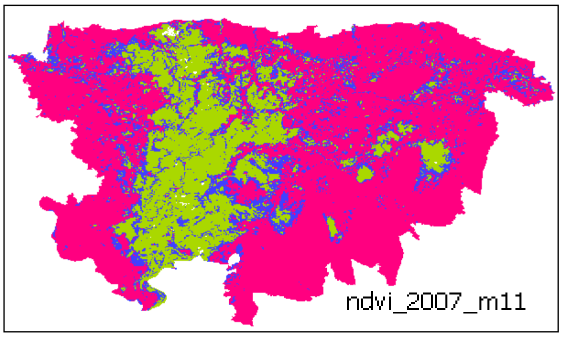

ndvi_2006_m7

ndvi_2006_m8

ndvi_2006_m9

ndvi_2006_m10

ndvi_2006_m11

ndvi_2006_m12

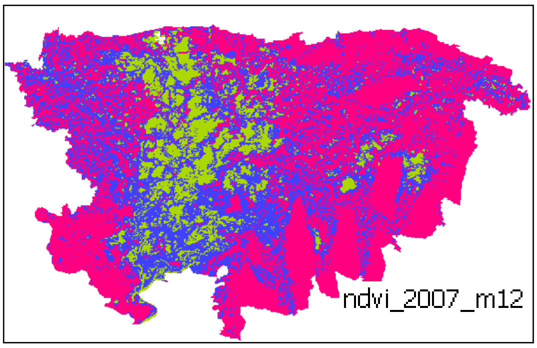
h) Spatial changes of Monthly NDVI of haor area during January and December of 2007



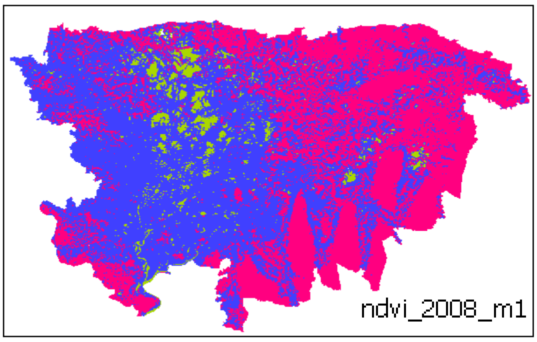


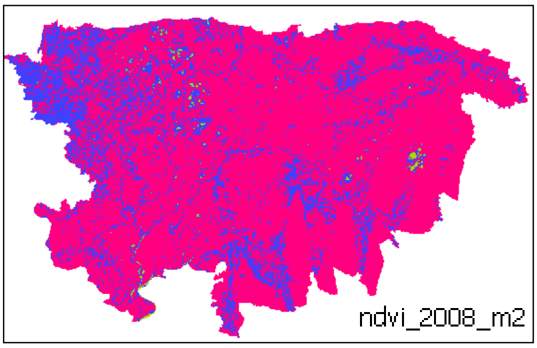



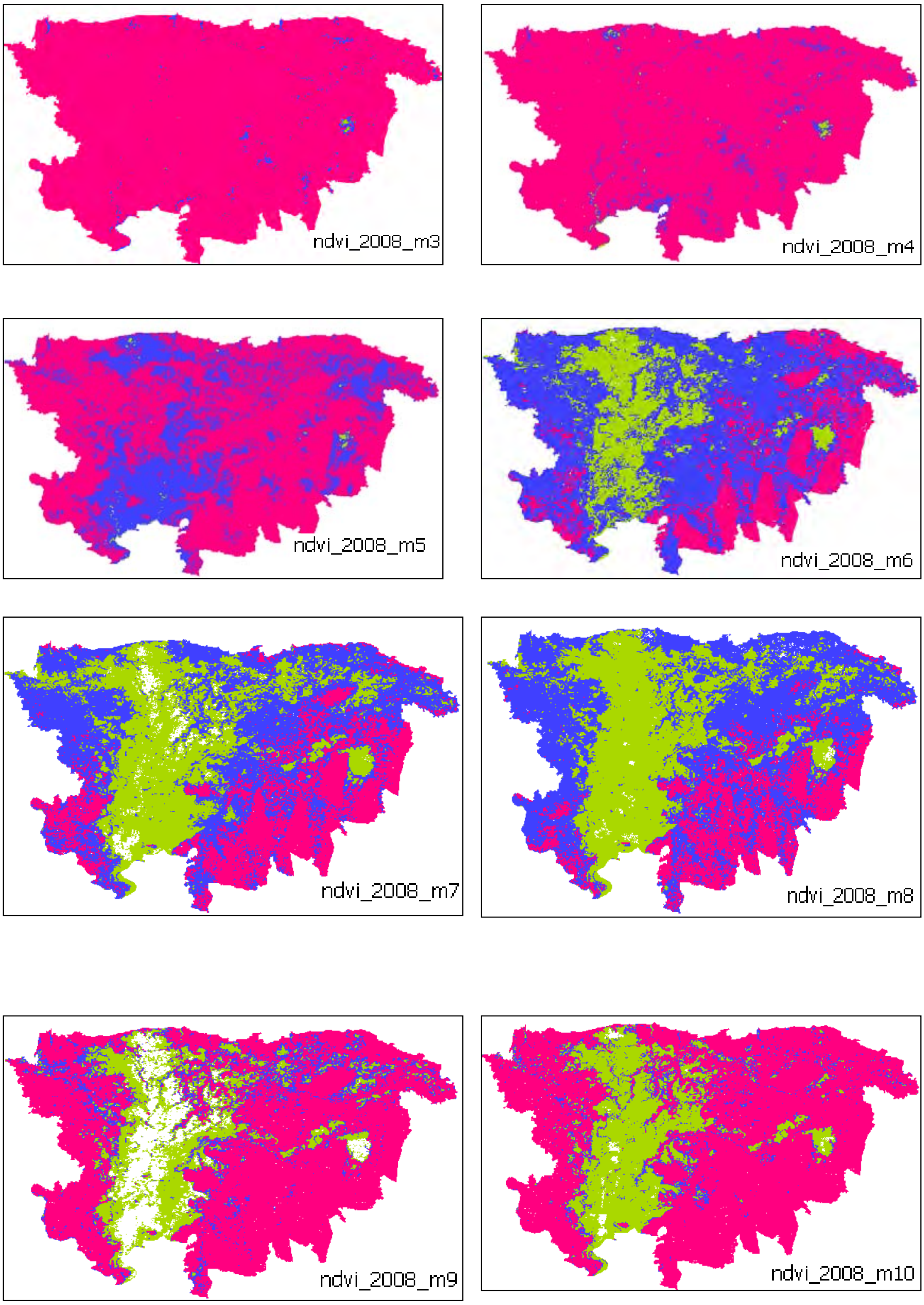



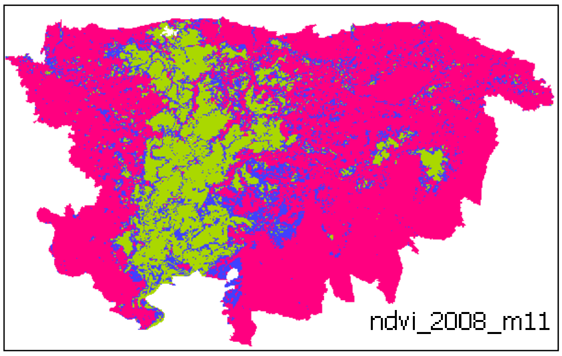



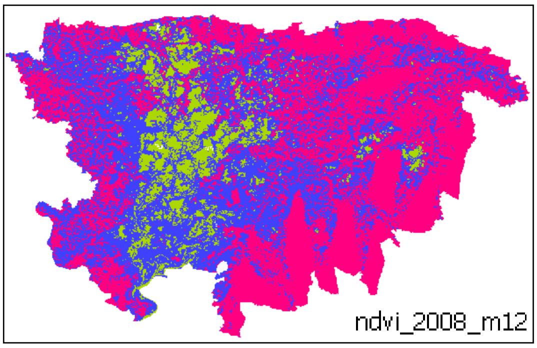

i) Spatial changes of Monthly NDVI of haor area during January and December of 2008



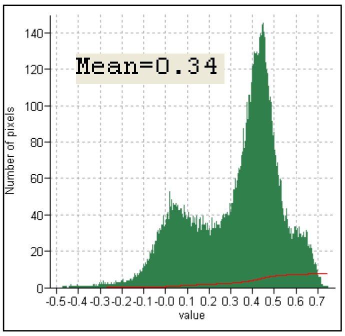



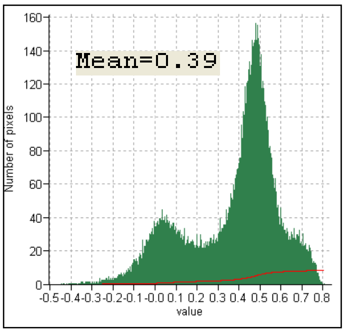

ndvi_2008_m3
ndvi_2008_m4
ndvi_2008_m5
ndvi_2008_m6
ndvi_2008_m7
ndvi_2008_m8
ndvi_2008_m9
ndvi_2008_m10

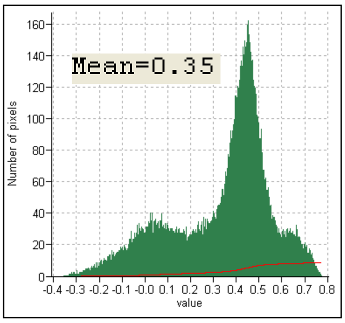

ndvi_2008_m11


ndvi_2008_m12

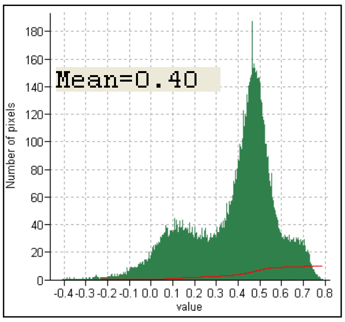
## APPENDIX II: Mean NDVI Change patterns in the respect of Histogram

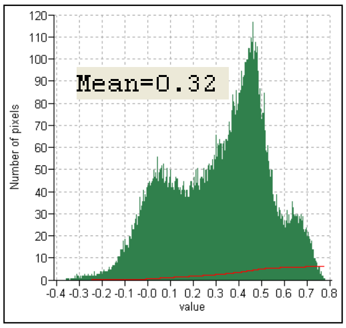


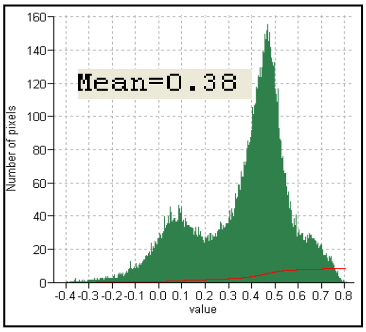



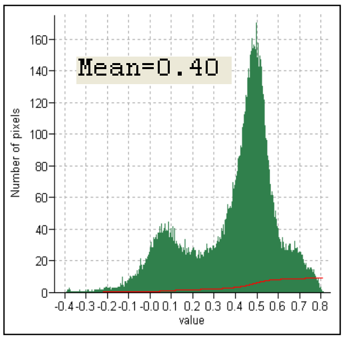

Mean_ndvi_haor_2000 Mean_ndvi_haor_2001 Mean_ndvi_haor_2002

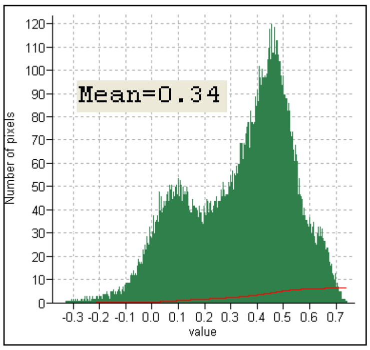


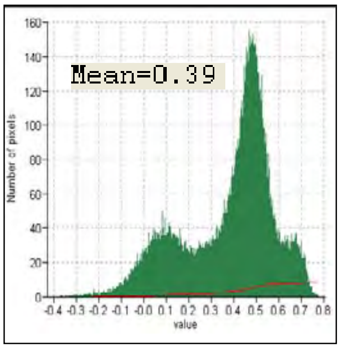




Mean_ndvi_haor_2003 Mean_ndvi_haor_2004 Mean_ndvi_haor_2005

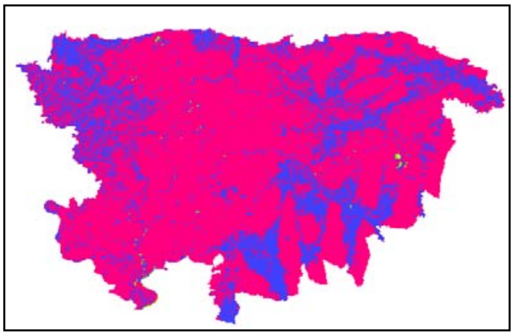


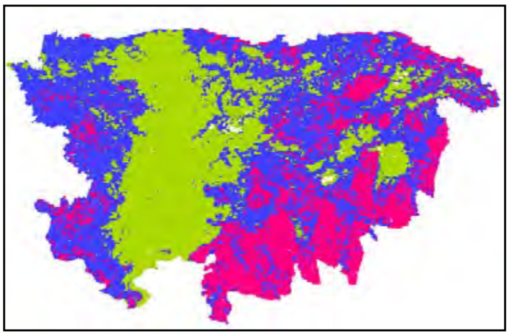



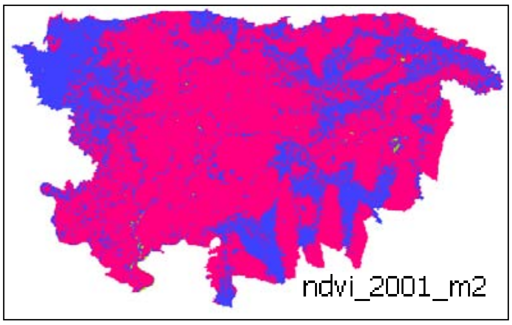

Mean_ndvi_haor_2006 Mean_ndvi_haor_2007 Mean_ndvi_haor_2008

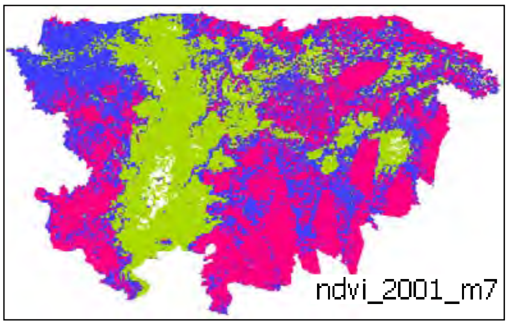
**APPENDIX III: Seasonal changes (Dry season and Wet season) of NDVI of haor area from 2000 to 2008.**

