IDENTIFICATION OF LAND COVER CHANGES OF THE HAOR AREA OF BANGLADESH USING MODIS IMAGES

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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. The agriculture sector of haor area is expected to be heavily impacted by land cover changes. Moreover, land cover changes are expected to increase the risk of flash floods in the haor region. Therefore, attempt has been made to identify the status of land cover of the haor areas. In this study, moderate resolution satellite MODIS images are used for detecting of the changes of Haor area. This study reveals the existing scenarios of haor area and change of patterns for the period of 9 years (2000-2008) of which satellite data are available. Studies have shown that Normalized Difference Vegetation Index (NDVI) as a measure of crop growth is minimum in 2004 of about 0.32 where NDVI value is maximum in 2006 of about 0.4 . Analysis revealed that over the last nine years, vegetative cover area has been increased about 8.35% compared to the vegetative cover in 2000. The change pattern of mixed land cover is somewhat unchanged except in 2001 and 2006. Water bodies has been reduced about greatly and converted to either vegetation areas or mixed land areas.

Keywords: *Land cover change, MODIS Satellite imagery, Remote Sensing GIS, Haor Area*

1. INTRODUCTION

The haor basin is a low lying bowl-shaped basin covering about 6,000 sq. km in Sylhet Division**,** mostly in Sunamganj district in Bangladesh. The topography of haor regions is uneven. Furthermore in terms of geographical elevation they are lower than the normal plain lands. 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 of Bangladesh and consists of mainly the districts of Sunamganj, Moulovibazar, Sylhet, Kishorganj and Netrokona. These wetlands area 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, fishing and recreation. According to Meyer (1999), every parcel of land on the Earth's surface is unique in the cover it possesses. Haor area can be altered by forces other than anthropogenic. Natural events such as weather, flooding, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover of Haor area.

Land cover and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disaster-flooding (Mas et al., 2004; Zhao et al., 2004). 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). Therefore, available data on land cover changes can provide critical input to decision-making of environmental management and planning the future (Fan, F. et al. 2007). 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. 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 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.

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. Land cover studies using remote sensing data have been received immense attention worldwide due to their importance in global change analysis (Cihlar, 2000). 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). The Moderate Resolution Imaging Spectroradiometer (MODIS) is one of the remote sensing instruments onboard the first NASA Earth Observing System (EOS) satellite (EOS, 2006). 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. The aim of change detection process is to recognize Land cover digital images that change features of interest between two or more dates. In this study, change detection comparison (pixel by pixel) technique was applied to the Land cover maps derived from satellite imagery. The aim of the study is to analyze land cover changes using satellite imagery and GIS techniques in Haor area of Bangladesh. An 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 MODIS surface reflectance imagery.

2. 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. Location of the greater Sylhet is shown in Fig. 1(a) and haor areas are shown in Fig. 1(b). 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 the greater Sylhet, the most prominent haors are Saneer haor, Hail haor, Hakaluki haor, Dekar haor, Maker haor, Chayer haor,Tanguar haor and Kawadighi haor.

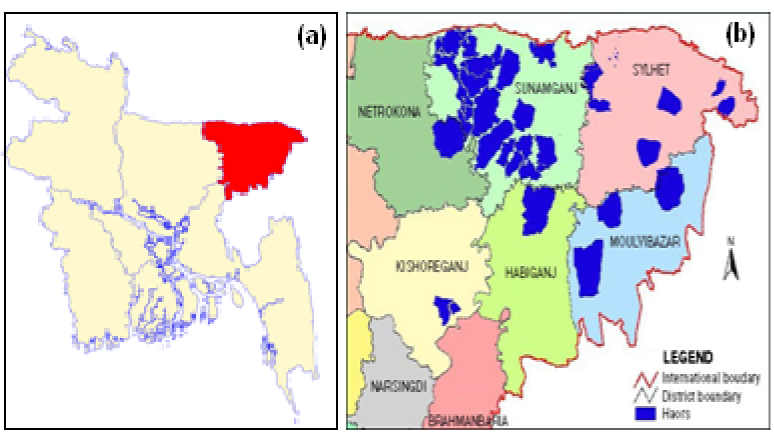

Fig. 1: (a) Location of the study area in the Bangladesh map and (b) Haor areas

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. During the winter season when the water level is lower, marginal land of the haor 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. The permanent water bodies support a rich and diverse aquatic habitat comprising unique assembly of flora.

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. 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. Mean monthly rainfall over the last 20 years is shown in Fig. 2.