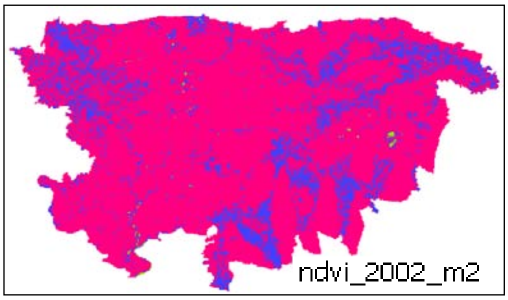


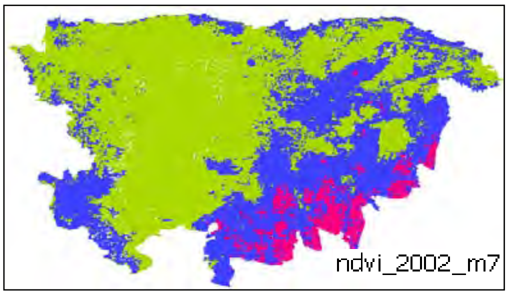


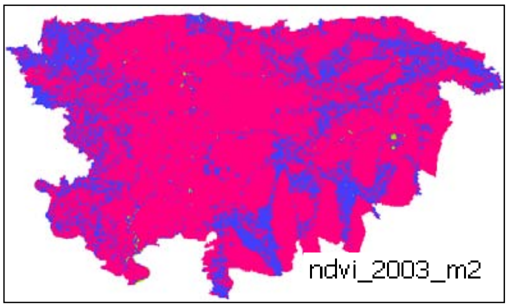
**February 2000** **July 2000**

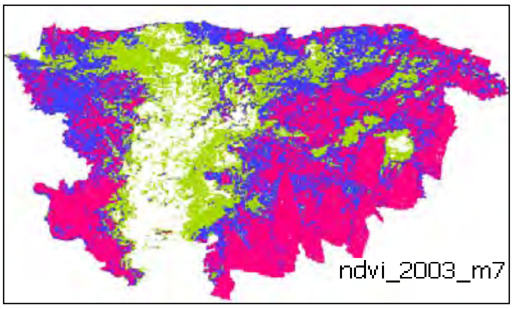


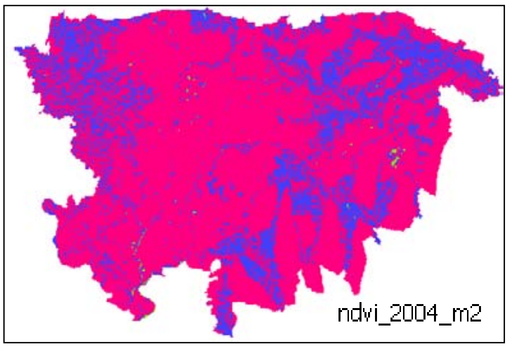



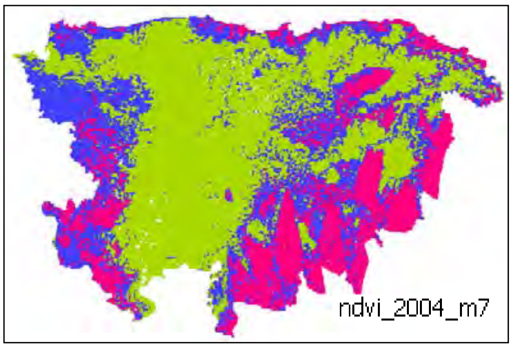



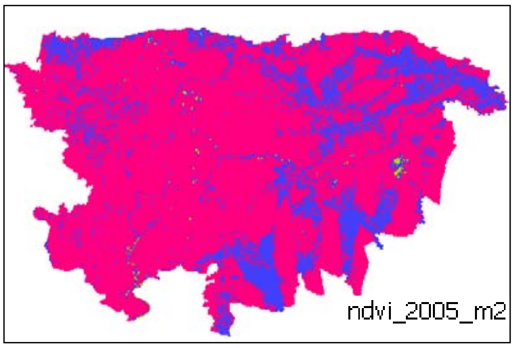



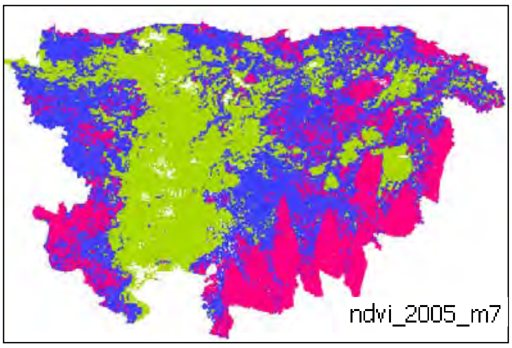



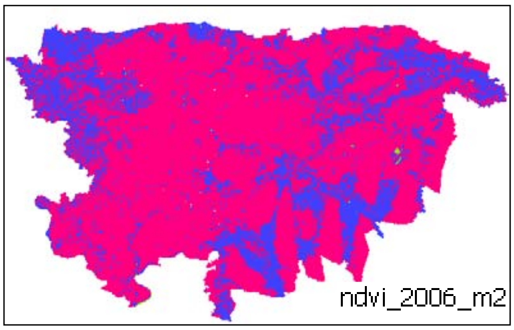



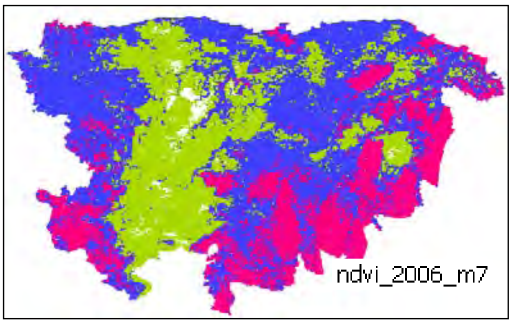

ndvi_2004_m2

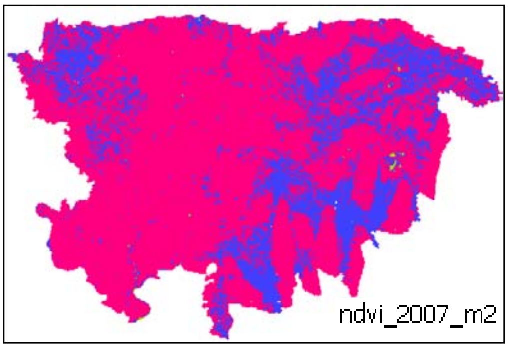

ndvi_2004_m7

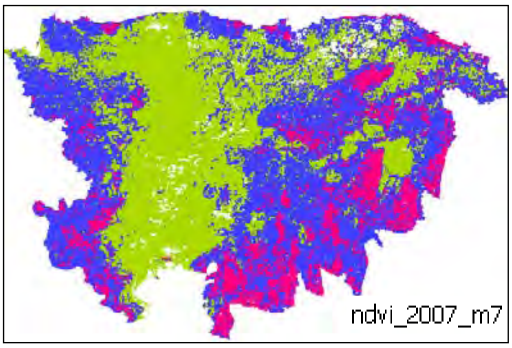

ndvi_2005_m2

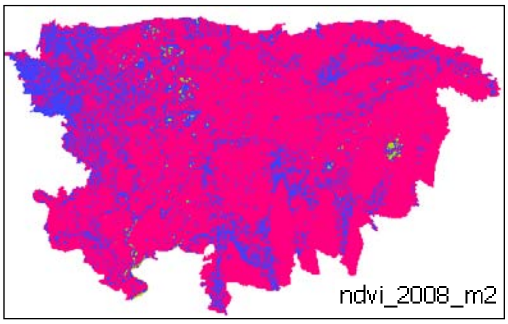

ndvi_2005_m7

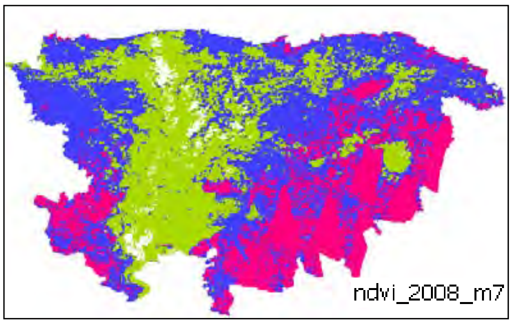

ndvi_2006_m2


ndvi_2006_m7


ndvi_2007_m2

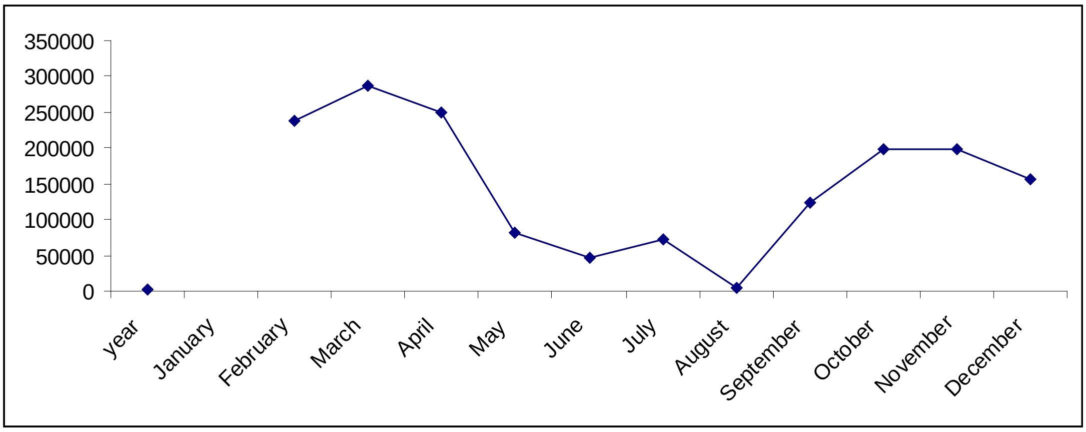

ndvi_2007_m7


ndvi_2008_m2

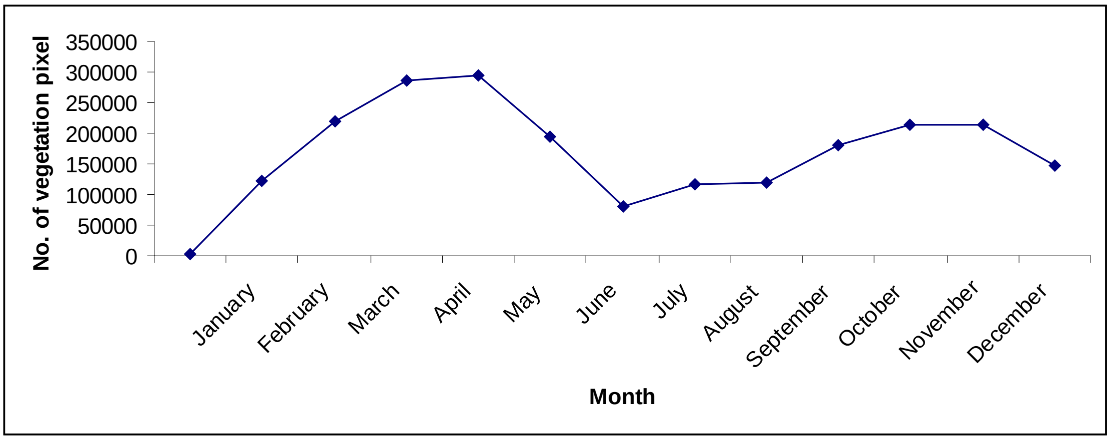

ndvi_2008_m7

**APPENDIX IV: Vegetation change patterns on the basis of Pixel information of MODIS images from 2000 to 2008**

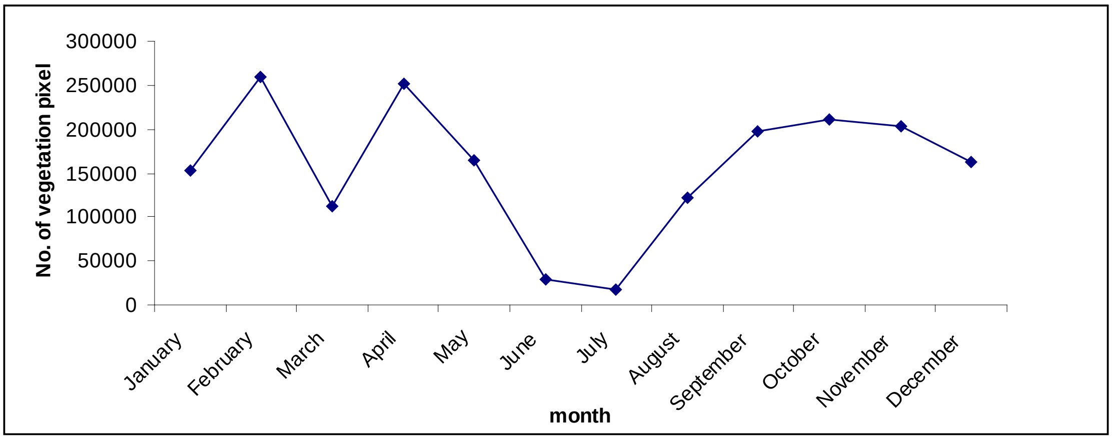
a) Monthly vegetation changes during January to December in 2000



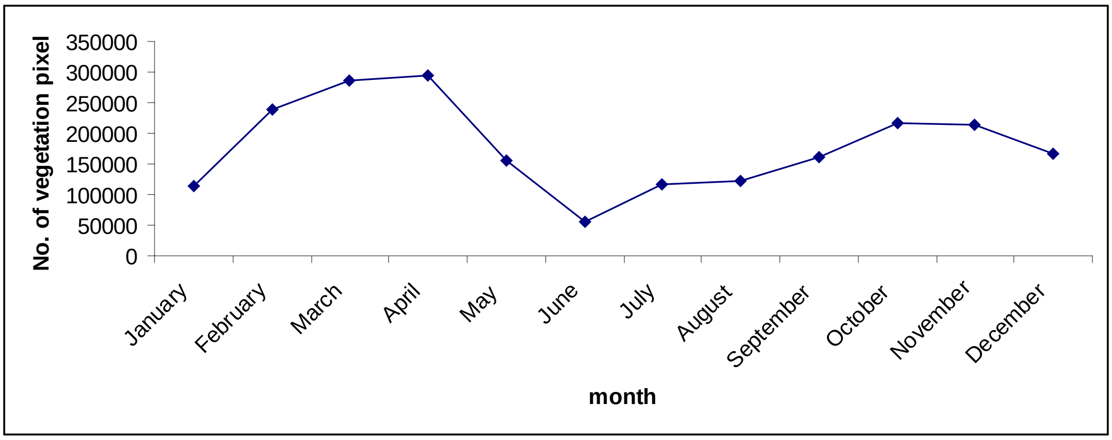

b) Monthly vegetation changes during January to December in 2001



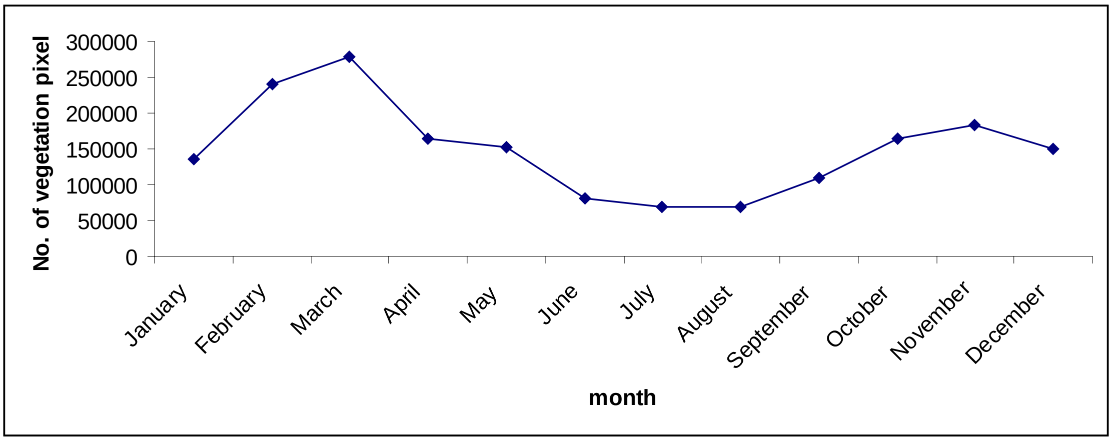

c) Monthly vegetation change during January to December in 2002



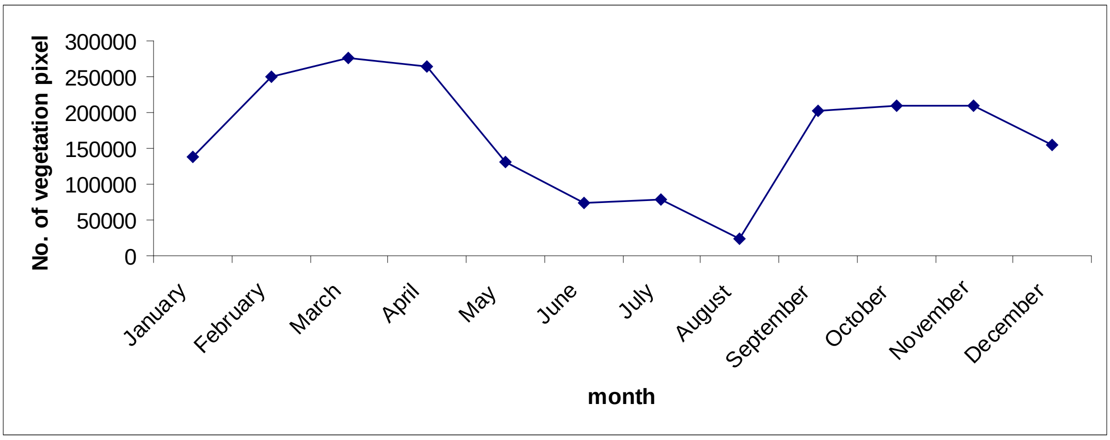
d) Monthly vegetation change during January to December in 2003



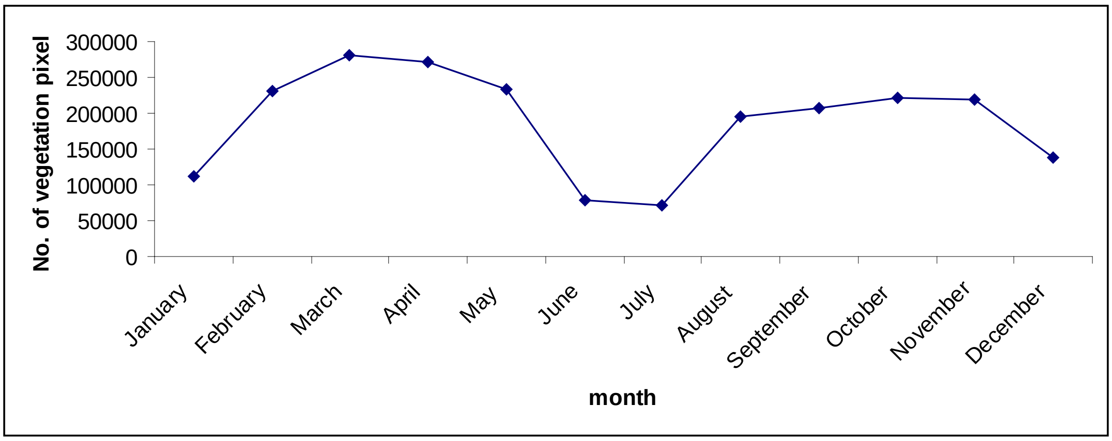

e) Monthly vegetation change during January to December in 2004



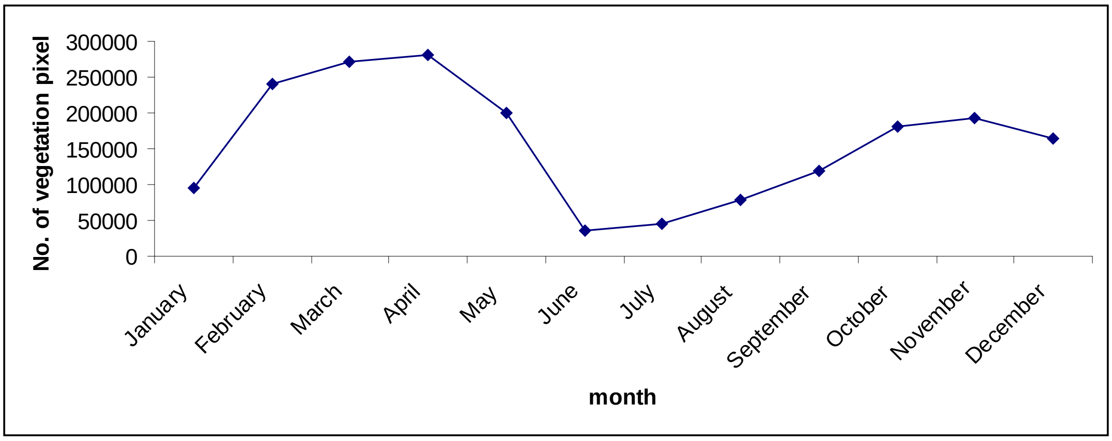

f) Monthly vegetation change during January to December in 2005



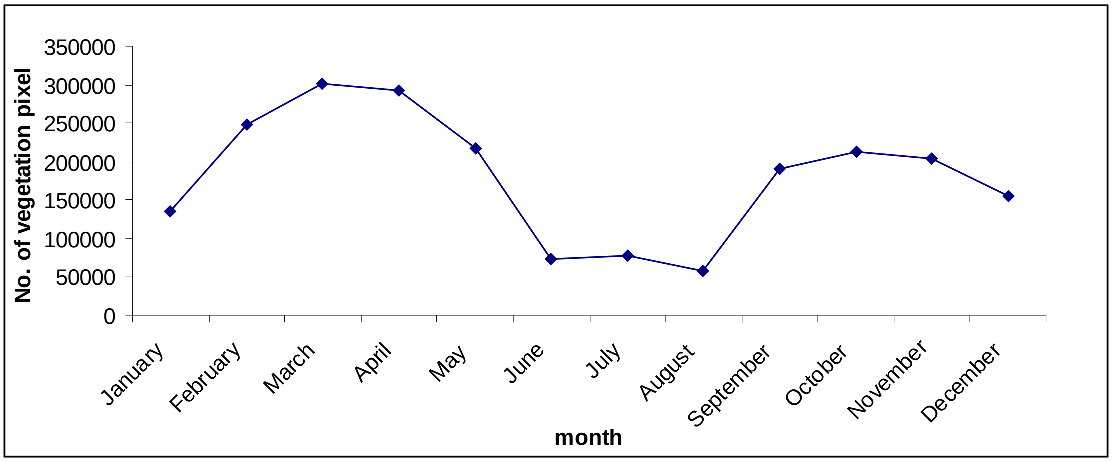
g) Monthly vegetation change during January to December in 2006



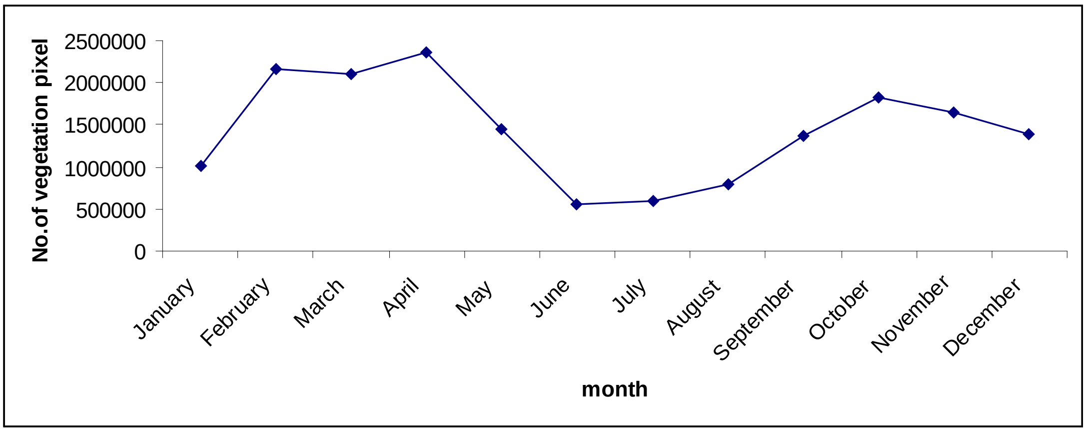

h) Monthly vegetation change during January to December in 2007



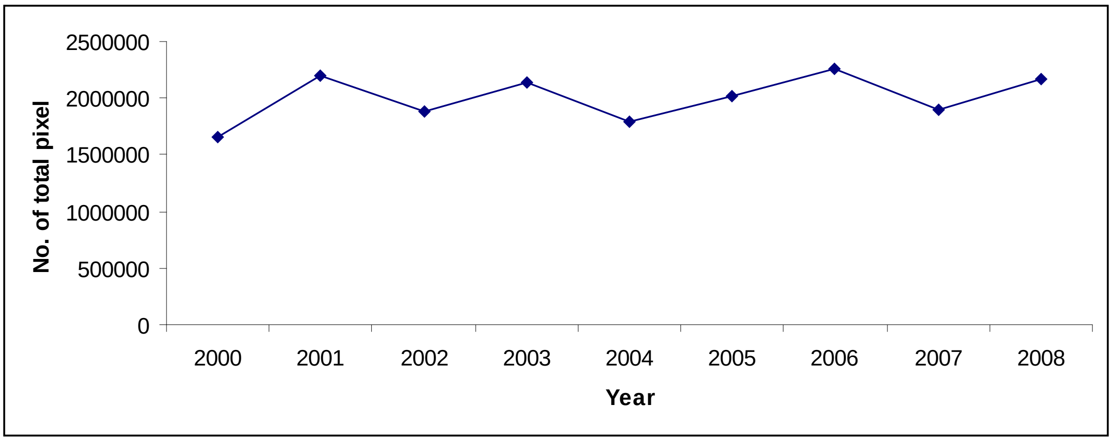

i) Monthly vegetation change during January to December in 2008



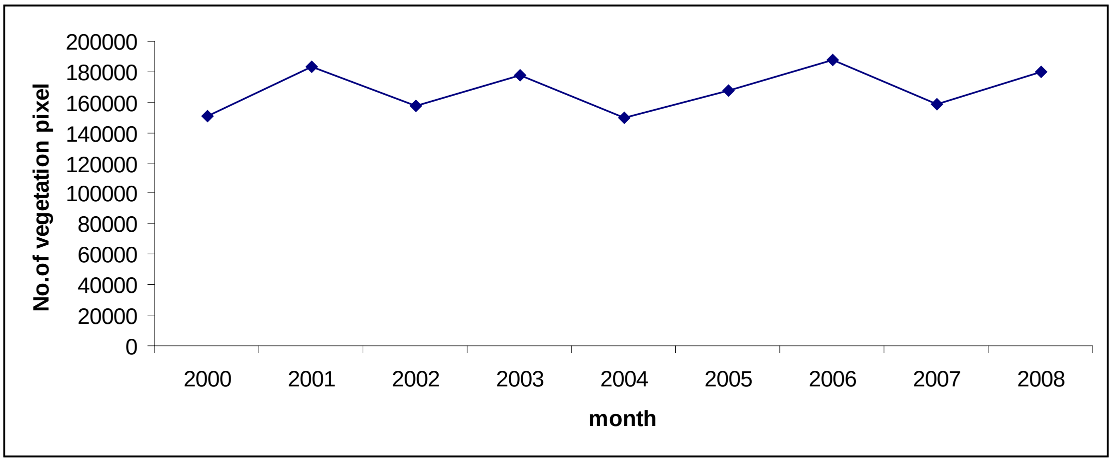
j) Monthly (total) vegetation change of the Haor area during January to December from 2000 to 2008



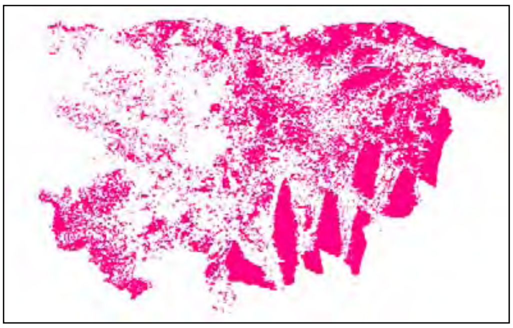

k) Yearly (total) vegetation change of the Haor area from 2000 to 2008



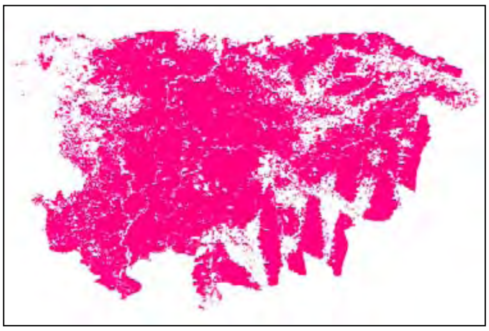

l) Yearly mean vegetation change of the Haor area from 2000 to 2008



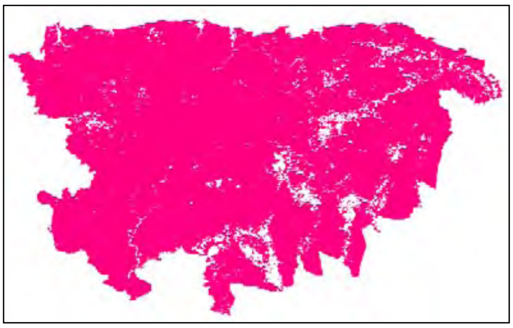
**APPENDIX V: Vegetation change patterns of the Haor area on the basis of MODIS image during January to December in 2001**



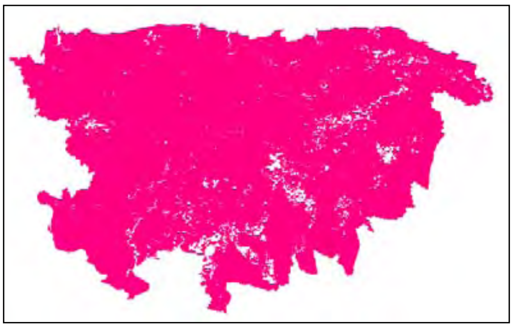
Vegetation_January, 2001



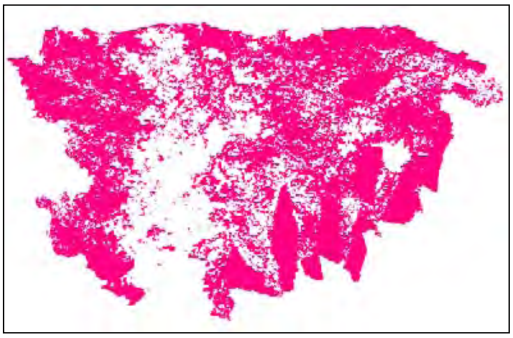
Vegetation_february, 2001



Vegetation_March, 2001

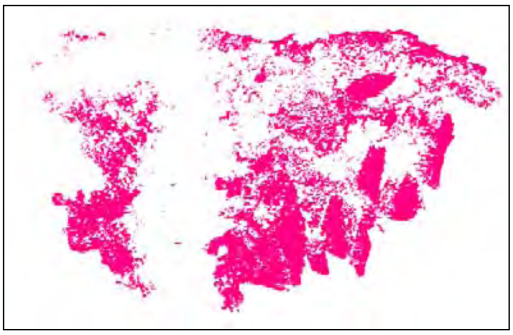


Vegetation_April, 2001

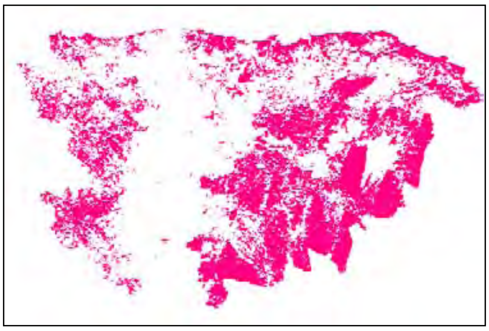


Vegetation_May, 2001

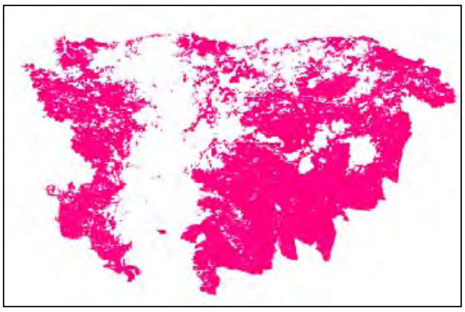
Vegetation_June, 2001

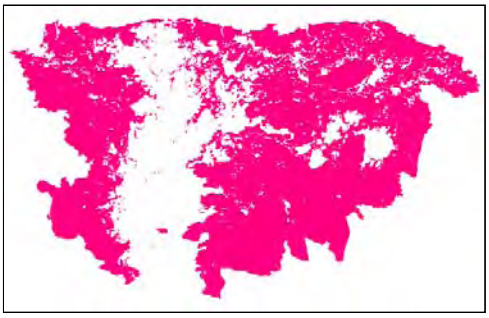


Vegetation_July, 2001



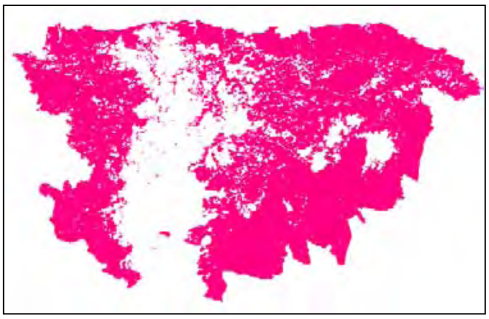
Vegetation_August, 2001

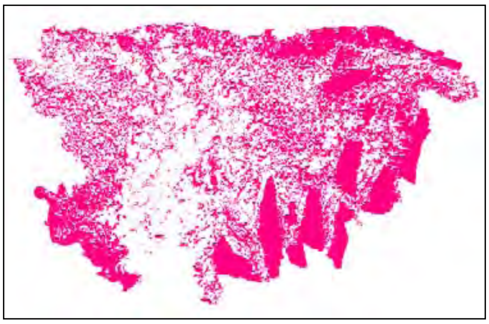




Vegetation_September, 2001

Vegetation_October, 2001



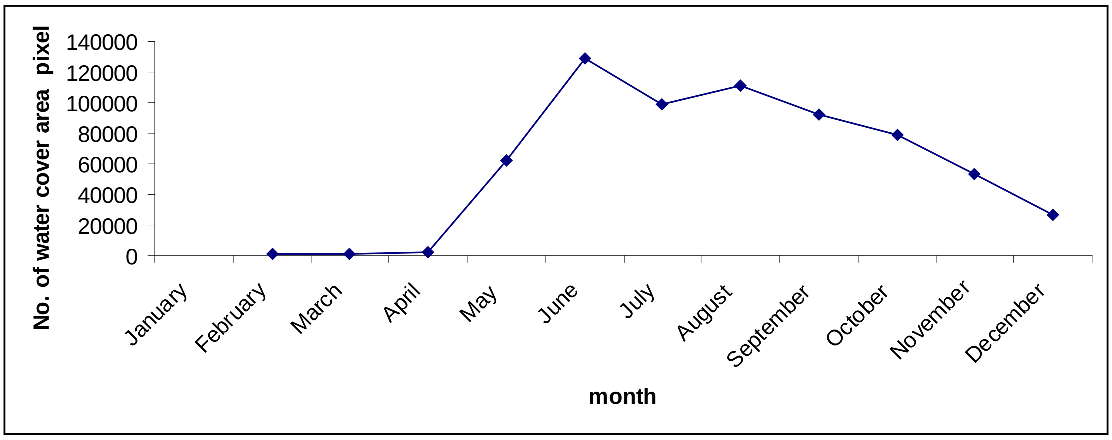


Vegetation_November, 2001

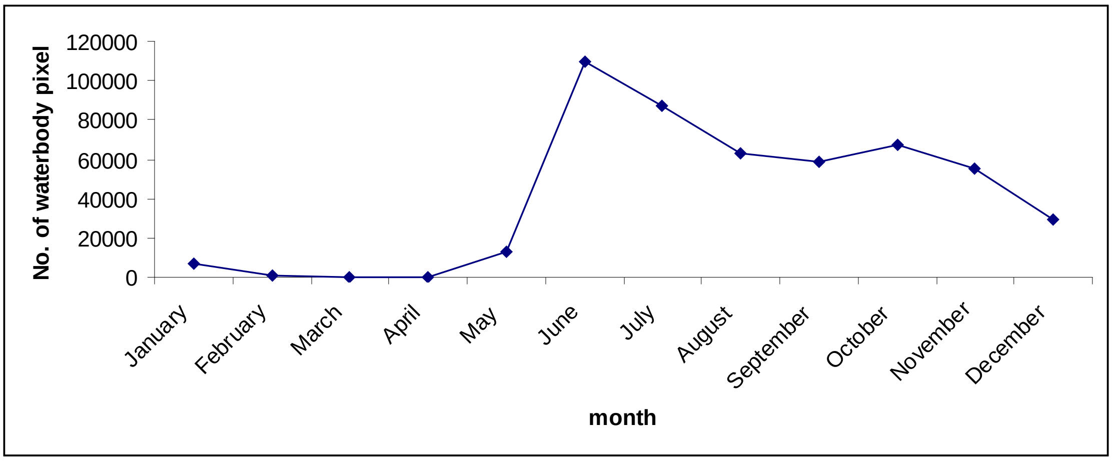
Vegetation_December, 2001

**APPENDIX VI: Water body change patterns on the basis of Pixel information of MODIS images from 2000 to 2008**

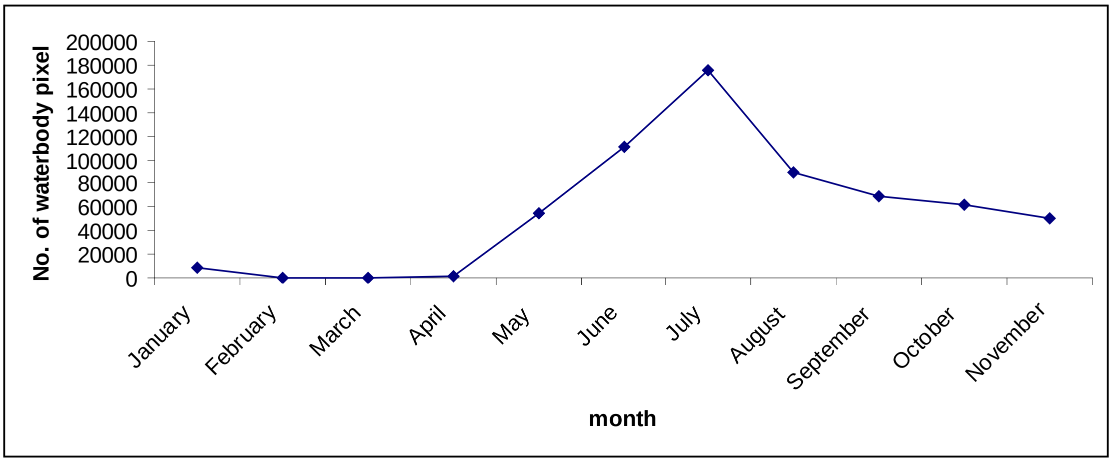
a) Monthly water cover area changes during January to December in 2000



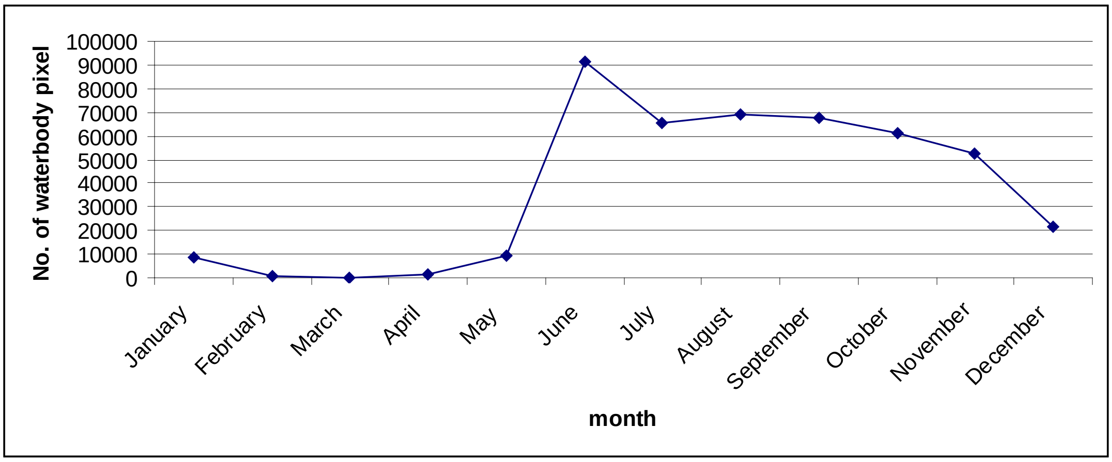

b) Monthly water cover area changes during January to December in 2001



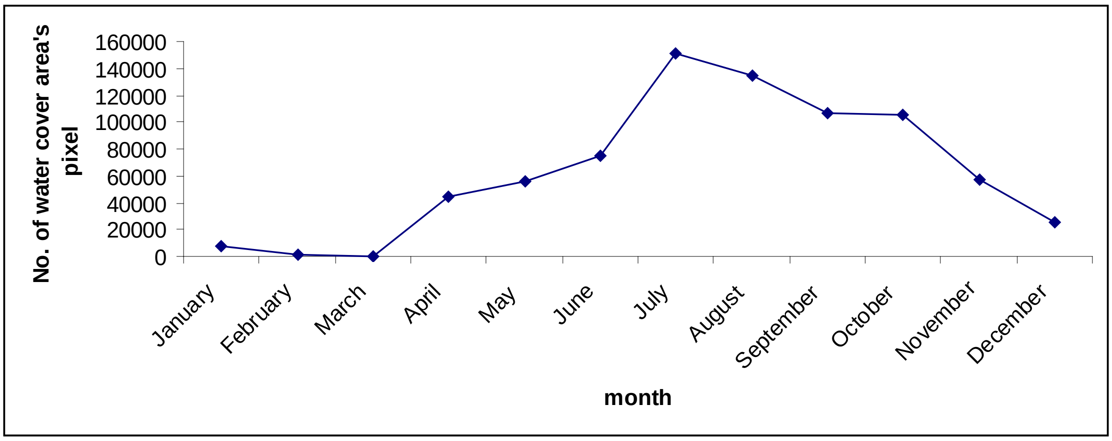

c) Monthly water cover area changes during January to December in 2002



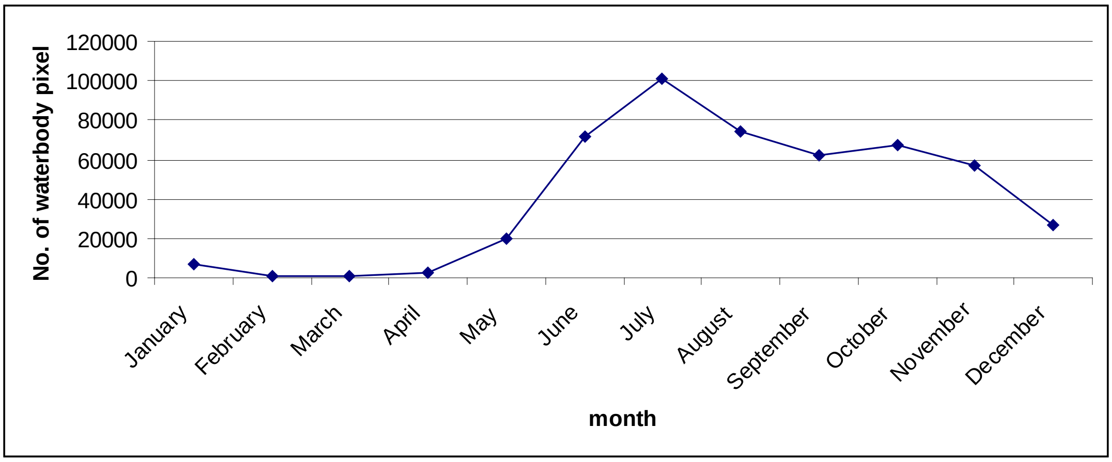
d) Monthly water cover area changes during January to December in 2003



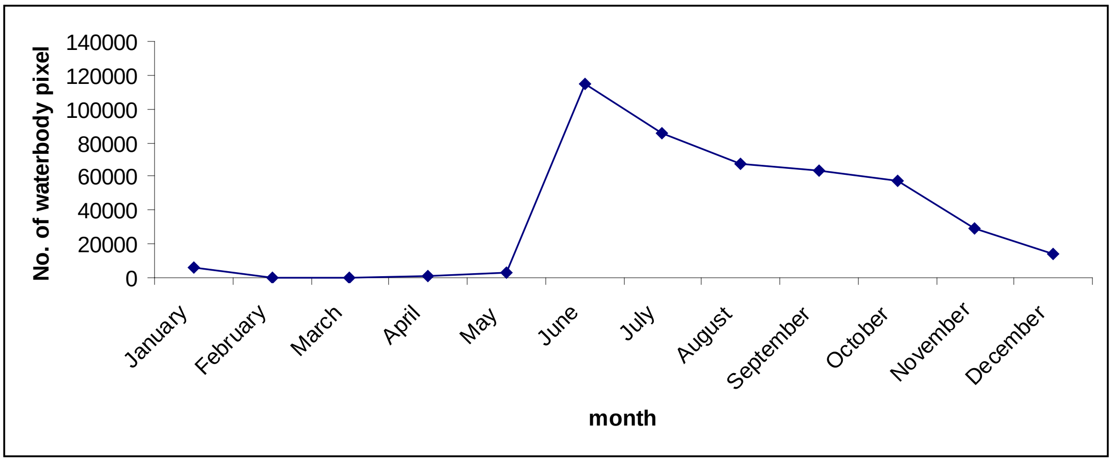

e) Monthly water cover area cha nges during J anuary t o December i n 2004



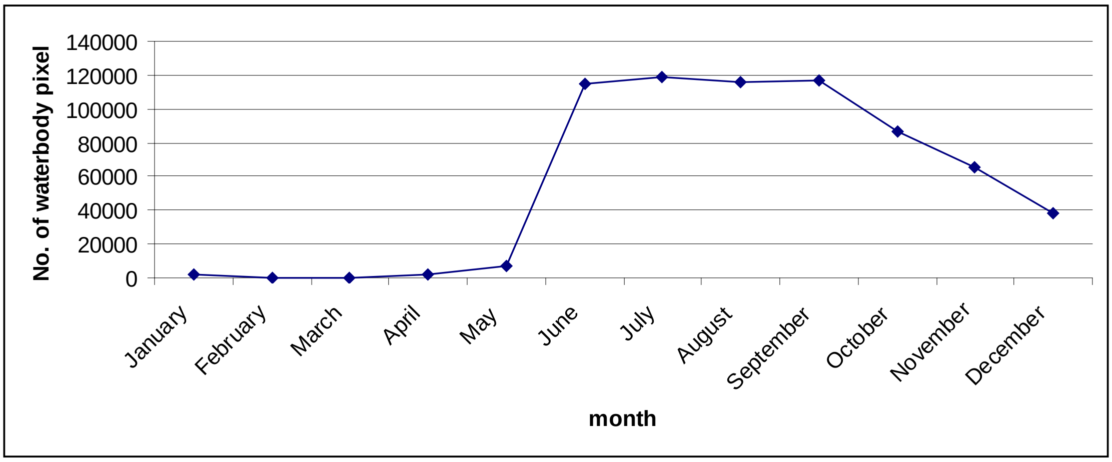

f) Monthly water cover area changes during January to December in 2005



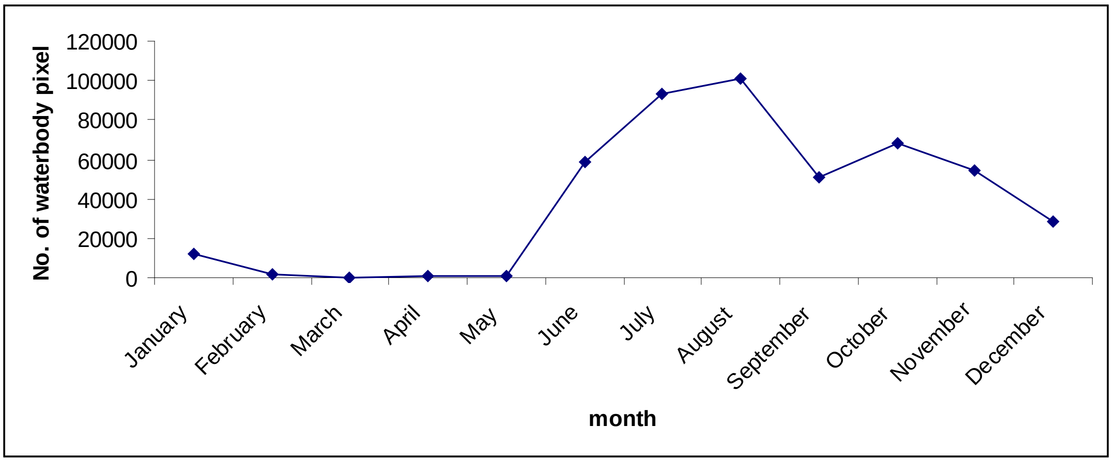
g) Monthly water cover area changes during January to December in 2006



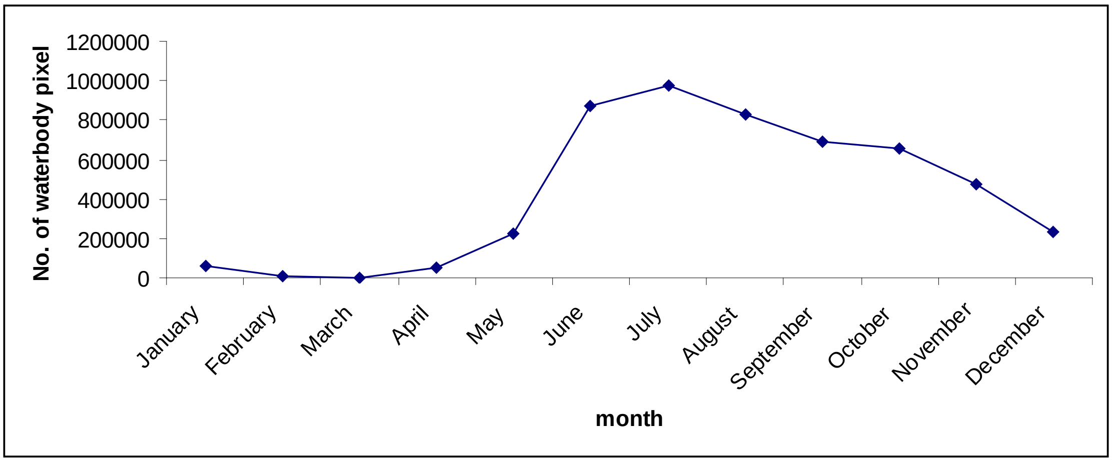

h) Monthly water cover area changes during January to December in 2007



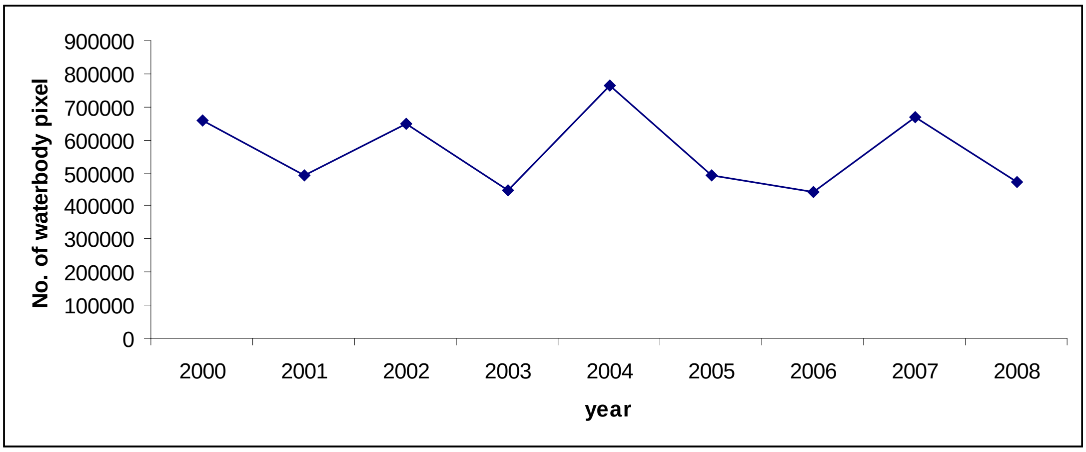

i) Monthly water cover area changes during January to December in 2008



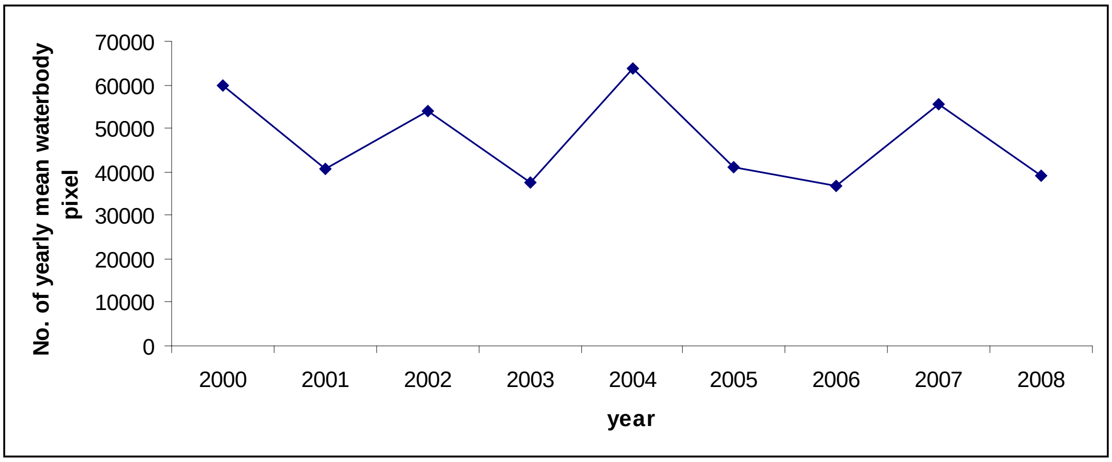
j) Monthly (total) water body changes of the Haor area during January to December from 2000 to 2008



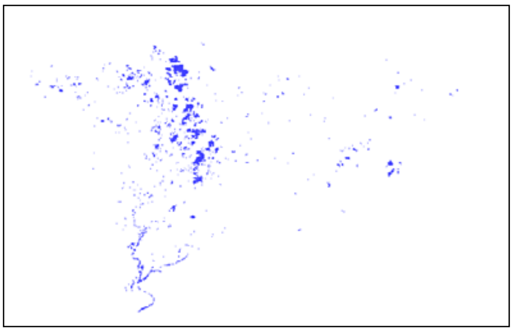

k) Yearly (total) water changes of the Haor area from 2000 to 2008



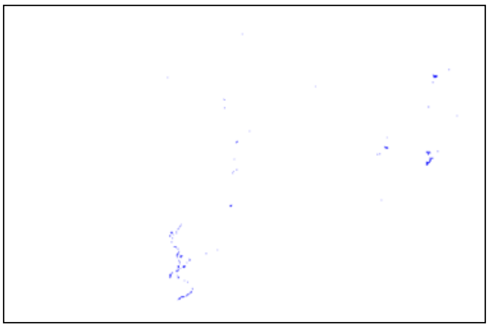

l) Yearly mean water cover changes of the Haor area from 2000 to 2008



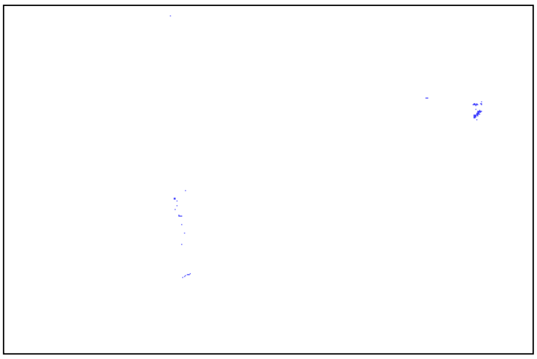
**APPENDIX VII: Water body change pattern of the haor area on the basis of MODIS image during January to December in 2001**