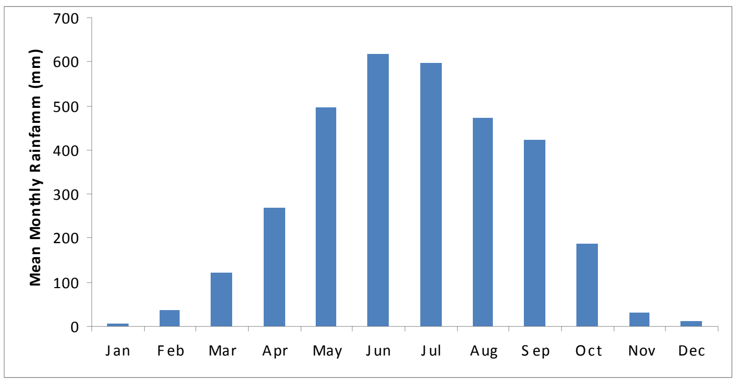

Fig. 2: Mean monthly rainfall (mm) of the study area

3. METHODS

3.1 Satellite Imagery

In this study, MODIS satellite images which are acquired by TERRA instrument were used. The images can be freely downloaded from the Earth Observing System Data Gateway (EOS, 2006) by using Warehouse Inventory Search Tool (WIST). 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 250 M SINGRID V005”. The spatial resolution of this product is approximately 500 m, and atmospheric correction has already been carried out (Vermote and 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. A total of MODIS about 419 images were used during 2000-2009. The location of Bangladesh is within the global dataset grid at 26th row and 6th column. MODIS has 36 bands of which band 1 and 2 are aggregated in 250 meter measure spectral range from 620 nm to 876 nm, bands 3 through 7 are aggregated in 500 meter measure spectral range of the 459 nm to 2155 nm and bands 8 through 36 are in 1 km resolution measure spectral range of the 405 nm to14.385µm.

3.2 Processing of Images

Integrated Land and Water Information System (ILWIS) software was used for image processing and spatial analysis. Using MODIS Re-projection Tool (MRT) software 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 and Layer stacking. Four main methods of post-processing of satellite imagery 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) and calculation of the area in square kilometers of the resulting land cover types for each study year and subsequently comparing the results.

3.3 Detecting Land cover changes using MODIS data

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. For MODIS surface reflectance 250m resolution images, NDVI is universally defined as follows:

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

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. Table 1 presents 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 1: land cover classification scheme

Code	Land cover categories	Range
1	Water body	<0.1
2	mixed	0.1<NDVI<0.4
3	vegetation	>0.4

Using the classification schemes presented in Table 1, a pixel can be composed of various mixture types of land surface. Figure 3 shows an example of various types of land cover areas in the study area on 12 July 2008.

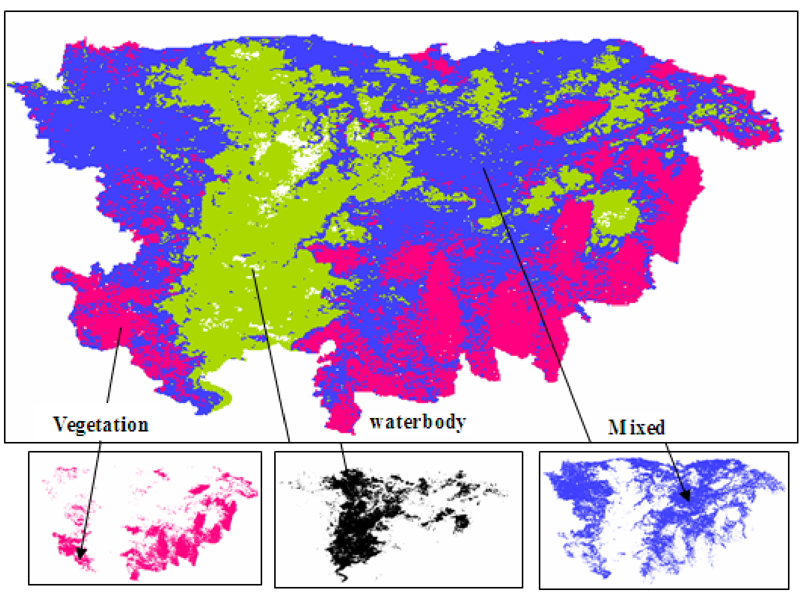

Fig. 3: Extraction of different land cover from NDVI original images

A flow chart of pre and post processing steps of the satellite images and classification schemes to determine various land cover classes in the study area has been presented in Figure 4.