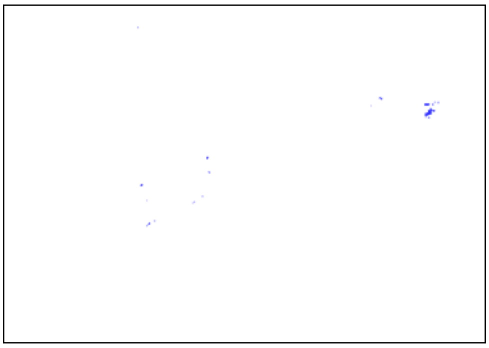
Waterbody_January, 2001



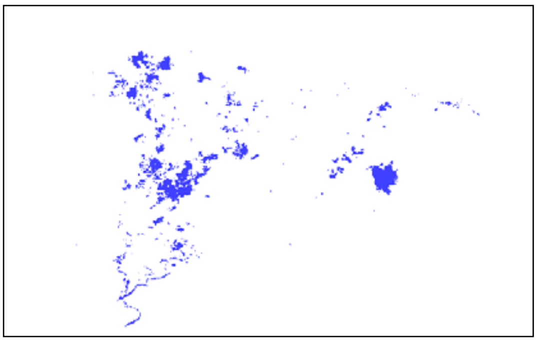
Waterbody_february, 2001



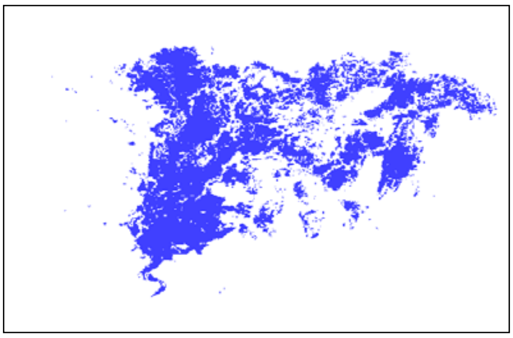
Waterbody_March, 2001



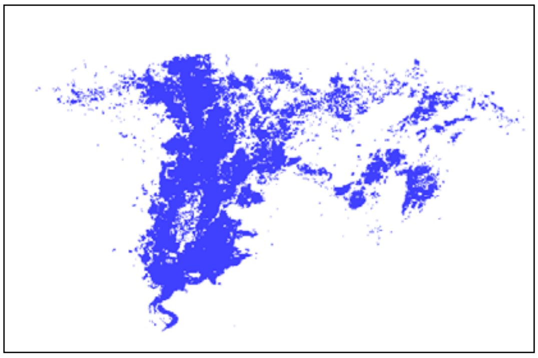
Waterbody_April, 2001



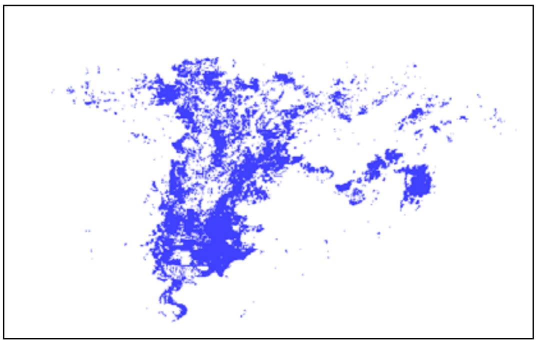
Waterbody_May, 2001



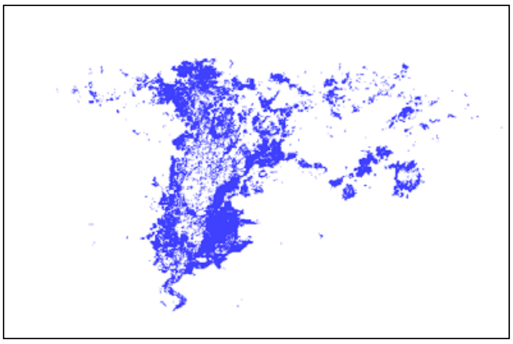
Waterbody_June, 2001



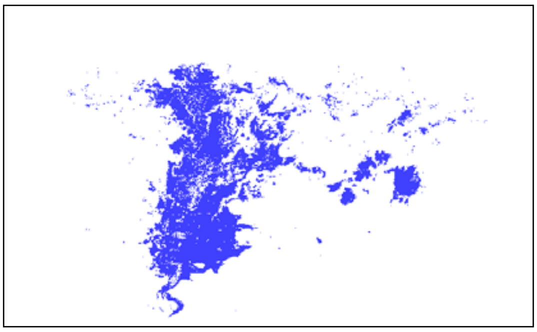
Waterbody_July, 2001



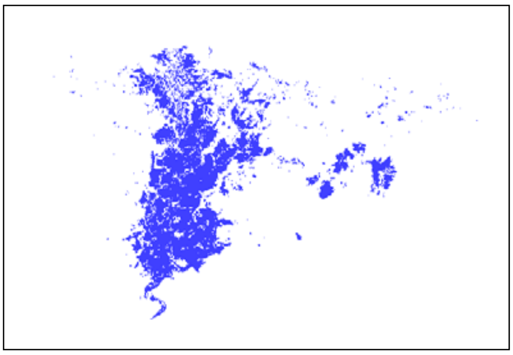
Waterbody_August, 2001



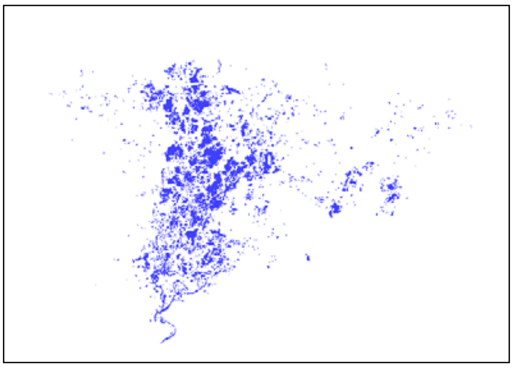
Waterbody_September, 2001



Waterbody_October, 2001

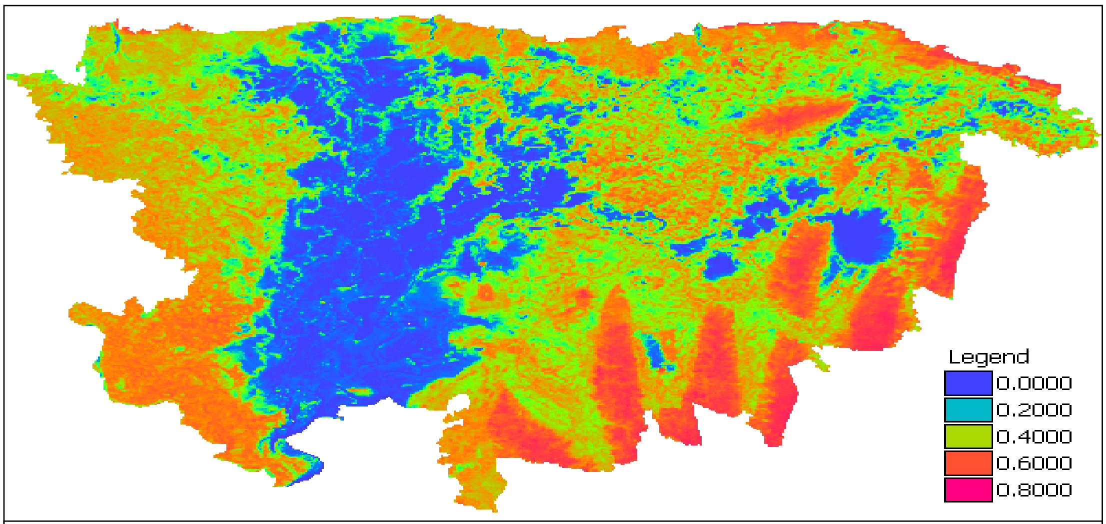


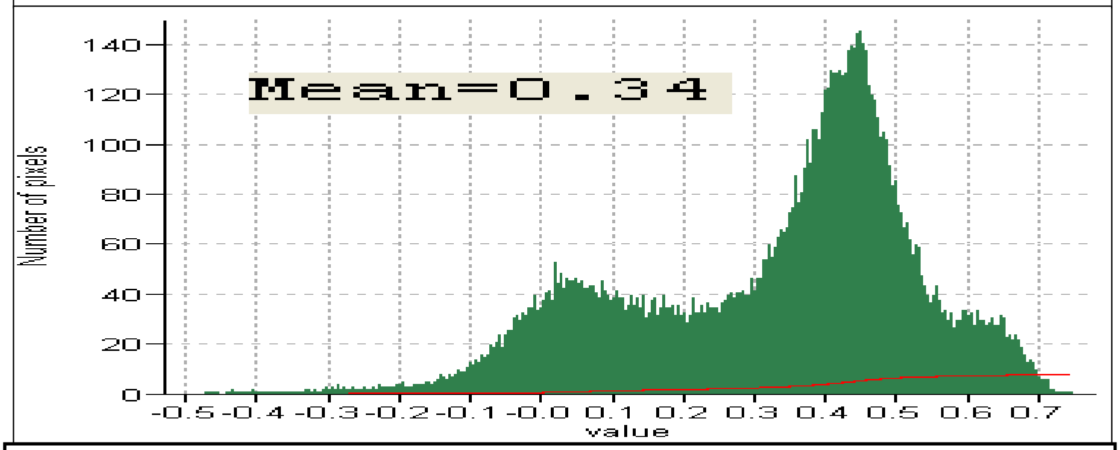
Waterbody_November, 2001

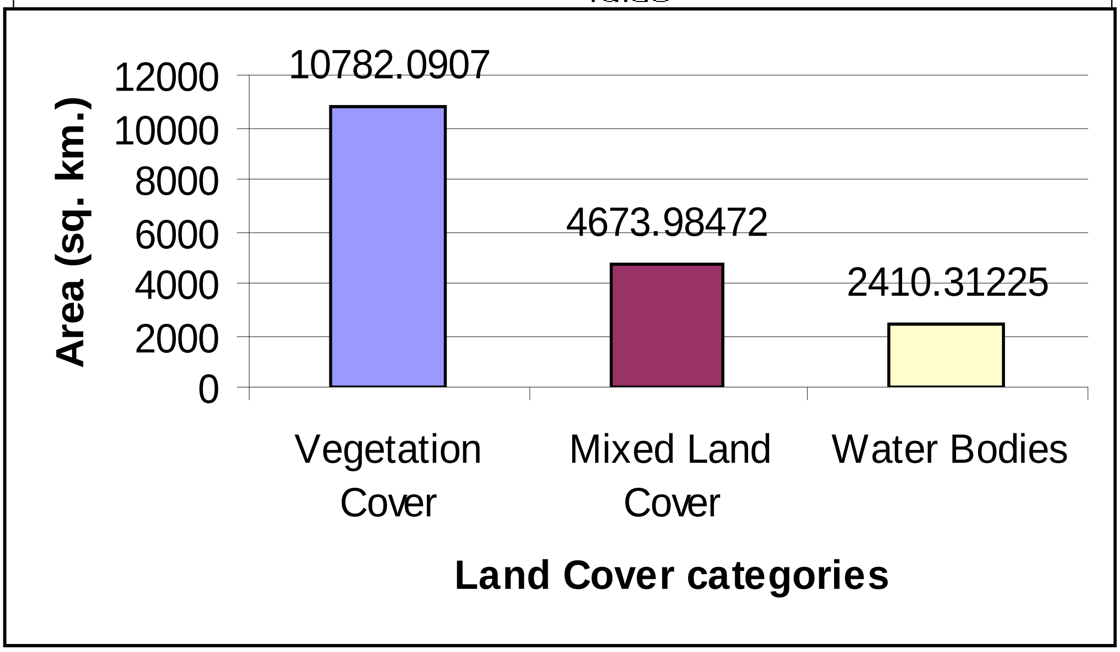


Waterbody_December, 2001

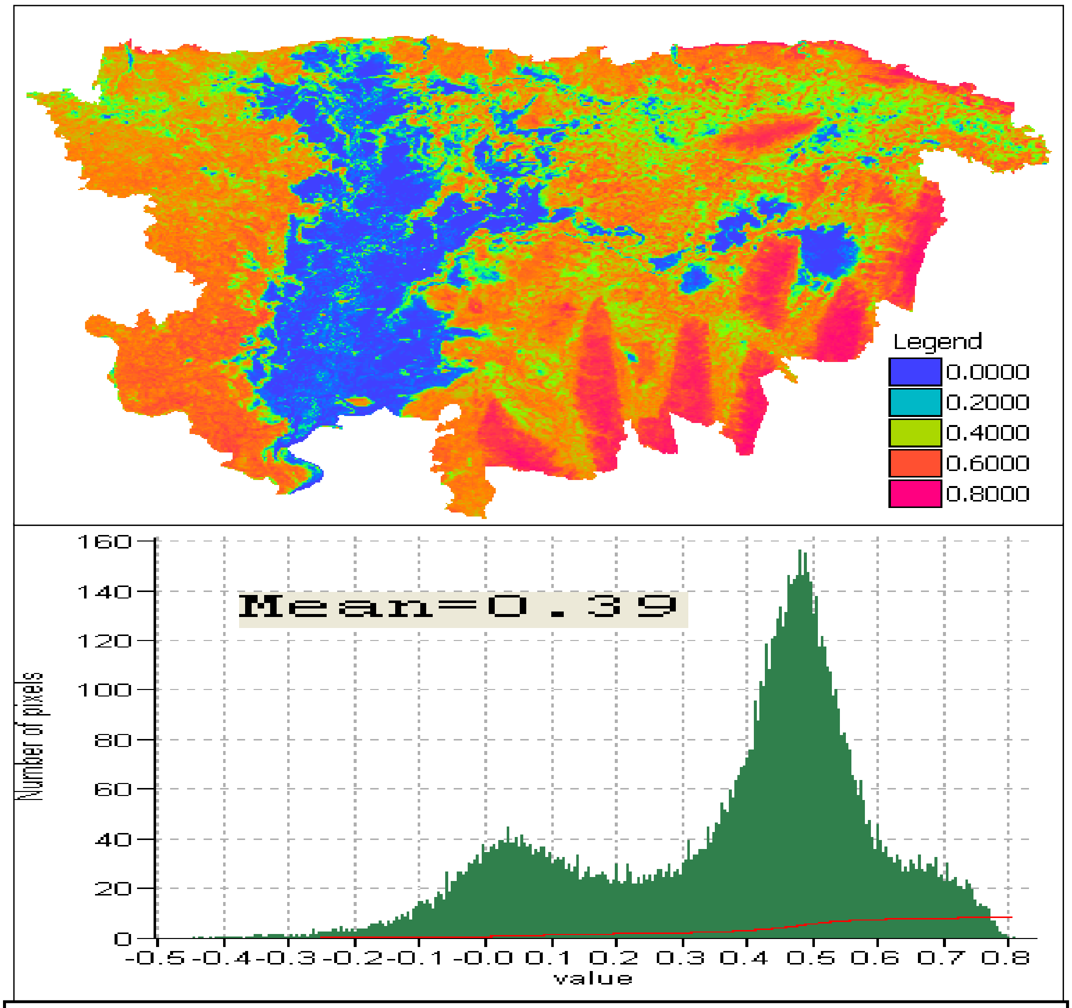
**APPENDIX VIII: Land Cover Pattern of the Study Area in 2000**

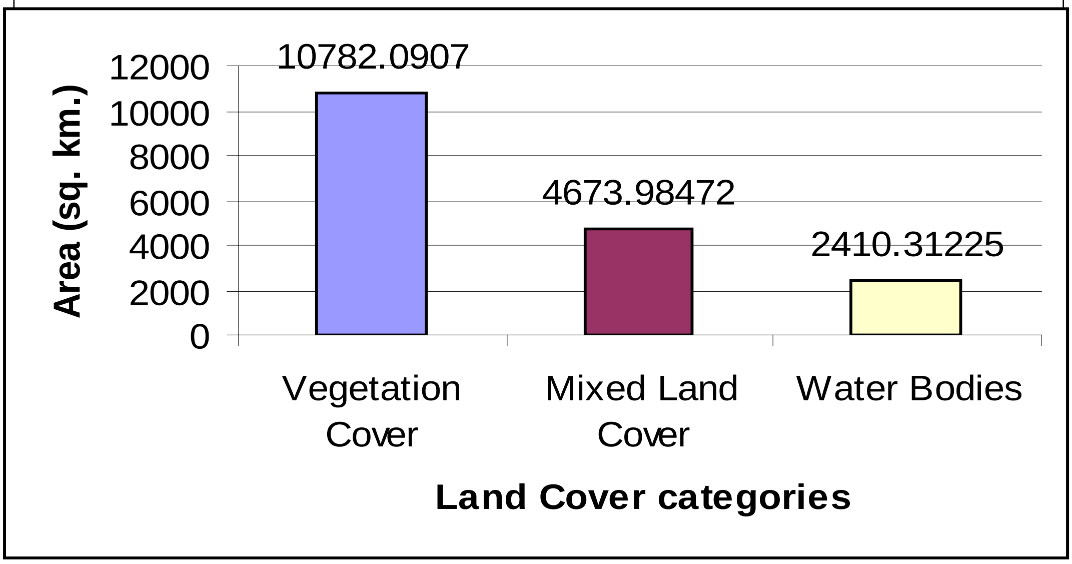


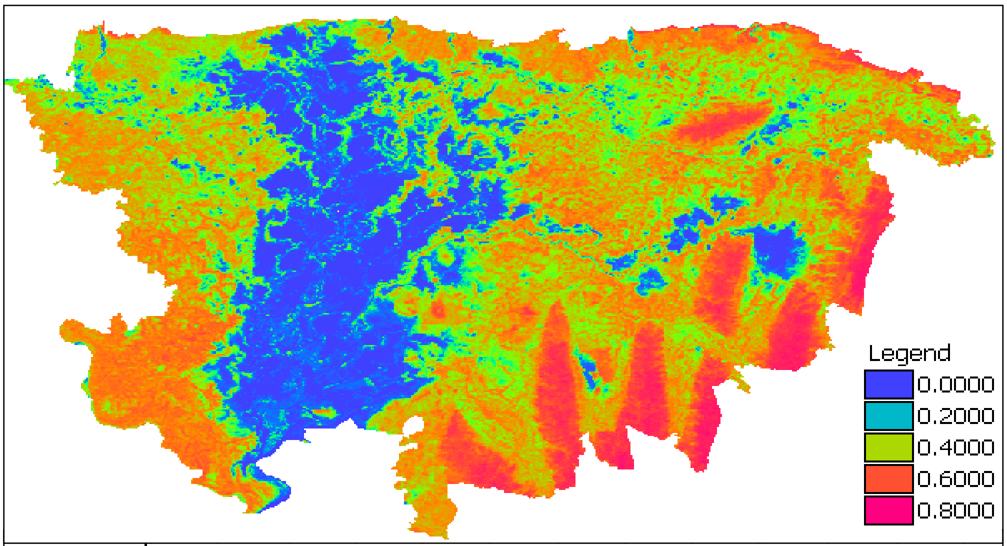



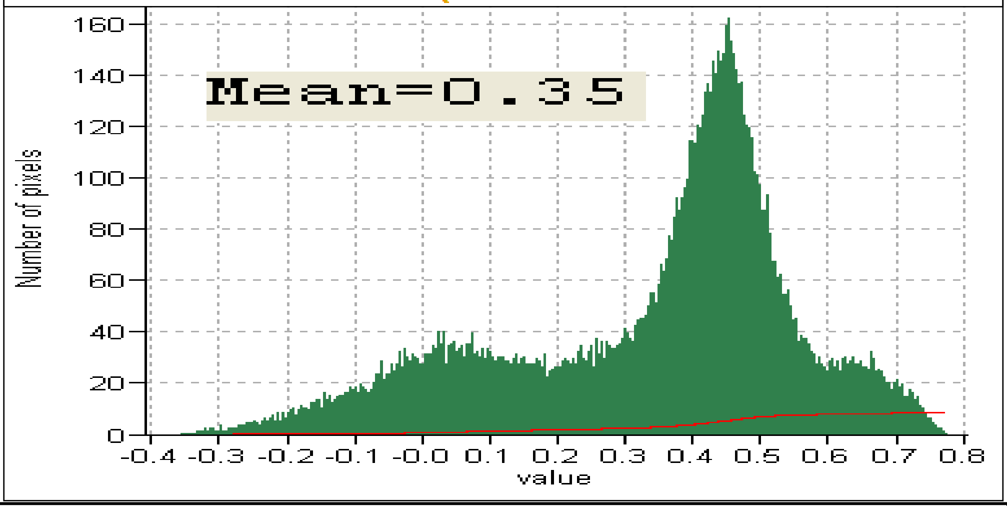
**APPENDIX IX: Land Cover Pattern of Study Area in 2001**

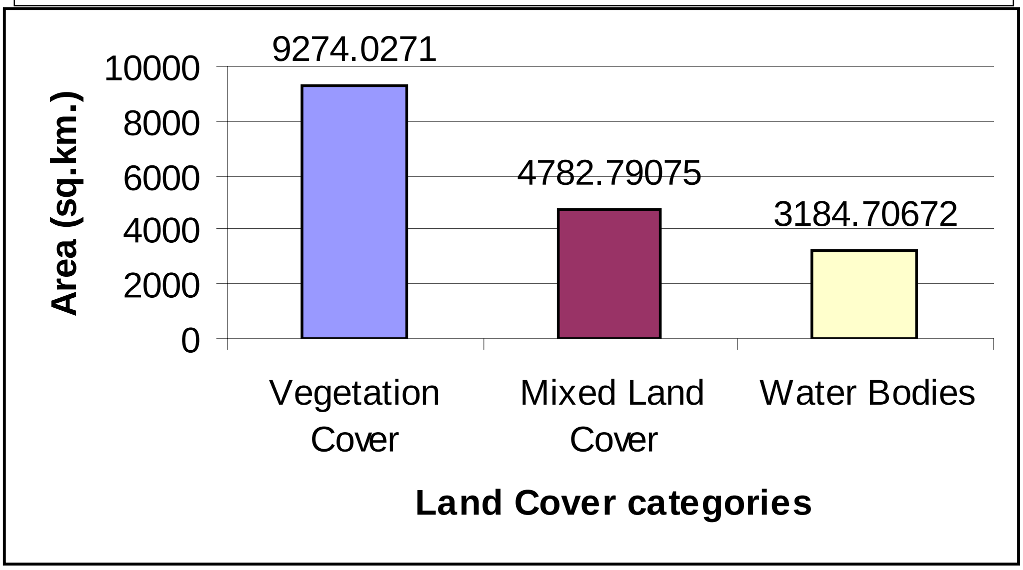


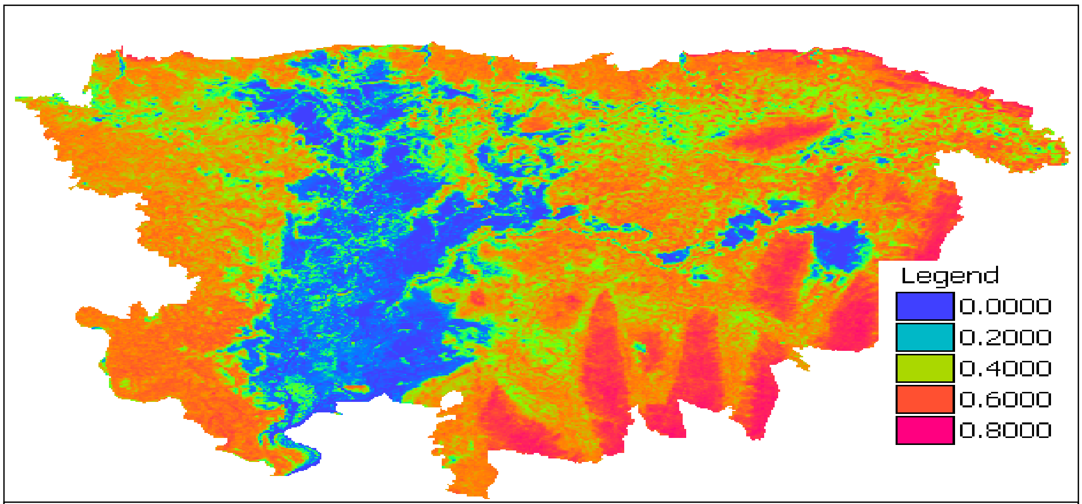
**APPENDIX X: Land Cover Pattern of Study Area in 2002**

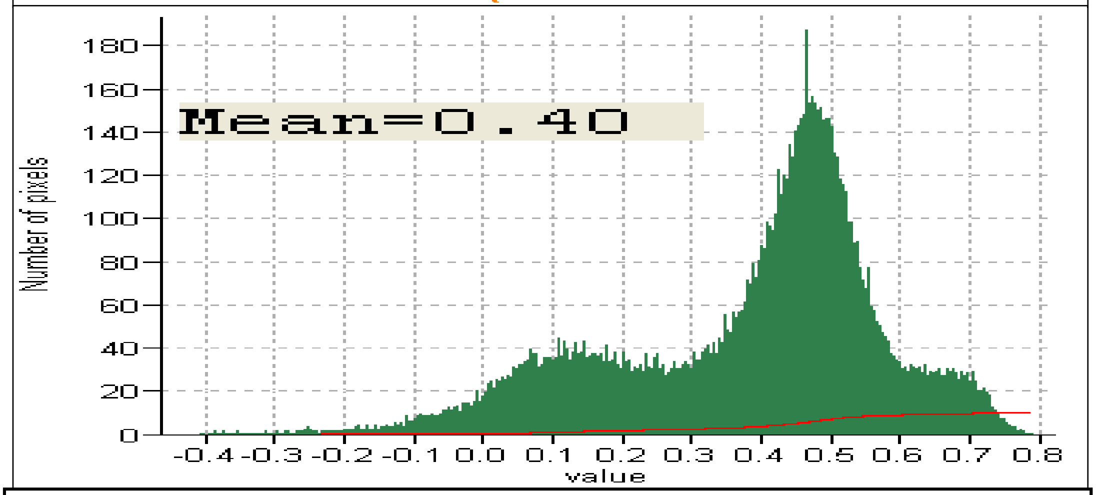


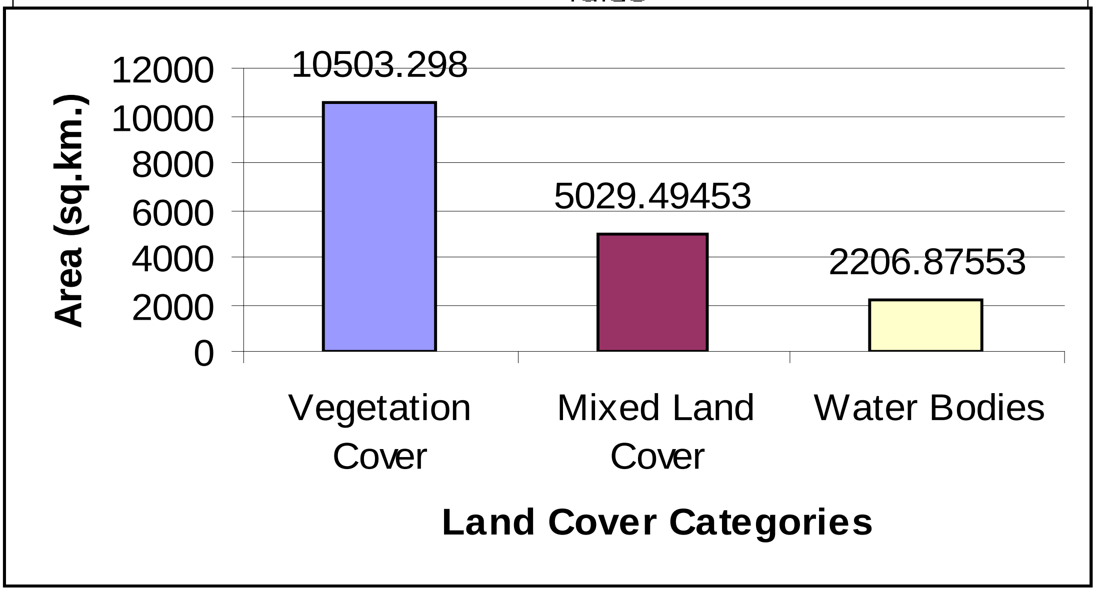



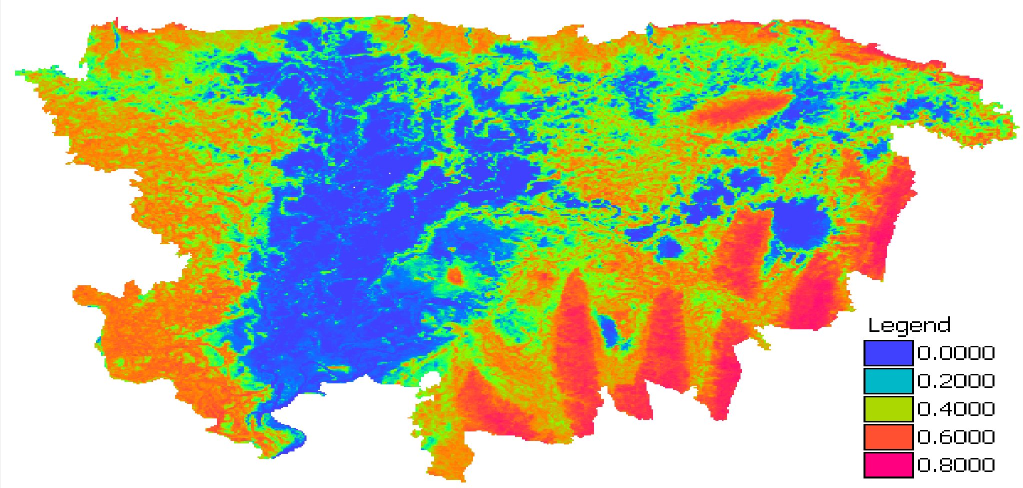
## APPENDIX XI: Land Cover Pattern of Study Area in 2003

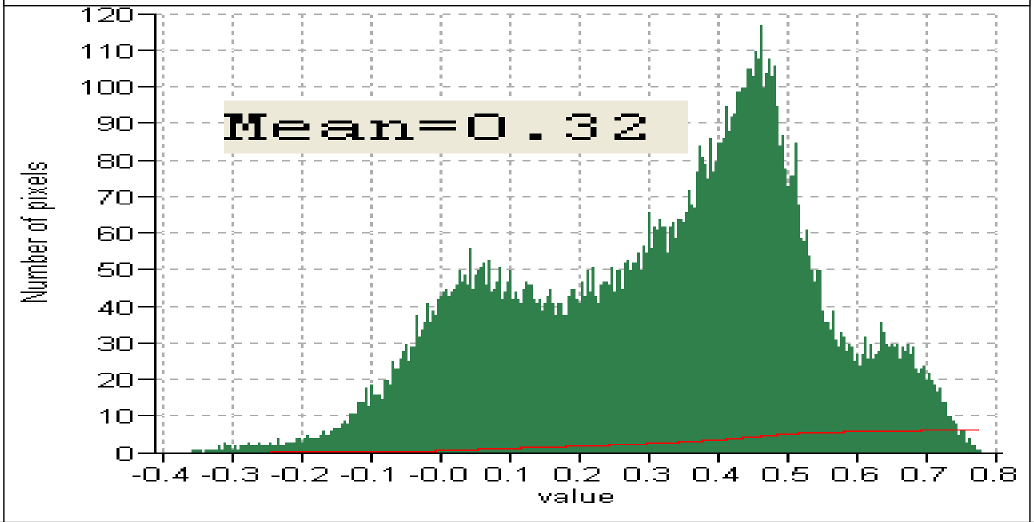


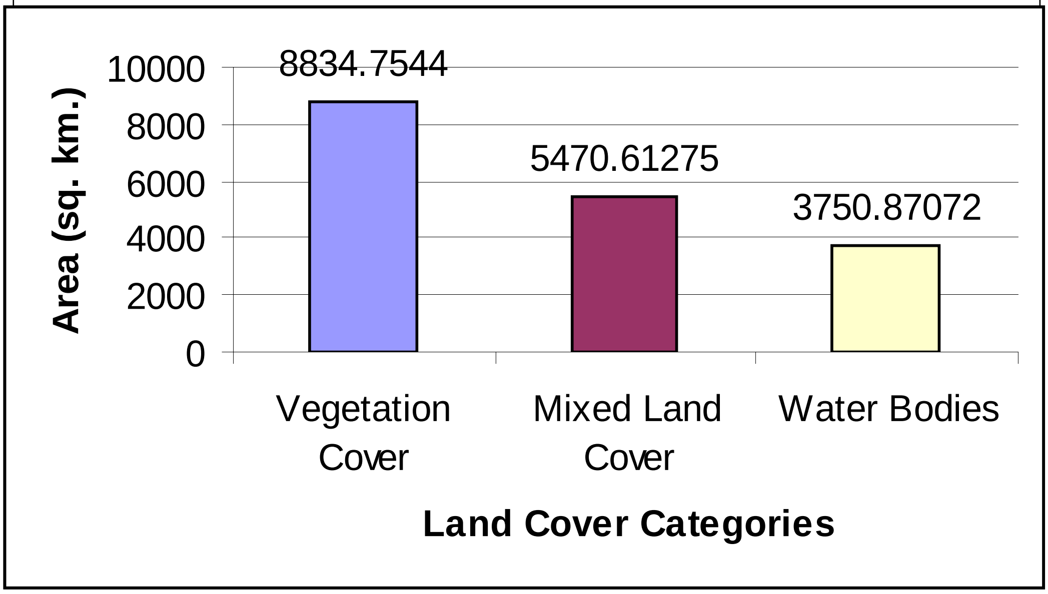



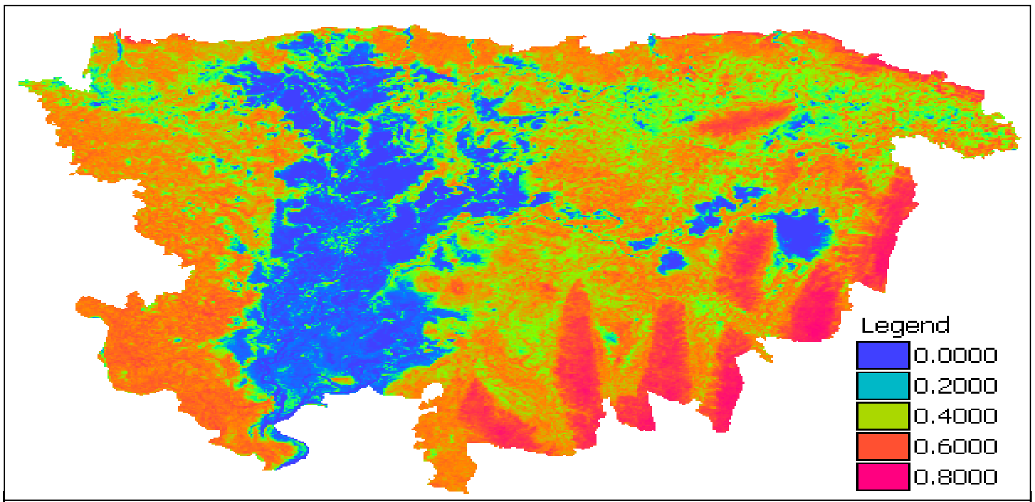
**APPENDIX XII: Land Cover Pattern of Study Area in 2004**

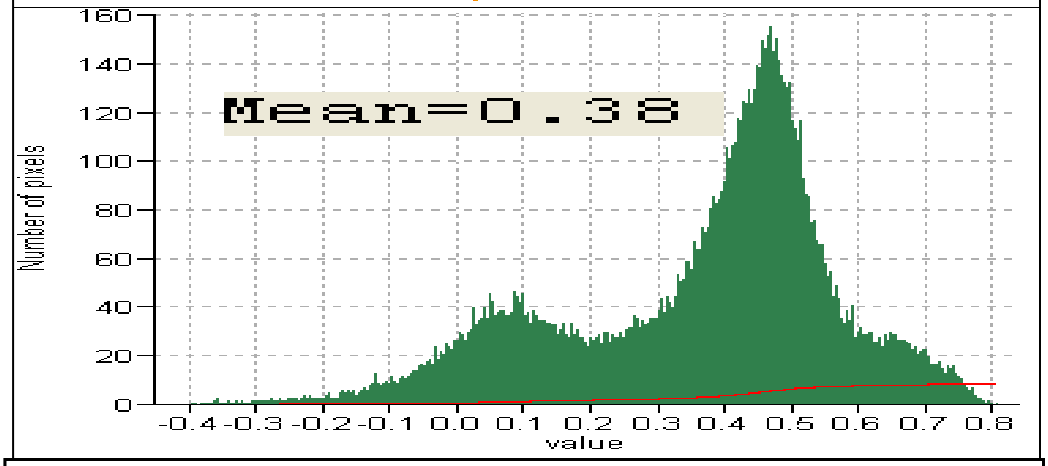


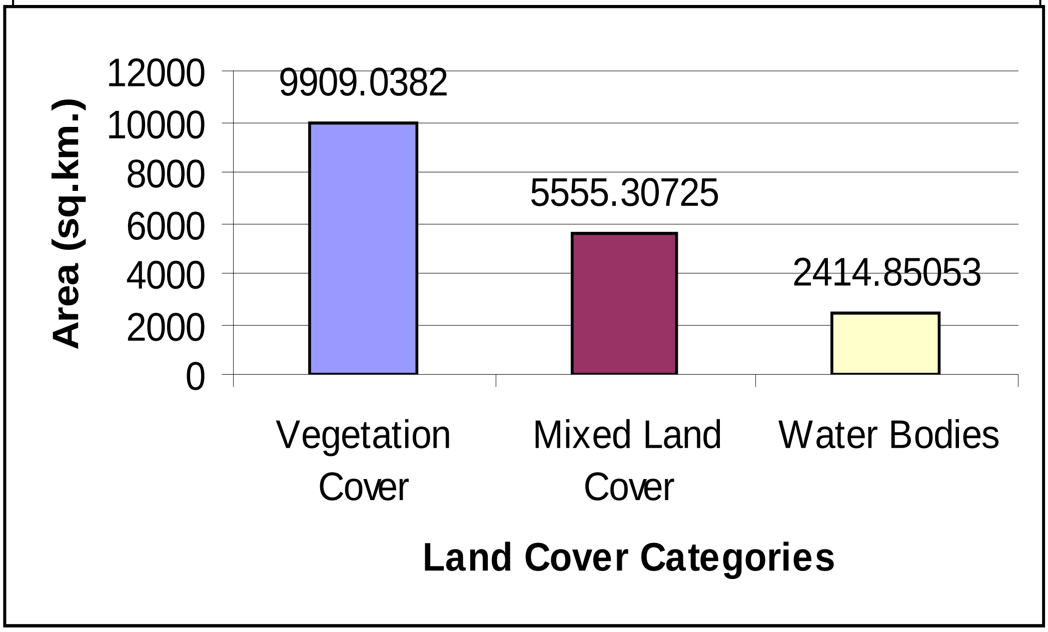



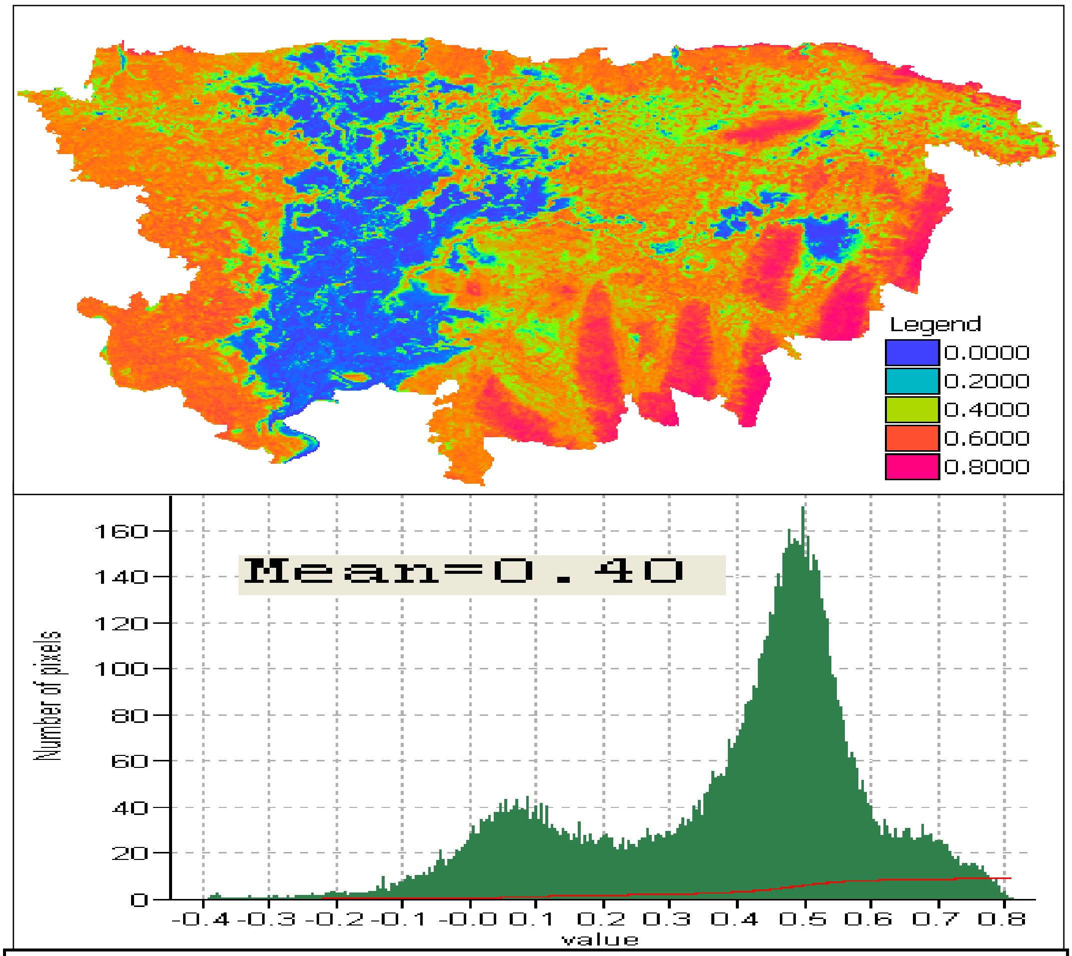
**APPENDIX XIII: Land Cover Pattern of Study Area in 2005**