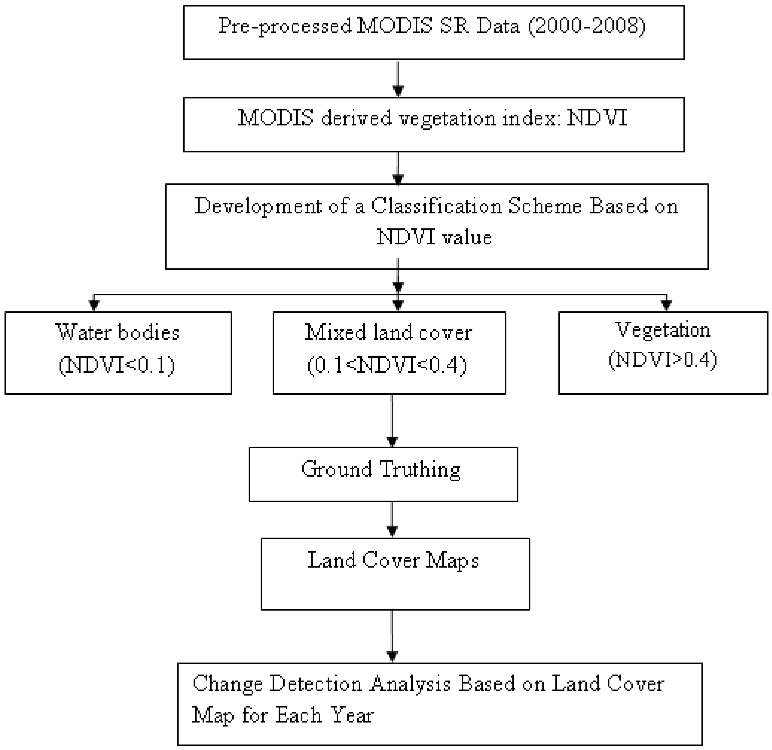

Fig. 4: Flow chart of detecting land use changes using MODIS data.

4. RESULTS AND DISCUSSIONS

4.2 Pattern of Land Cover Changes

Land cover changes during the dry season and wet season for the study area are shown in Figure 5(a) and 5(b) respectively. Analysis revealed that in the dry season, the vegetation cover area is the maximum in the haor area where as water bodies are the minimum or low. In the wet season, the vegetation cover has decreasing trends where as the water body has 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 the 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.

The monthly change of pattern in vegetation cover is similar except in 2000, 2002 and 2004 and shown in Figure 6. Water body remains at zero level from January to March and then starts to rise and again goes downward from August. Mostly, it reaches at the highest in June and July. The mixed land cover reaches at the highest during December and January and goes downward from January to April and then again starts to rise upward from April to September.

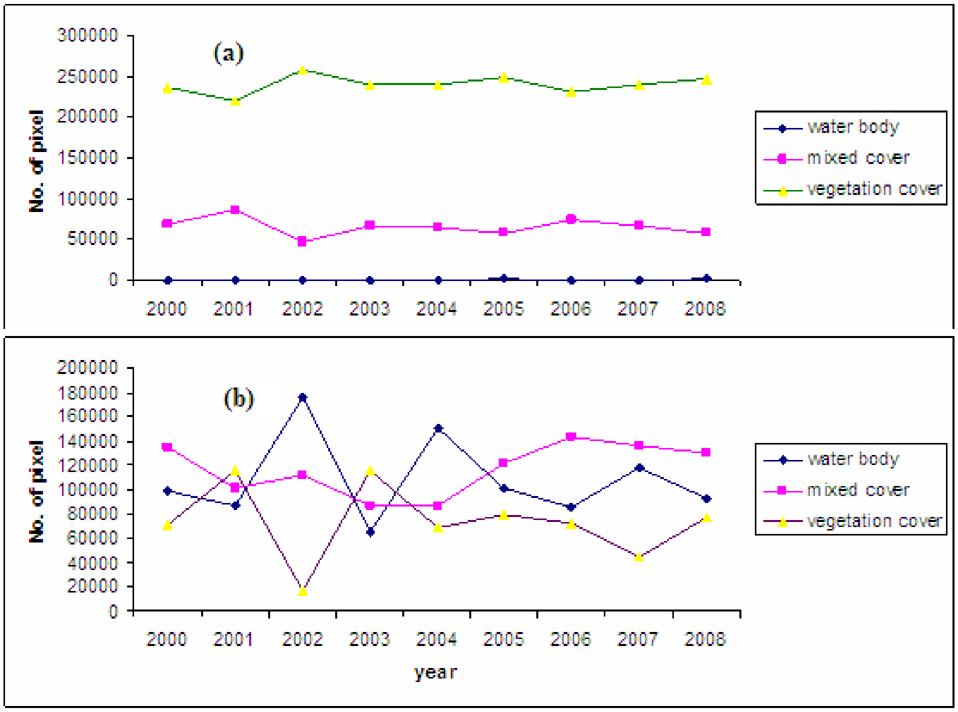

Fig. 5: Land cover changes in (a) Dry season and (b) Wet Season from 2000 to 2008