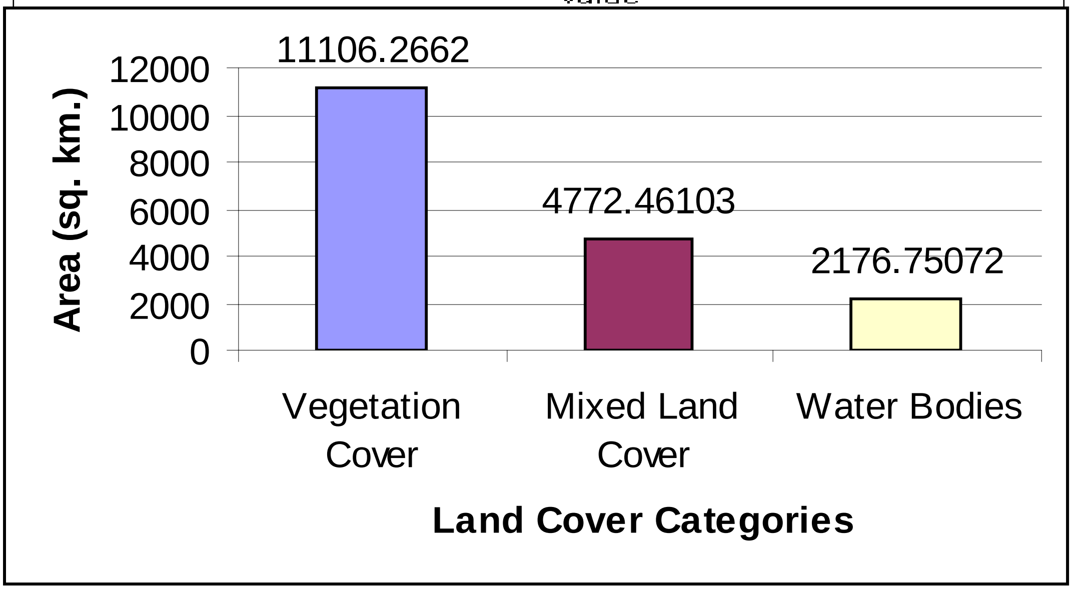


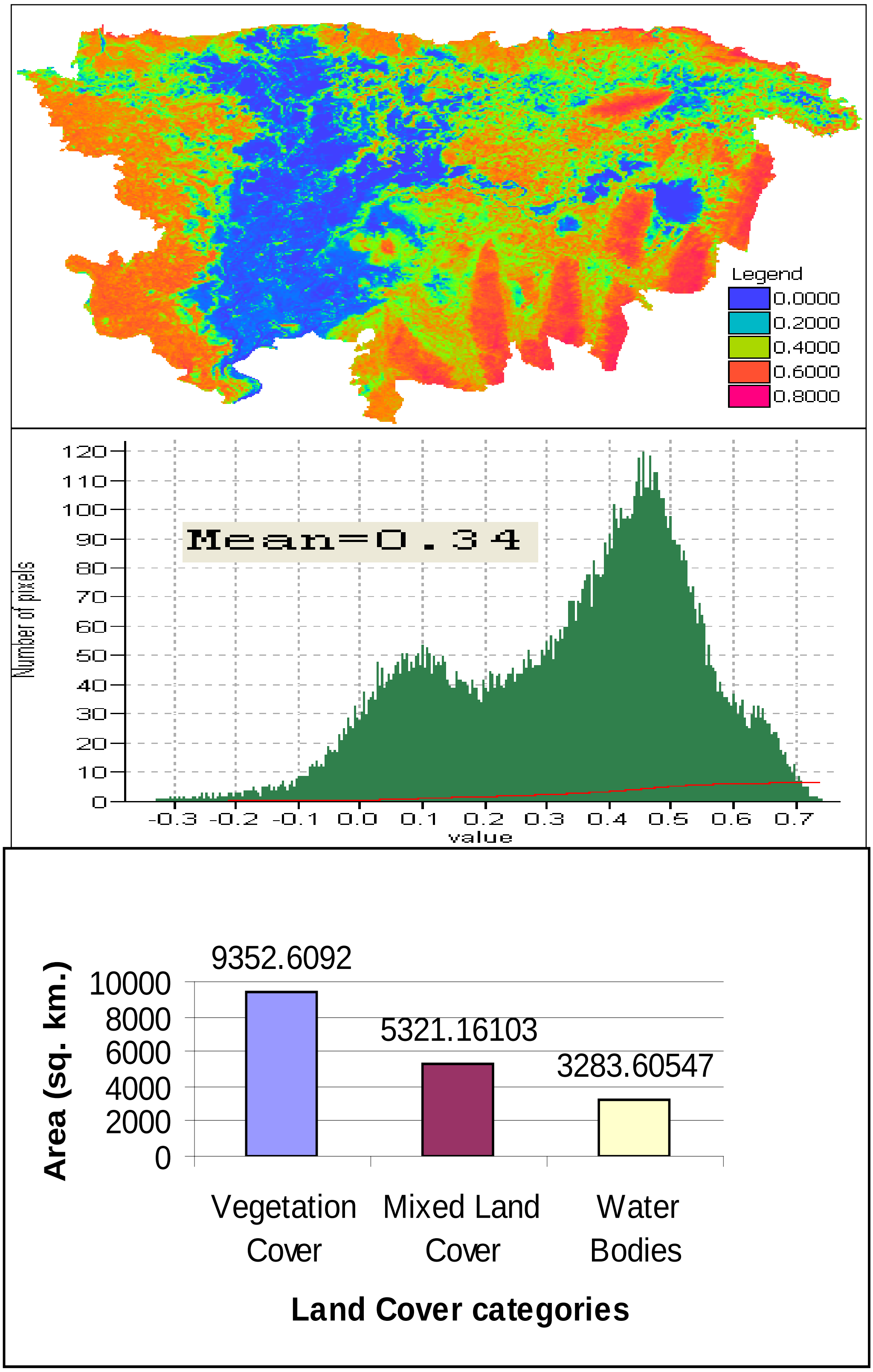



## APPENDIX XIV: Land Cover Pattern of Study Area in 2006

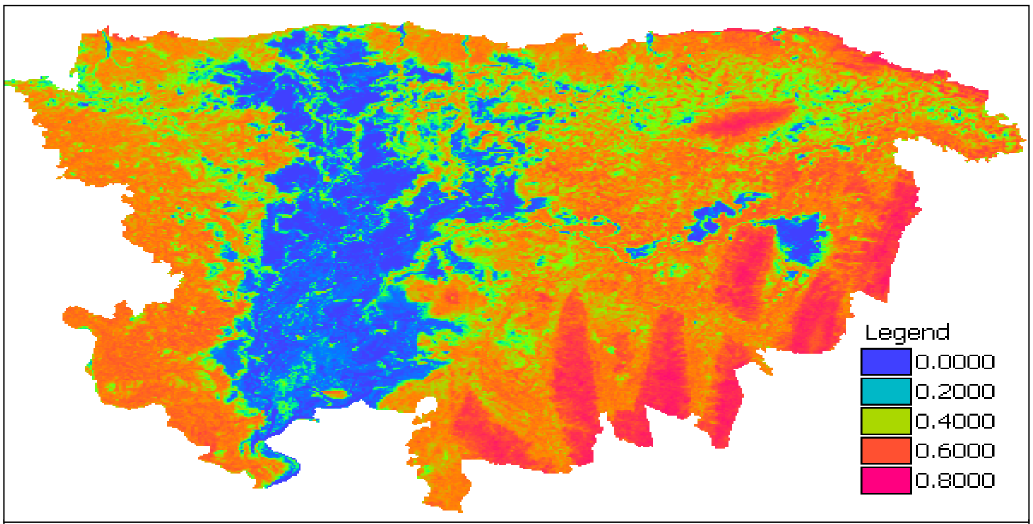


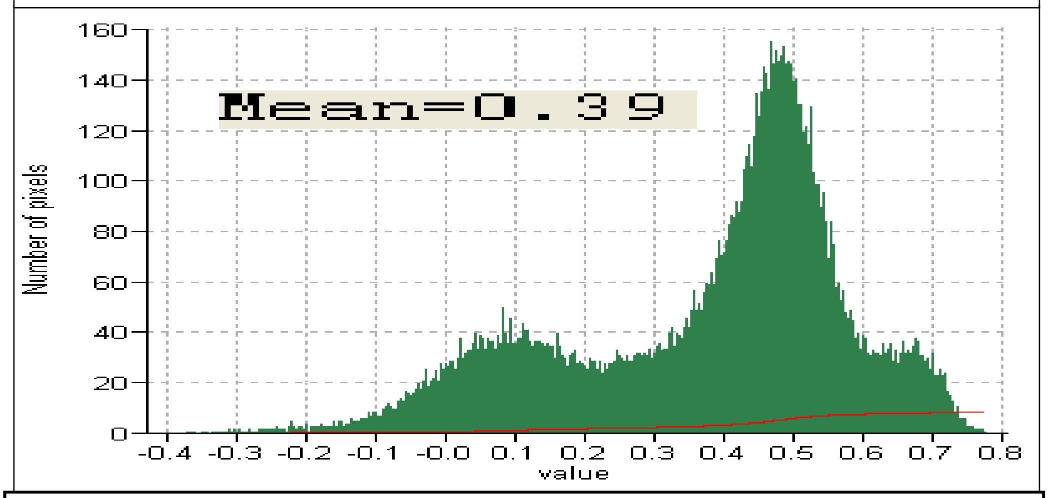



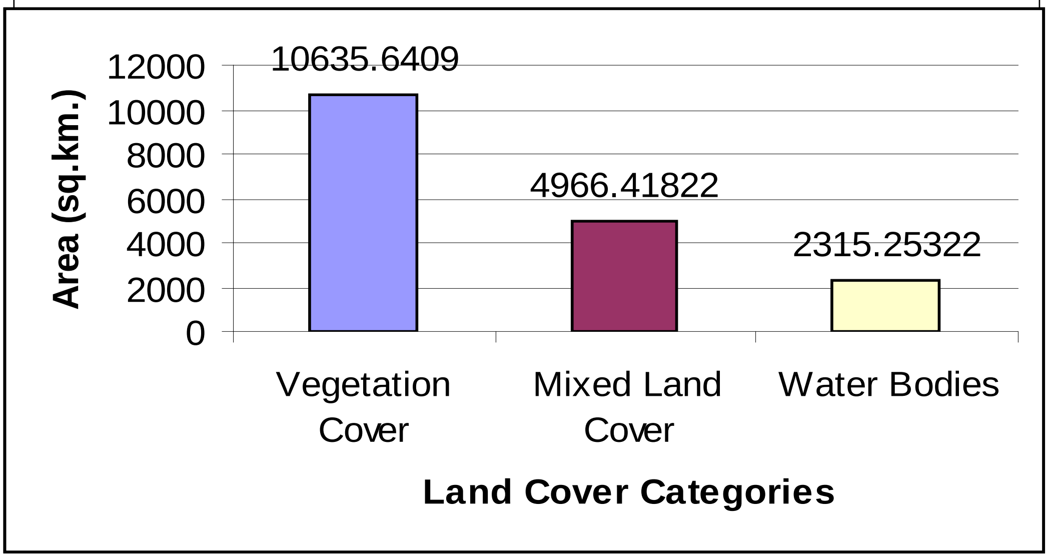
**APPENDIX XV: Land Cover Pattern of Study Area in 2007**



**APPENDIX XVI: Land Cover Pattern of Study Area in 2008**

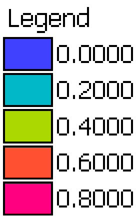


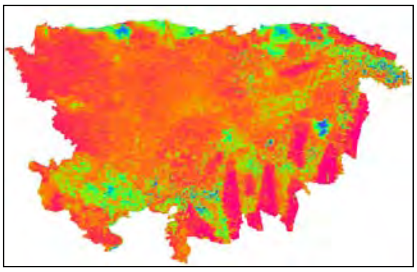



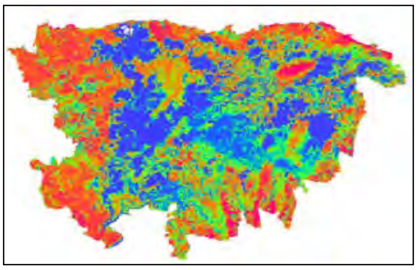
**APPENDIX XVII: Flash flood timing in 2000 and 2008 from 8 days interval MODIS images of 2000 and 2008**

a) Flash flood timing in 2000 from 8 days interval MODIS images of 2000

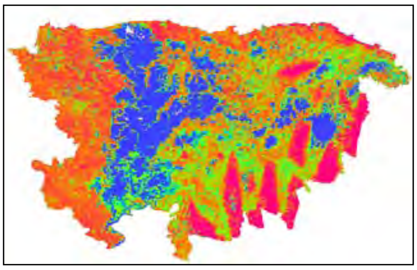


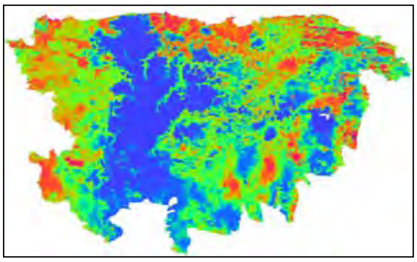
**ndvi_haor_2000113 (22, April)**



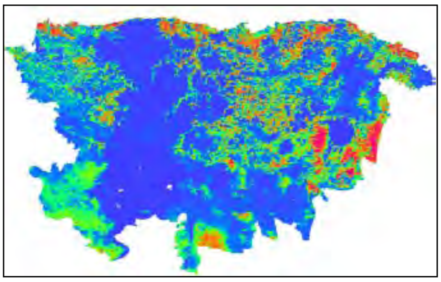
**ndvi_haor_2000121 (30, April)**



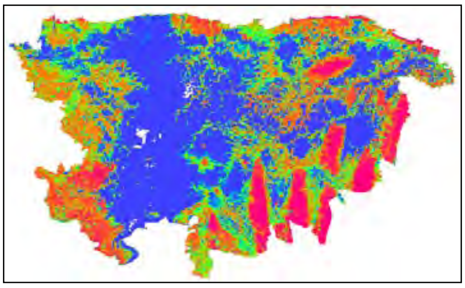
**ndvi_haor_2000129 (08, May)**



**ndvi_haor_2000137 (16, May)**

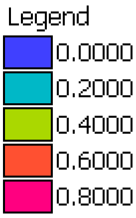


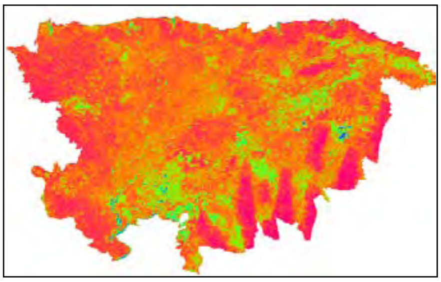
**ndvi_haor_2000145 (24, May)**



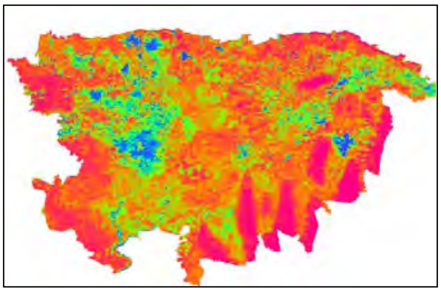
**ndvi_haor_2000153 (01, June)**

b) Flash flood timing in 2001 from 8 days interval MODIS images of 2001

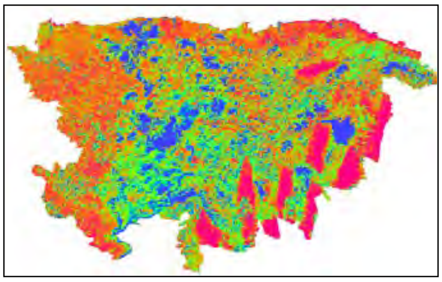


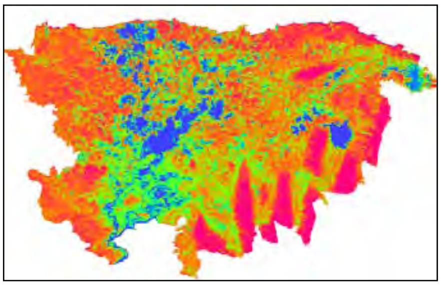
**ndvi_haor_2001113 (23, April)**



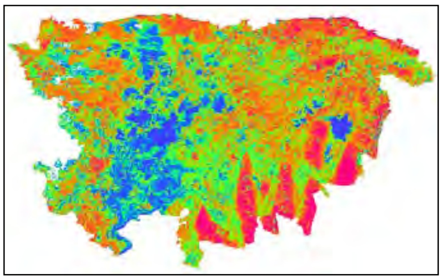
**ndvi_haor_2001121 (01, May)**



**ndvi_haor_2001129 (09, May)**

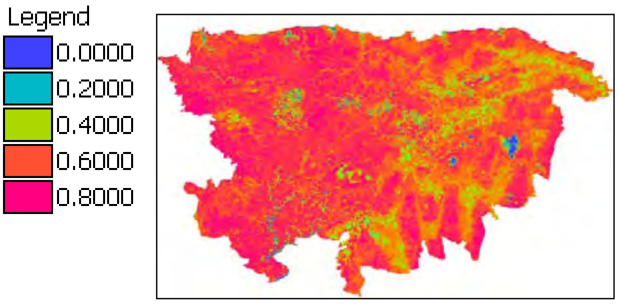


**ndvi_haor_2001137 (17, May)**

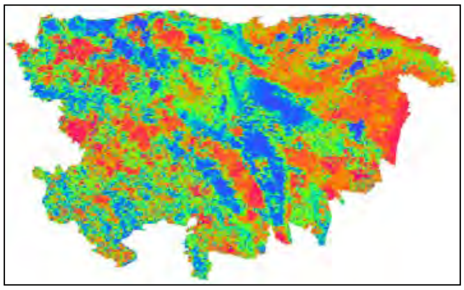


**ndvi_haor_2001145 (25, May)**

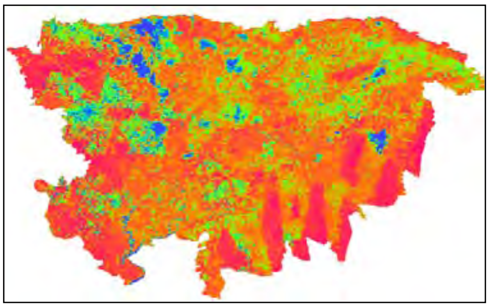
c) Flash flood timing in 2002 from 8 days interval MODIS images of 2002



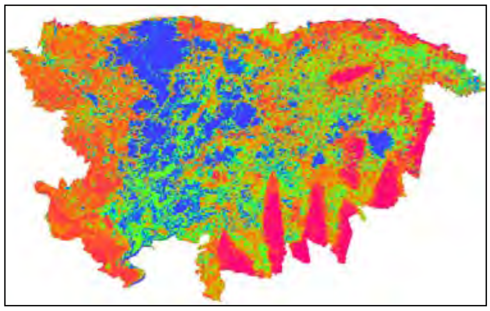

**ndvi_haor_2002097 (07, April)**



**ndvi_haor_2002105 (15, April)**

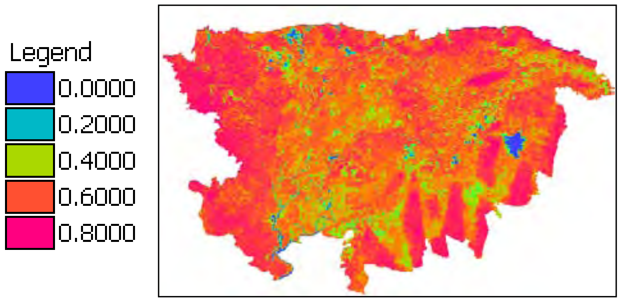


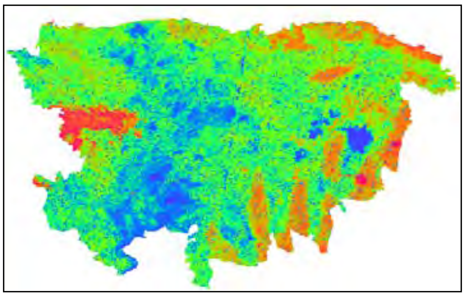
**ndvi_haor_2002113 (23, April)**



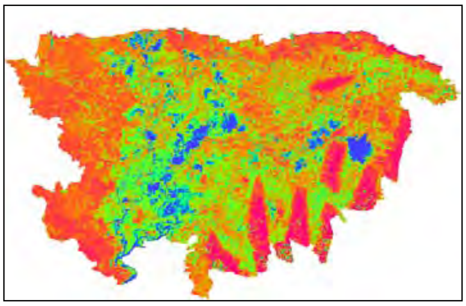
**ndvi_haor_2002121 (01, May)**

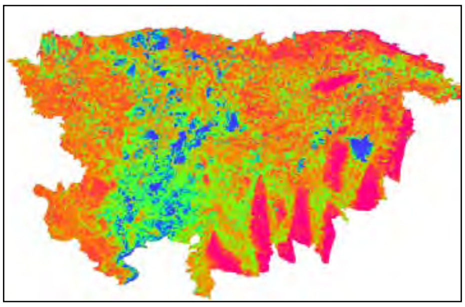
d) Flash flood timing in 2003 from 8 days interval MODIS images of 2003



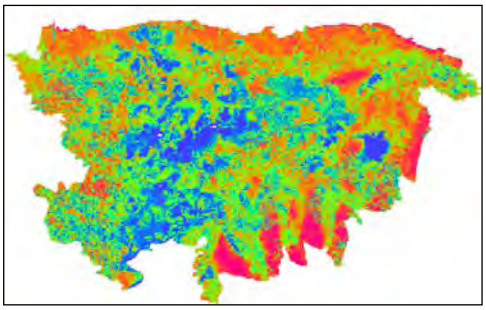



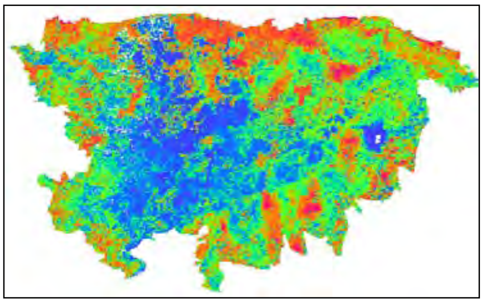
**ndvi_haor_2003113 (23, April)** **ndvi_haor_2003121 (01, May)**



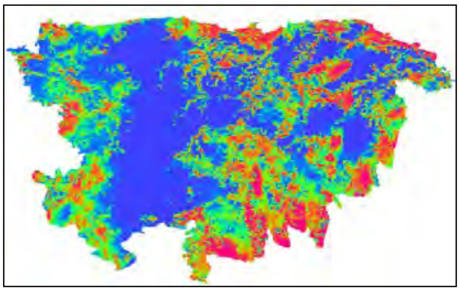


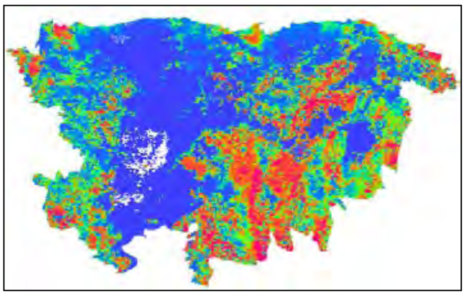
**ndvi_haor_2003129 (09, May)** **ndvi_haor_2003137 (17, May)**





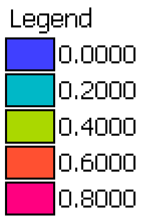
**ndvi_haor_2003145 (25, May)** **ndvi_haor_2003153 (02, June)**

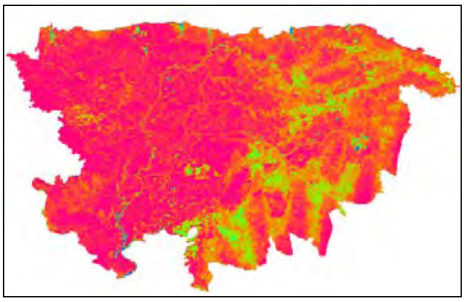




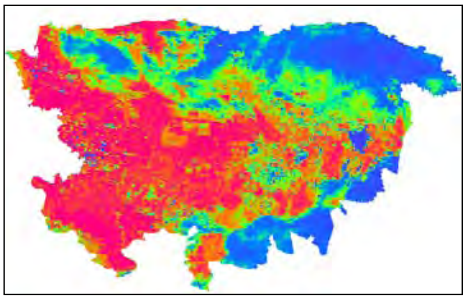
**ndvi_haor_2003161 (10, June)** **ndvi_haor_2003161 (18, June)**

e) Flash flood timing in 2004 from 8 days interval MODIS images of 2004

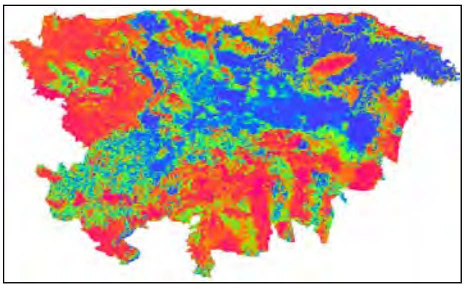


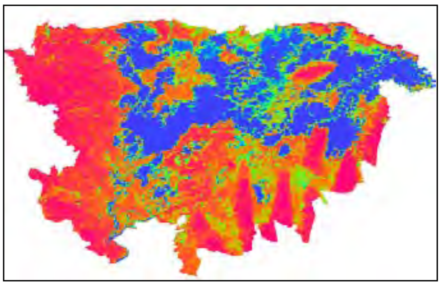
**ndvi_haor_2004089 (29, March)**



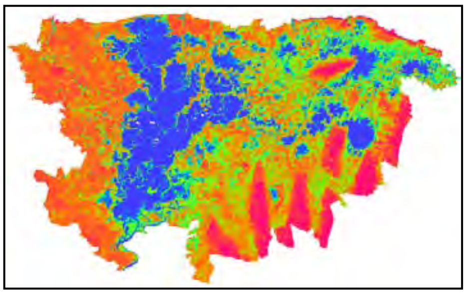
**ndvi_haor_2004097 (06, April)**



**ndvi_haor_2004105 (14, April)**

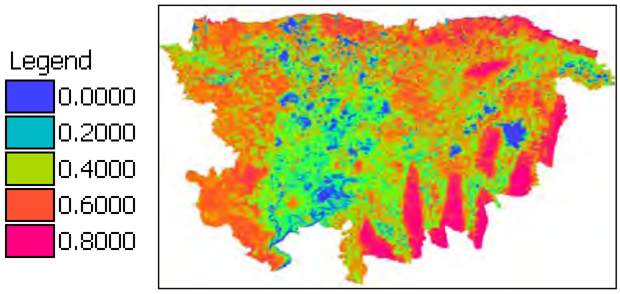


**ndvi_haor_2004113 (22, April)**

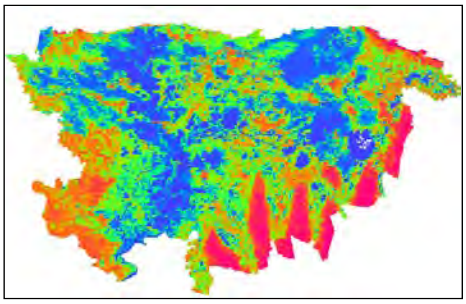


**ndvi_haor_2004121 (30, April)**

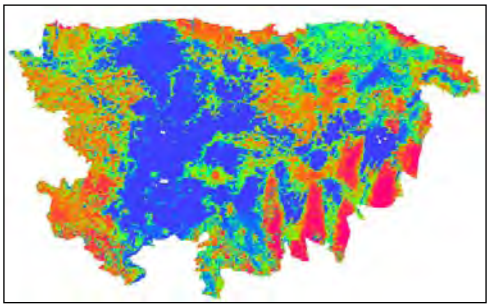
f) Flash flood timing in 2005 from 8 days interval MODIS images of 2005



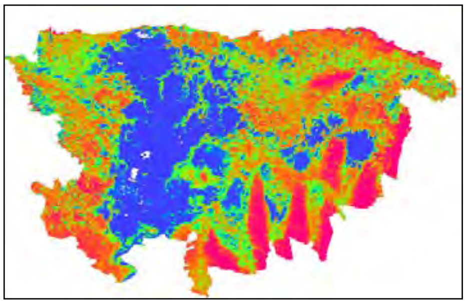

ndvi_haor_2005129 (09, May)



**ndvi_haor_2005137 (17, May)**

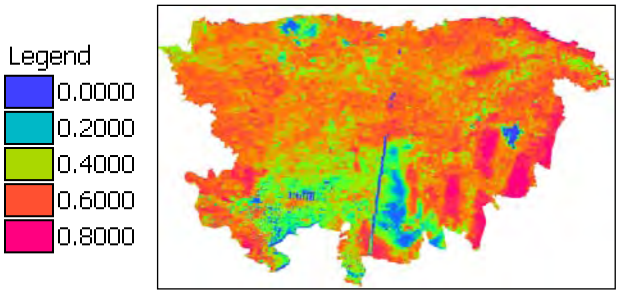


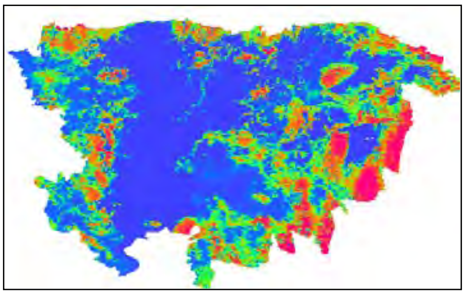
**ndvi_haor_2005145 (25, May)**



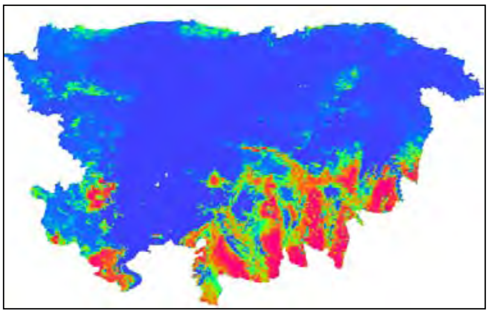
**ndvi_haor_2005153 (02, June)**

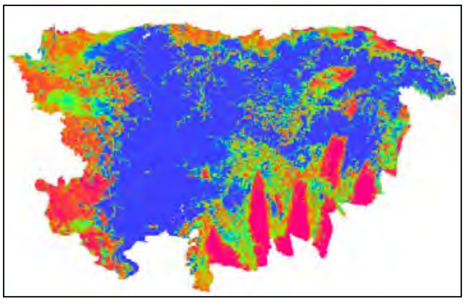
g) Flash flood timing in 2006 from 8 days interval MODIS images of 2006



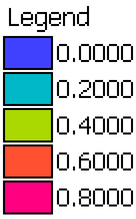
**ndvi_haor_2006145 (25, May)** **ndvi_haor_2006153 (02, June)**

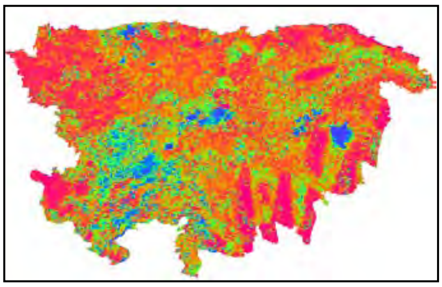




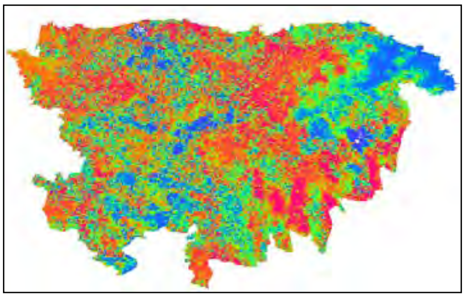
**ndvi_haor_2006161 (10, June)** **ndvi_haor_2006169 (18, June)**

h) Flash flood timing in 2007 from 8 days interval MODIS images of 2007

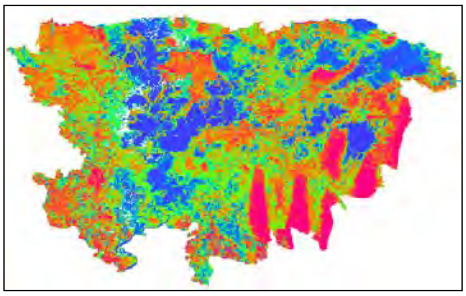


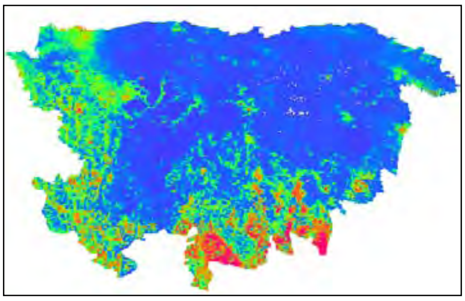
**ndvi_haor_2007129 (09, May)**



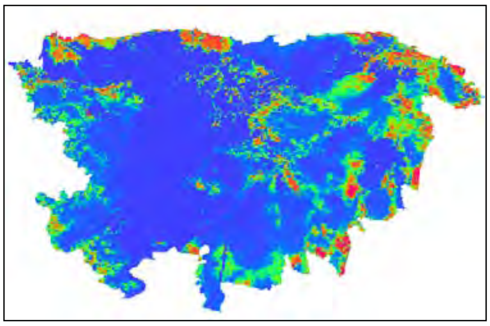
**ndvi_haor_2007137 (17, May)**



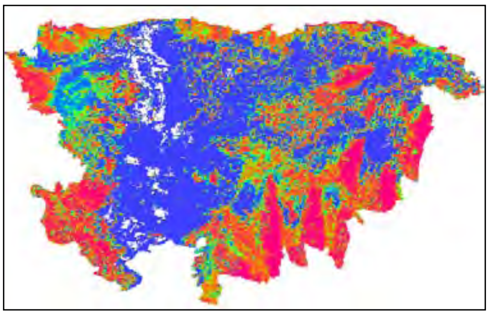
**ndvi_haor_2007145 (25, May)**



**ndvi_haor_2007153 (02 June)**

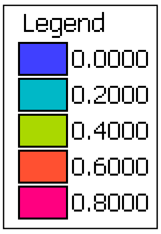


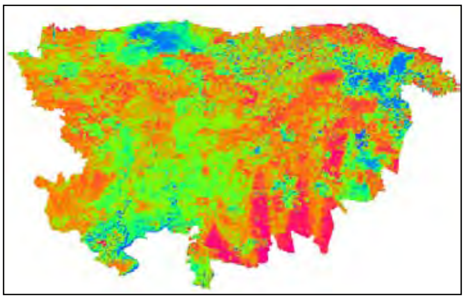
**ndvi_haor_2007161 (10, June)**



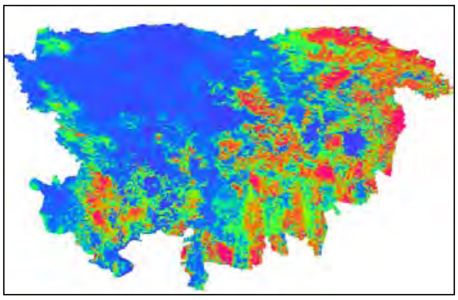
**ndvi_haor_2007169 (18, June)**

i) Flash flood timing in 2008 from 8 days interval MODIS images of 2008

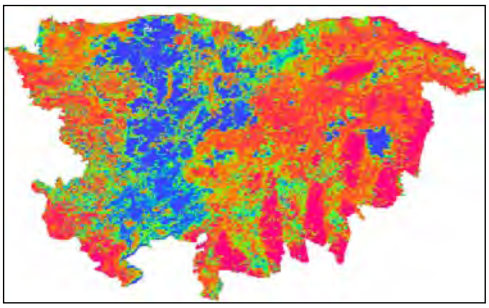


**ndvi_haor_2008137 (16, May)**



**ndvi_haor_2008153 (01, June)**



**ndvi_haor_2008161 (09, June)**

**APPENDIX XVII: Semi-Structured Questionnaires for interviews of livelihood groups of Haor Area**

1). District Name: Upazila Name: Union Name:

2. Name of the interview:

3, Father's name:

4) Number of Family Members (Family Size):

5) Number of Earning Family Members:

6) Educational Qualification:

Illiterate/Primary/Secondary/SSC/ Dakhil/HSC/Fazil/Graduate/Masters/ Medical/ Engineering/Diploma/ polytechnic/ others

7) Religion: a) Islam b) Hindu c) Buddhist d) Christian e) Others -------------------

8) Village:

9. Type of house

10. What is the main occupation (livelihood) of your family?

| | |
|---|---|
| a) Agriculture ( own land, leased, orchard, nursery) | b) Fishing ( full time , part time , leased, guard, trader) |
| c) Transport related activities (Boatman, bus driver) | d) Laborer ( Agriculture, industrial, trading) |
| e) Small business (handicraft etc.) | f) Remittance |
| fuel wood collector | h) Crab/ medicinal plant collector |
| h) others (Livestock, poultry, herbal healers student, service holder) | |

11. Type of livelihood group

| | | | | |
|---|---|---|---|---|
| Farmer ( Landless and marginal) | Fisherman | Fuel wood collector | Boatman (Majhi) | Crab collector |
| Medicinal plant collector | Women (vulnerable group) etc. | | | |

12. Average monthly income?

1. Maximum 1500 BDT
2. 1500 - 3000 BDT
3. 3000 - 5000 BDT
4. 5000 - 7000 BDT
5. above 7000 BDT

13. What was the source of income?

| Sources | | Income |
|---|---|---|
| Agriculture | From crops | |
| | Leased | |
| | Nursery and orchard | |
| Laborer | Agriculture | |
| | Industrial and Trade | |
| Fishing/cultivation Fish | From river, haor, beel | |
| | Pond | |
| Transportation | Road | |
| | Water way | |
| Business | Handicrafts | |
| | Shops | |
| | Small industry | |
| Remittance | Foreign | |
| | Inland | |
| Rearing | Livestock | |
| | Poultry | |
| Others | | |

14. General information (Questions) required to analysis the vulnerability context for livelihood framework in the haor area

| Trends | Shocks | Seasonality |
|---|---|---|
| Population trends/ resources trends/ national economic trends/ trends in governance/ technological trends | Natural Shocks(flash flood, recurrent flood)/ Economic shocks/ conflicts/ crop health shocks / livestock health shocks | Price fluctuation/ employment opportunity(agriculture, non-farm, )/ food availability |

15. What type of Natural resources (assets) do you extract from Haor Area?

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fisheries | Waterfowl | Vegetation | Livestock | Forests | Water | Firewood | Medicines | Crop | Water use |
| Plant species comp. | Water sources | Haor | Agricultural land | River | Beel | Wild foods | Thatch | Pasture | soil |

16. What type of financial resources (assets) do you extract from Haor Area?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wetland goods | Fish trading | Services | Fish production | Rice production | Cattle& buffalo rearing | Duck rearing | Collection of reeds& grasses, | collection of aquatic & other plants |
| Fish harvest | | Production | Micro-climate | Aesthetic benefit | Transport | | Recreation | Fish hatchling supplies |

17. What type of Human resources (assets) are prevailed Haor Area?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Health | Physical labor | Skill | Knowledge | Experience in Haor | training and extension services | Ownership of assets | Skilled labors | Access of marginal groups to education |

18.What type of physical resources (assets) does you used in the Haor Area?

| | | | | | |
|---|---|---|---|---|---|
| Roads | Irrigation works | Electricity | Reticulated equipment | Housing | Building poles |

19. What type of Social capitals (assets) are exist in the Haor Area?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Trade associations | framers' Associations | Family network | Local markets | Market committee | Mosque/temple committee | Farm workers | Sharing of responsibility |
| Fishermen society | farmer-labor union | industrial labor union | volunteer | youth society | cooperative | women cooperatives | others |

20. What are the changes of the land cover of haor area last 9 years

21. Impact of land cover changes on Livelihood Assets

| | | | | | |
|---|---|---|---|---|---|
| food insecurity | depletion of fish stock | lack of employment opportunities | lack of access to formal education | shortage of water | shortage of medical facilities |
| poor transportation-communication networks | shortage of fire wood | problems of dairy farming | problems of poultry farming | silt deposits on rivers, canals, beels, and other water bodies | shortage of fruits and vegetables |
| Homes and homestead lands are threatened by erosion | degradation of aquatic tress, vegetation | shortage of sanitary latrines | problems of agricultural activities | poor people lack access to community lands | |

22. How do you cope up/resilience with the changes of haor area?

23. Key question related to livelihood groups

| Livelihood group | List of key Questions |
|---|---|
| Farmers(Krishok) | 1. What is the existing cropping pattern and intensity? |
| | 2. Is there any scarcity of water for your crop cultivation? |
| | 3. What are the dry season water conditions for farming? |
| | 4. What is the current yield? Is it varies year to year? If yes what is the reason? |
| | 5. Is there any crop damage happening? If yes, what is the reason? (Flash floods/drainage congestion/drought/others) |
| | 6. What are the adaptation strategies for saving crops against natural hazards? |
| Fisherman(Jele) | 1. What are the current fish species in the area? |
| | 2. What are the yields of capture fisheries in the area? Is it varies year to year (declined/increased)? If yes, what is the reason? |
| | 3. Is the quality of water is satisfactory for fish habitat? |
| | 4. Is any water management project/subproject is the reason for fish vulnerability? If yes how to mitigate these problems? |
| | 5. Whether the no. of capture fishermen increases or decreases? What is the reason for that? |
| Boatman(Majhi) | 1. What is the existing navigation condition in the haor? |
| | 2. Is existing water management project/subproject creating problem for their community? If yes how to mitigate these problems? |
| | 3. Are they changing their livelihood pattern? |
| | 4. What is your opinion to improve the navigation? |
| Agricultural labor | What is the impact of changing pattern of haor on their life and livelihood? |
| Woman | 1. What's the source of water they used for domestic water supply & sanitation? |
| | 2. Is the quantity and quality of water is satisfactory for all over the year? |
| | 3. At what distance they collect their water for household purpose? |

24. Question related to livelihood indicators

| Capitals | Dimensions | Livelihood Assets indicators’ |
|---|---|---|
| Natural Capital | Productivity | land productivity |
| | | Crop production ( Agriculture land area) |
| | | Swamp Forest health status |
| | Sustainability | Sustainability of land |
| | | Land quality of haor area |
| | | Effectiveness of Swamp forest management |
| | Equity | Access to Natural resources by landless and marginal farmer groups |
| | | Control to Natural resources by landless and marginal farmer group |
| | Risks | Pressure on land |
| | | Pressure on swamp forest |
| Physical Capital | Productivity | % of Population have own house (housing condition) |
| | | Option for drinking water / Distance to nearest safe drinking water source |
| | | Transportation and communication |
| | Sustainability | Disaster management |
| | Equity | Access to physical resources by landless and marginal farmer groups |
| | | Control to physical resources by landless and marginal farmer group |
| | Risk | Failure of engineering/earthen structure |
| Human Capital | Productivity | Education facilities |
| | | health status |
| | | Training facilities |
| | | Knowledge on land cover change |

| | | |
|---|---|---|
| | Sustainability | Level of adopted coping mechanism |
| | Equity | Accessibility and affordability to social services |
| | Risk | Occupational hazard |
| | | Out migration of skilled manpower |
| Financial Capital | Productivity | Income productivity |
| | | Scope of alternative job |
| | | Source and system of credit |
| | | Household income level, sources, stability and sufficiency |
| | Sustainability | Stability of income generating activities |
| | | Income levels and stability |
| | | Revolving funds /Savings |
| | Equity | Access of farmers group to cash credits |
| | | control of farmers group to cash credits |
| | Risk | Instability of government approach towards their livelihood |
| | | Banning of harvesting in haor area |
| Social Capital | Productivity | Institutional structure |
| | | Social network |
| | Sustainability | Safety nets |
| | | Effectiveness of GO, NGO or other social network |
| | Equity | Involvement of farmers group in relevant resource inventory |
| | | Participating of farmers group in training and workshops |
| | Risk | Local politics |

**APPENDIX XVIII: Some of the Pictures of interviews and FGD**

**APPENDIX XIX: Livelihood assets of Farmer, Boatman, and Fuel wood collector and Fisherman**

a) Assets distribution of farmer groups

| **Capitals** | **Assets** |
|---|---|
| Natural Capital | Agricultural Land, water, river, Beel, Haor, crops, pasture, firewood, thatch, wild food etc. |
| Physical Capital | Roads, irrigation works, electricity, drainage, Housing etc |
| Human Capital | Access of farmer to education, health, Ownership assets, skilled farmer, training and extension services, Physical labor, Knowledge, and Experience in Haor etc |
| Financial Capital | Wetland goods, Income generating activities, Savings, Rice production, Cattle and buffalo rearing, Duck rearing, Collection of reeds and grasses, collection of aquatic and other plants etc |
| Social Capital | Trade associations, farmer associations, Membership to organizations, Sharing of responsibility, Households, Farmers, Farm workers, Community, cooperatives. Institutions etc. |

b) Access of haor resources extraction of Farmer Groups

| Farmers group (size of participant-27) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators' | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | land productivity | 82 | 85.33 | 0.80 |
| | | Crop production (Agriculture land area) | 84 | | |
| | | Swamp Forest health status | 90 | | |
| | Sustainability | Sustainability of land | 78 | 78 | |
| | | Land quality of haor area | 80 | | |
| | | Effectiveness of Swamp forest management | 76 | | |
| | Equity | Access to Natural resources by landless and marginal farmer groups | 75 | 75.5 | |
| | | Control to Natural resources by landless and marginal farmer group | 76 | | |
| | Risks | Pressure on land | 84 | 81 | |
| | | Pressure on swamp forest | 78 | | |
| | | | | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 82 | 78 | 0.79 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 78 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | Transportation and communication | 74 | | |
| | Sustainability | Disaster management | 76 | 76 | |
| | Equity | Access to physical resources by landless and marginal farmer groups | 82 | 83 | |
| | | Control to physical resources by landless and marginal farmer group | 84 | | |
| | Risk | Failure of engineering/earthen structure | 78 | 78 | |
| Human Capital | Productivity | Education facilities | 54 | 68.67 | 0.76 |
| | | health status | 84 | | |
| | | Training facilities | 68 | | |
| | Sustainability | Knowledge on land cover change | 72 | 77 | |
| | | Level of adopted coping mechanism | 82 | | |
| | Equity | Accessibility and affordability to social services | 78 | 78 | |
| | Risk | Occupational hazard | 84 | 82 | |
| | | Out migration of skilled manpower | 80 | | |
| Financial Capital | Productivity | Income productivity | 76 | 71.5 | 0.76 |
| | | Scope of alternative job | 68 | | |
| | | Source and system of credit | 70 | | |
| | | Household income level, sources, stability and sufficiency | 72 | | |
| | Sustainability | Stability of income generating activities | 76 | 76 | |

| | | | | | |
|---|---|---|---|---|---|
| | | Income levels and stability | 74 | | |
| | | Revolving funds /Savings | 78 | | |
| | Equity | Access of farmers group to cash credits | 77 | 75.5 | |
| | | control of farmers group to cash credits | 74 | | |
| | Risk | Instability of government approach towards their livelihood | 78 | 81 | |
| | | Banning of harvesting in haor area | 84 | | |
| Social Capital | Productivity | Institutional structure | 82 | 80 | 0.81 |
| | | Social network | 78 | | |
| | Sustainability | Effectiveness of GO, NGO or other social network | 81 | 81 | |
| | Equity | Involvement of farmers group in relevant resource inventory | 76 | 77 | |
| | | Participating of farmers group in training and workshops | 78 | | |
| | Risk | Local politics | 86 | 86 | |

c) Assets Distribution of Labour Groups

| Capitals | Assets |
|---|---|
| Natural Capital | Agricultural Land, water, river, Beel, Haor, crops, pasture, firewood, thatch, wild food etc. |
| Physical Capital | Roads, irrigation works, electricity, drainage, housing, building poles etc |
| Human Capital | Access of laborer group to education, health, Ownership assets, skilled labour, training and extension services, Physical labor, Knowledge, and Experience in Haor etc |
| Financial Capital | Wetland goods, Income generating activities, Savings, Cattle and buffalo rearing, Duck rearing, Collection of reeds and grasses, collection of aquatic and other plants, Flood control benefits etc |
| Social Capital | Trade associations, laborer associations, Membership to organizations, Sharing of responsibility, Households, laborers, Community, cooperatives. Institutions etc. |

c) Access of haor resources extraction of Labour Groups

| laborer group (size of participant-25) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators' | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | Haor productivity (land, water bodies ) | 84 | 83.67 | 0.81 |
| | | Crop production/fish production | 81 | | |
| | | Forage production | 86 | | |
| | Sustainability | Sustainability of land and water bodies | 78 | 78.33 | |
| | | Land and water quality of haor area | 80 | | |
| | | Effectiveness of Swamp forest management | 77 | | |
| | Equity | Access to Natural resources by laborer groups | 78 | 78 | |
| | | Control to Natural resources by laborer group | 78 | | |
| | Risks | Pressure on land and water bodies | 84 | 82 | |
| | | Pressure on swamp forest | 80 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 78 | 76.33 | 0.77 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 77 | | |
| | | Transportation and communication | 74 | | |
| | Sustainability | Disaster management | 74 | 74 | |
| | Equity | Access to physical resources by laborer groups | 81 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | Control to physical resources by laborer group | 79 | 80 | |
| | Risk | Failure of engineering/earthen structure | 78 | 78 | |
| Human Capital | Productivity | Education facilities | 56 | 67.33 | 0.76 |
| | | health status | 80 | | |
| | | Training facilities | 66 | | |
| | Sustainability | Knowledge on land cover/water cover change | 74 | 77 | |
| | | Level of adopted coping mechanism | 80 | | |
| | Equity | Accessibility and affordability to social services | 78 | 78 | |
| | Risk | Occupational hazard | 82 | 81 | |
| | | Out migration of skilled manpower | 80 | | |
| Financial Capital | Productivity | Income productivity | 78 | 73 | 0.75 |
| | | Scope of alternative job | 66 | | |
| | | Source and system of credit | 72 | | |
| | | Household income level, sources, stability and sufficiency | 76 | | |
| | Sustainability | Stability of income generating activities | 72 | 72.66 | |
| | | Income levels and stability | 70 | | |
| | | Revolving funds /Savings | 76 | | |
| | Equity | Access of laborer group to cash credits | 78 | 77 | |
| | | control of laborer group to cash credits | 76 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Risk | Instability of government approach towards their livelihood | 74 | 78 | |
| | | Banning of harvesting in haor area | 82 | | |
| Social Capital | Productivity | Institutional structure | 82 | 80 | 0.80 |
| | | Social network | 78 | | |
| | Sustainability | Effectiveness of GO, NGO or other social network | 82 | 82 | |
| | Equity | Involvement of laborer group in relevant resource inventory | 72 | 73 | |
| | | Participating of laborer group in training and workshops | 74 | | |
| | Risk | Local politics | 84 | 84 | |

e) Assets Distribution of Fisherman Group

| **Capitals** | **Assets** |
|---|---|
| Natural Capital | Water, river, Beel, Haor, crops, pasture, firewood, thatch, wild food etc. |
| Physical Capital | Roads, irrigation works, electricity, drainage, Housing, Building poles etc |
| Human Capital | Access of fisherman to education, health, Ownership assets, skilled fisherman, training and extension services, Physical labor, Knowledge, and Experience in Haor etc |
| Financial Capital | Wetland goods, Income generating activities, Savings, Fish production, Cattle and buffalo rearing, Duck rearing, Collection of reeds and grasses, collection of aquatic and other plants, Aesthetic benefit, Transport, Biodiversity benefits etc |
| Social Capital | Trade associations, fisherman associations, Membership to organizations, Sharing of responsibility, Households, Fishermen, Community, cooperatives. Institutions etc. |

f) Access of haor resources extraction of Fisherman Groups

| Fisherman group (size of participant-27) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators' | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | Haor productivity (specially water bodies, Beel) | 86 | 88 | 0.82 |
| | | Fish production | 90 | | |
| | | Swamp Forest health status | 88 | | |
| | Sustainability | Sustainability of water | 80 | 80 | |
| | | Water quality of haor area | 82 | | |
| | | Effectiveness of Swamp forest management | 78 | | |
| | Equity | Access to Natural resources by fisherman groups | 80 | 79 | |
| | | Control to Natural resources by fisherman group | 78 | | |
| | Risks | Pressure on haor, Beel | 84 | 82 | |
| | | Pressure on swamp forest | 80 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 82 | 79.33 | 0.80 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 78 | | |
| | | Transportation and communication | 78 | | |
| | Sustainability | Disaster management | 76 | 76 | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access to physical resources by fisherman groups | 80 | 81 | |
| | | Control to physical resources by fisherman group | 82 | | |
| | Risk | Failure of engineering/earthen structure | 82 | 82 | |
| Human Capital | Productivity | Education facilities | 62 | 60.67 | 0.75 |
| | | health status | 82 | | |
| | | Training facilities | 68 | | |
| | Sustainability | Knowledge on water cover change | 72 | 77 | |
| | | Level of adopted coping mechanism | 82 | | |
| | Equity | Accessibility and affordability to social services | 80 | 80 | |
| | Risk | Occupational hazard | 82 | 81 | |
| | | Out migration of skilled manpower | 80 | | |
| Financial Capital | Productivity | Income productivity | 86 | 77.25 | 0.76 |
| | | Scope of alternative job | 70 | | |
| | | Source and system of credit | 75 | | |
| | | Household i ncome l evel, s ources, s tability and sufficiency | 78 | | |
| | Sustainability | Stability of income generating activities | 78 | 77 | |
| | | Income levels and stability | 77 | | |
| | | Revolving funds /Savings | 76 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access of fisherman group to cash credits | 78 | 79 | |
| | | control of fisherman group to cash credits | 80 | | |
| | Risk | Instability of government approach towards their livelihood | 78 | 81 | |
| | | Banning of harvesting in haor area | 84 | | |
| Social Capital | Productivity | Institutional structure | 82 | 80 | 0.80 |
| | | Social network | 78 | | |
| | Sustainability | Effectiveness of GO, NGO or other social network | 79 | 79 | |
| | Equity | Involvement of farmers group in relevant resource inventory | 76 | 77 | |
| | | Participating of farmers group in training and workshops | 78 | | |
| | Risk | Local politics | 84 | 84 | |

g) Assets Distribution of Boatman Group

| Capitals | Assets |
|---|---|
| Natural Capital | Water, river, Beel, Haor, firewood, thatch, wild food etc. |
| Physical Capital | Roads, irrigation works, electricity, drainage, Housing, Building poles etc |
| Human Capital | Access of bo atman to e ducation, he alth, Ownership a ssets, s killed boatman, training and extension services, Physical labor, Knowledge, and Experience in Haor etc |
| Financial Capital | Wetland g oods, Income ge nerating activities, Savings, Cattle and buffalo rearing, Duck r earing, Collection of r eeds and grasses, collection of a quatic a nd ot her pl ants, Aesthetic be nefit, T ransport, Biodiversity benefits etc |
| Social Capital | Trade associations, boa tman associations, H ouseholds, B oatmans, Community, cooperatives. Institutions etc. |

h) Access of haor resources extraction of Boatman Groups

| Boatman group (size of participant-19) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators’ | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | Haor productivity (especially river, Beel) | 83 | 84.67 | 0.79 |
| | | Water level of river, Beel (surface water) | 85 | | |
| | | Rainfall | 86 | | |
| | Sustainability | Sustainability of river network, Beel | 81 | 79 | |
| | | Water quality of haor area | 80 | | |
| | | Effectiveness of haor management | 76 | | |
| | Equity | Access to Natural resources by boatman groups | 78 | 75 | |
| | | Control to Natural resources by boatman group | 72 | | |
| | Risks | Pressure on river navigation | 82 | 79 | |
| | | Pressure on Beel | 76 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 78 | 76 | 0.78 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 76 | | |
| | | Transportation and communication | 74 | | |
| | Sustainability | Disaster management | 76 | 76 | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access to physical resources by boatman groups | 82 | 81 | |
| | | Control to physical resources by boatman group | 80 | | |
| | Risk | Failure of engineering/earthen structure | 78 | 78 | |
| Human Capital | Productivity | Education facilities | 58 | 69 | 0.75 |
| | | health status | 82 | | |
| | | Training facilities | 67 | | |
| | Sustainability | Knowledge on river navigation change | 78 | 77.5 | |
| | | Level of adopted coping mechanism | 77 | | |
| | Equity | Accessibility and affordability to social services | 76 | 76 | |
| | Risk | Occupational hazard | 80 | 79 | |
| | | Out migration of skilled manpower | 78 | | |
| Financial Capital | Productivity | Income productivity | 76 | 70.5 | 0.75 |
| | | Scope of alternative job | 66 | | |
| | | Source and system of credit | 68 | | |
| | | Household income level, sources, stability and sufficiency | 72 | | |
| | Sustainability | Stability of income generating activities | 74 | 73.67 | |
| | | Income levels and stability | 72 | | |
| | | Revolving funds /Savings | 75 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access of boatman group to cash credits | 77 | 76 | |
| | | control of boatman group to cash credits | 75 | | |
| | Risk | Instability of government approach towards their livelihood | 78 | 80 | |
| | | impediment river network in haor area | 82 | | |
| Social Capital | Productivity | Institutional structure | 76 | 78 | 0.80 |
| | | Social network | 80 | | |
| | Sustainability | Effectiveness of G O, N GO or ot her s ocial network | 80 | 80 | |
| | Equity | Involvement of boa tman g roup in relevant resource inventory | 75 | 76 | |
| | | Participating of boa tman g roup in t raining a nd workshops | 77 | | |
| | Risk | Local politics | 86 | 86 | |

i) Assets Distribution of Women Group

| **Capitals** | **Assets** |
|---|---|
| Natural Capital | Agricultural Land, water, river, Beel, Haor, crops, pasture, firewood, thatch, wild food etc. |
| Physical Capital | Roads, irrigation works, electricity, drainage, Housing, Building poles etc |
| Human Capital | Access of women to education, health, Ownership assets, skilled, training and extension services, Physical labor, Knowledge, and Experience in Haor etc |
| Financial Capital | Wetland goods, Income generating activities, Savings, Cattle and buffalo rearing, Duck rearing, Collection of reeds and grasses, collection of aquatic and other plants etc |
| Social Capital | Trade associations, Women associations, Sharing of responsibility, Households, Community, cooperatives. Institutions etc. |

j) Access of haor resources extraction of Women Groups

| Women group (size of participant-23) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators’ | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | Haor productivity | 82 | 86 | 0.80 |
| | | Crop production/ fish production | 84 | | |
| | | Forage production | 92 | | |
| | Sustainability | Sustainability of land, water, vegetation | 80 | 79 | |
| | | Land/water/vegetation quality of haor area | 79 | | |
| | | Effectiveness of Swamp forest management | 78 | | |
| | Equity | Access to Natural resources by women groups | 82 | 80 | |
| | | Control to Natural resources by women group | 78 | | |
| | Risks | Pressure on haor area | 82 | 81 | |
| | | Pressure on haor resources | 80 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 78 | 77 | 0.79 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 78 | | |
| | | Transportation and communication | 75 | | |
| | Sustainability | Disaster management | 76 | 76 | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access to physical resources by landless and marginal farmer groups | 82 | 83 | |
| | | Control to physical resources by landless and marginal farmer group | 84 | | |
| | Risk | Failure of engineering/earthen structure | 78 | 78 | |
| Human Capital | Productivity | Education facilities | 54 | 68.67 | 0.76 |
| | | health status | 84 | | |
| | | Training facilities | 68 | | |
| | Sustainability | Knowledge on land cover change | 72 | 77 | |
| | | Level of adopted coping mechanism | 82 | | |
| | Equity | Accessibility and affordability to social services | 78 | 78 | |
| | Risk | Occupational hazard | 84 | 82 | |
| | | Out migration of skilled manpower | 80 | | |
| Financial Capital | Productivity | Income productivity | 66 | 63.75 | 0.69 |
| | | Scope of alternative job | 64 | | |
| | | Source and system of credit | 63 | | |
| | | Household income level, sources, stability and sufficiency | 62 | | |
| | Sustainability | Stability of income generating activities | 60 | 65.33 | |
| | | Income levels and stability | 64 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | Revolving funds /Savings | 72 | | |
| | Equity | Access of women group to cash credits | 67 | 65.5 | |
| | | control of women group to cash credits | 64 | | |
| | Risk | Instability of government approach towards their livelihood | 78 | 81 | |
| | | Banning of harvesting in haor area | 84 | | |
| Social Capital | Productivity | Institutional structure | 72 | 70 | 0.74 |
| | | Social network | 68 | | |
| | Sustainability | Effectiveness of GO, NGO or other social network | 68 | 68 | |
| | Equity | Involvement of women group in relevant resource inventory | 72 | 73 | |
| | | Participating of women group in training and workshops | 74 | | |
| | Risk | Local politics | 86 | 86 | |

k) Access of haor resources extraction of Farmer Groups due to land cover changes

| Farmers group (size of participant-27) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators' | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | land productivity | 70 | 78.67 | 0.70 |
| | | Crop production (Agriculture land area) | 88 | | |
| | | Swamp Forest health status | 78 | | |
| | Sustainability | Sustainability of land | 72 | 70 | |
| | | Land quality of haor area | 68 | | |
| | | Effectiveness of Swamp forest management | 70 | | |
| | Equity | Access to Natural resources by landless and marginal farmer groups | 65 | 66.5 | |
| | | Control to Natural resources by landless and marginal farmer group | 68 | | |
| | Risks | Pressure on land | 65 | 66 | |
| | | Pressure on swamp forest | 67 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 90 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | Option for drinking water / Distance to nearest safe drinking water source | 82 | 85.33 | 0.81 |
| | | Transportation and communication | 84 | | |
| | Sustainability | Disaster management | 84 | 84 | |
| | Equity | Access to physical resources by landless and marginal farmer groups | 74 | 73 | |
| | | Control to physical resources by landless and marginal farmer group | 72 | | |
| | Risk | Failure of engineering/earthen structure | 82 | 82 | |
| Human Capital | Productivity | Education facilities | 74 | 76 | 0.80 |
| | | health status | 76 | | |
| | | Training facilities | 78 | | |
| | Sustainability | Knowledge on land cover change | 78 | 83 | |
| | | Level of adopted coping mechanism | 88 | | |
| | Equity | Accessibility and affordability to social services | 84 | 84 | |
| | Risk | Occupational hazard | 80 | 75 | |
| | | Out migration of skilled manpower | 70 | | |
| Financial Capital | Productivity | Income productivity | 84 | 79.25 | |
| | | Scope of alternative job | 79 | | |
| | | Source and system of credit | 78 | | |
| | | Household income level, sources, stability and | 76 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | sufficiency | | | 0.78 |
| | Sustainability | Stability of income generating activities | 81 | 79.67 | |
| | | Income levels and stability | 78 | | |
| | | Revolving funds /Savings | 80 | | |
| | Equity | Access of farmers group to cash credits | 79 | 77 | |
| | | control of farmers group to cash credits | 75 | | |
| | Risk | Instability of government approach towards their livelihood | 82 | 77 | |
| | | Banning of harvesting in haor area | 72 | | |
| Social Capital | Productivity | Institutional structure | 84 | 83 | 0.82 |
| | | Social network | 82 | | |
| | Sustainability | Effectiveness of GO, NGO or other social network | 84 | 84 | |
| | Equity | Involvement of farmers group in relevant resource inventory | 79 | 80 | |
| | | Participating of farmers group in training and workshops | 81 | | |
| | Risk | Local politics | 80 | 80 | |

l) Access of haor resources extraction of Laborer Groups due to land cover changes

| laborer group (size of participant-25) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators' | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | Haor productivity (land, water bodies ) | 78 | 76.33 | 0.73 |
| | | Crop production/fish production | 77 | | |
| | | Forage production | 74 | | |
| | Sustainability | Sustainability of land and water bodies | 72 | 73.33 | |
| | | Land and water quality of haor area | 70 | | |
| | | Effectiveness of Swamp forest management | 78 | | |
| | Equity | Access to Natural resources by laborer groups | 68 | 67 | |
| | | Control to Natural resources by laborer group | 66 | | |
| | Risks | Pressure on land and water bodies | 76 | 74 | |
| | | Pressure on swamp forest | 72 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 84 | 81 | 0.78 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 81 | | |
| | | Transportation and communication | 78 | | |
| | Sustainability | Disaster management | 78 | 78 | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access to physical resources by laborer groups | 73 | 72 | |
| | | Control to physical resources by laborer group | 71 | | |
| | Risk | Failure of engineering/earthen structure | 82 | 82 | |
| Human Capital | Productivity | Education facilities | 72 | 73 | 0.78 |
| | | health status | 74 | | |
| | | Training facilities | 73 | | |
| | Sustainability | Knowledge on land cover/water cover change | 78 | 81.5 | |
| | | Level of adopted coping mechanism | 85 | | |
| | Equity | Accessibility and affordability to social services | 82 | 82 | |
| | Risk | Occupational hazard | 76 | 75 | |
| | | Out migration of skilled manpower | 74 | | |
| Financial Capital | Productivity | Income productivity | 79 | 75.5 | 0.74 |
| | | Scope of alternative job | 72 | | |
| | | Source and system of credit | 74 | | |
| | | Household income level, sources, stability and sufficiency | 77 | | |
| | Sustainability | Stability of income generating activities | 74 | 73.33 | |
| | | Income levels and stability | 70 | | |
| | | Revolving funds /Savings | 76 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access of laborer group to cash credits | 72 | 71 | |
| | | control of laborer group to cash credits | 70 | | |
| | Risk | Instability of government approach towards their livelihood | 78 | 76 | |
| | | Banning of harvesting in haor area | 74 | | |
| Social Capital | Productivity | Institutional structure | 82 | 81 | 0.80 |
| | | Social network | 80 | | |
| | Sustainability | Effectiveness of G O, N GO or ot her s ocial network | 82 | 82 | |
| | Equity | Involvement of laborer group in relevant resource inventory | 76 | 76 | |
| | | Participating o f l aborer gr oup in training a nd workshops | 76 | | |
| | Risk | Local politics | 80 | 80 | |

m) Access of haor resources extraction of Fisherman Groups due to land cover changes

| Fisherman group (size of participant-27) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators' | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | Haor productivity (specially water bodies, Beel) | 74 | 75.67 | 0.75 |
| | | Fish production | 75 | | |
| | | Swamp Forest health status | 78 | | |
| | Sustainability | Sustainability of water | 72 | 76 | |
| | | Water quality of haor area | 76 | | |
| | | Effectiveness of Swamp forest management | 80 | | |
| | Equity | Access to Natural resources by fisherman groups | 73 | 72 | |
| | | Control to Natural resources by fisherman group | 71 | | |
| | Risks | Pressure on haor, Beel | 78 | 76 | |
| | | Pressure on swamp forest | 74 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 90 | 86.33 | 0.83 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 85 | | |
| | | Transportation and communication | 84 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Sustainability | Disaster management | 82 | 82 | |
| | Equity | Access to physical resources by fisherman groups | 80 | 81 | |
| | | Control to physical resources by fisherman group | 82 | | |
| | Risk | Failure of engineering/earthen structure | 84 | 84 | |
| Human Capital | Productivity | Education facilities | 73 | 75.67 | 0.79 |
| | | health status | 80 | | |
| | | Training facilities | 74 | | |
| | Sustainability | Knowledge on water cover change | 78 | 81 | |
| | | Level of adopted coping mechanism | 84 | | |
| | Equity | Accessibility and affordability to social services | 81 | 81 | |
| | Risk | Occupational hazard | 78 | 77 | |
| | | Out migration of skilled manpower | 76 | | |
| Financial Capital | Productivity | Income productivity | 70 | 71 | 0.71 |
| | | Scope of alternative job | 68 | | |
| | | Source and system of credit | 72 | | |
| | | Household income level, sources, stability and sufficiency | 74 | | |
| | Sustainability | Stability of income generating activities | 72 | 72 | |
| | | Income levels and stability | 73 | | |
| | | Revolving funds /Savings | 71 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access of fisherman group to cash credits | 72 | 71 | |
| | | control of fisherman group to cash credits | 70 | | |
| | Risk | Instability of government approach towards their livelihood | 68 | 68.5 | |
| | | Banning of harvesting in haor area | 69 | | |
| Social Capital | Productivity | Institutional structure | 80 | 79 | 0.79 |
| | | Social network | 78 | | |
| | Sustainability | Effectiveness of G O, N GO or ot her s ocial network | 80 | 80 | |
| | Equity | Involvement of f armers g roup in relevant resource inventory | 78 | 79 | |
| | | Participating of f armers g roup in training a nd workshops | 80 | | |
| | Risk | Local politics | 77 | 77 | |

n) Access of haor resources extraction of Boatman Groups due to land cover changes

| Boatman group (size of participant-19) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators' | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | Haor productivity (especially river, Beel) | 63 | 74.33 | 0.72 |
| | | Water level of river, Beel (surface water) | 76 | | |
| | | Rainfall | 84 | | |
| | Sustainability | Sustainability of river network, Beel | 75 | 74 | |
| | | Water quality of haor area | 71 | | |
| | | Effectiveness of haor management | 76 | | |
| | Equity | Access to Natural resources by boatman groups | 69 | 68 | |
| | | Control to Natural resources by boatman group | 67 | | |
| | Risks | Pressure on river navigation | 74 | 72 | |
| | | Pressure on Beel | 70 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 82 | 81 | 0.79 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 80 | | |
| | | Transportation and communication | 81 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Sustainability | Disaster management | 78 | 78 | |
| | Equity | Access to physical resources by boatman groups | 76 | 75 | |
| | | Control to physical resources by boatman group | 74 | | |
| | Risk | Failure of engineering/earthen structure | 80 | 80 | |
| Human Capital | Productivity | Education facilities | 65 | 74.33 | 0.79 |
| | | health status | 80 | | |
| | | Training facilities | 78 | | |
| | Sustainability | Knowledge on river navigation change | 81 | 80 | |
| | | Level of adopted coping mechanism | 79 | | |
| | Equity | Accessibility and affordability to social services | 78 | 78 | |
| | Risk | Occupational hazard | 77 | 75 | |
| | | Out migration of skilled manpower | 73 | | |
| Financial Capital | Productivity | Income productivity | 66 | 68 | 0.71 |
| | | Scope of alternative job | 68 | | |
| | | Source and system of credit | 68 | | |
| | | Household income level, sources, stability and sufficiency | 70 | | |
| | Sustainability | Stability of income generating activities | 72 | 71.67 | |
| | | Income levels and stability | 70 | | |
| | | Revolving funds /Savings | 73 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access of boatman group to cash credits | 73 | 72 | |
| | | control of boatman group to cash credits | 71 | | |
| | Risk | Instability of government approach towards their livelihood | 76 | 74 | |
| | | impediment river network in haor area | 72 | | |
| Social Capital | Productivity | Institutional structure | 78 | 79 | 0.79 |
| | | Social network | 80 | | |
| | Sustainability | Effectiveness of GO, NGO or other social network | 80 | 80 | |
| | Equity | Involvement of boatman group in relevant resource inventory | 76 | 77 | |
| | | Participating of boatman group in training and workshops | 78 | | |
| | Risk | Local politics | 80 | 80 | |

o) Access of haor resources extraction of Women Groups due to land cover changes

| Women group (size of participant-23) | | | | | |
|---|---|---|---|---|---|
| Capitals | Dimensions | Livelihood Assets indicators' | Avg. Score showing access to assets | Total Access in dimensions of capitals | Total access in Capitals (%) |
| Natural Capital | Productivity | Haor productivity | 69 | 73 | 0.71 |
| | | Crop production/ fish production | 74 | | |
| | | Forage production | 76 | | |
| | Sustainability | Sustainability of land, water, vegetation | 75 | 76.33 | |
| | | Land/water/vegetation quality of haor area | 76 | | |
| | | Effectiveness of Swamp forest management | 78 | | |
| | Equity | Access to Natural resources by women groups | 66 | 65 | |
| | | Control to Natural resources by women group | 64 | | |
| | Risks | Pressure on haor area | 72 | 71 | |
| | | Pressure on haor resources | 70 | | |
| Physical Capital | Productivity | % of Population have own house (housing condition) | 84 | 82 | 0.79 |
| | | Option for drinking water / Distance to nearest safe drinking water source | 80 | | |
| | | Transportation and communication | 82 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Sustainability | Disaster management | 78 | 78 | |
| | Equity | Access to physical resources by women groups | 76 | 75 | |
| | | Control to physical resources by women group | 74 | | |
| | Risk | Failure of engineering/earthen structure | 78 | 78 | |
| Human Capital | Productivity | Education facilities | 68 | 78.67 | 0.80 |
| | | health status | 80 | | |
| | | Training facilities | 88 | | |
| | Sustainability | Knowledge on land cover change | 78 | 81 | |
| | | Level of adopted coping mechanism | 84 | | |
| | Equity | Accessibility and affordability to social services | 80 | 80 | |
| | Risk | Occupational hazard | 80 | 80 | |
| | | Out migration of skilled manpower | 80 | | |
| Financial Capital | Productivity | Income productivity | 68 | 69 | 0.70 |
| | | Scope of alternative job | 72 | | |
| | | Source and system of credit | 67 | | |
| | | Household income level, sources, stability and sufficiency | 69 | | |
| | Sustainability | Stability of income generating activities | 62 | 67.33 | |
| | | Income levels and stability | 66 | | |
| | | Revolving funds /Savings | 74 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Equity | Access of women group to cash credits | 69 | 67.5 | |
| | | control of women group to cash credits | 66 | | |
| | Risk | Instability of government approach towards their livelihood | 80 | 78 | |
| | | Banning of harvesting in haor area | 76 | | |
| Social Capital | Productivity | Institutional structure | 74 | 72 | 0.78 |
| | | Social network | 70 | | |
| | Sustainability | Effectiveness of G O, N GO or ot her s ocial network | 76 | 76 | |
| | Equity | Involvement of women group in relevant resource inventory | 78 | 79 | |
| | | Participating of w omen g roup in t raining a nd workshops | 80 | | |
| | Risk | Local politics | 84 | 84 | |