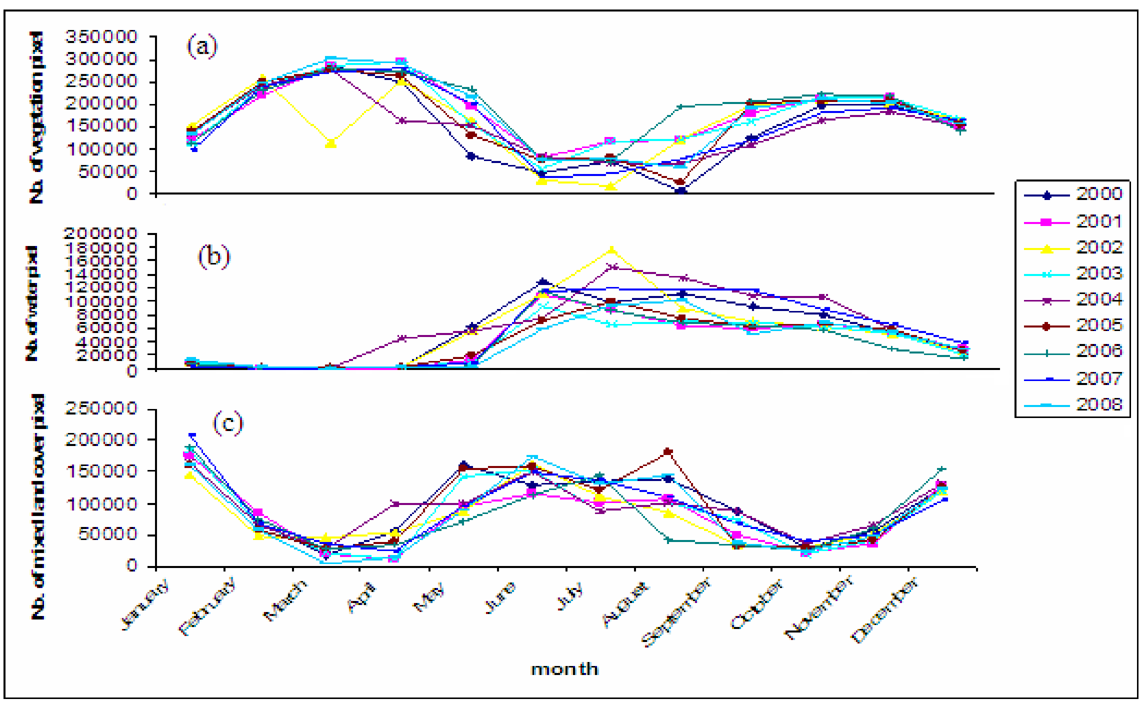

Fig. 6: Monthly (a) vegetation (b) water body and (c) mixed land cover change of the Haor area from 2000 to 2008

4.3 Vegetation Cover Maps

Vegetation cover maps of the study area were developed using NDVI values during the dry season from 2000 to 2008. Figure 7 shows spatial distribution of the vegetation covers of the haor areas during the dry season.

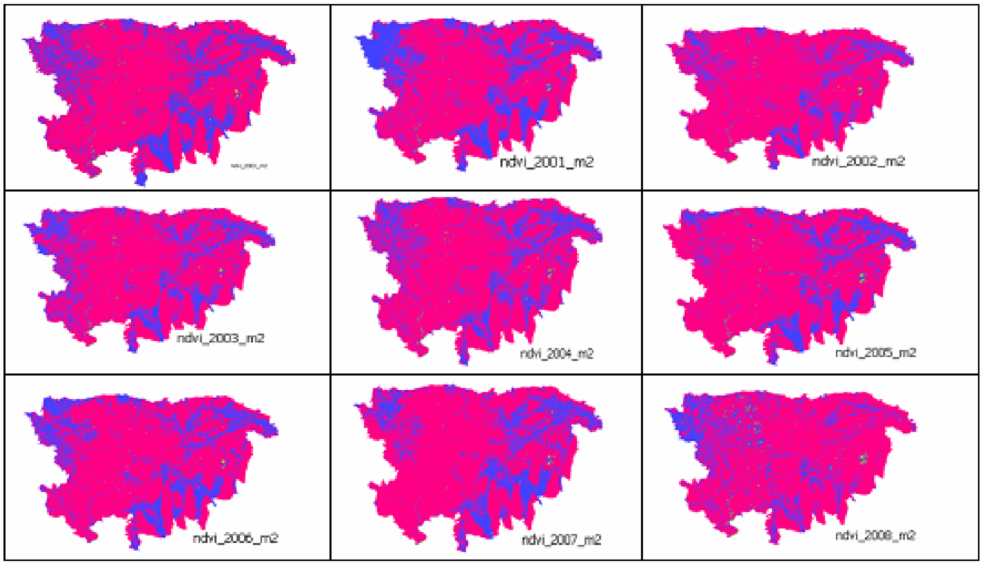

Fig. 7: Spatial distribution of NDVI of the haor area during dry season from 2000 to 2008. Vegetation is shown in red and mixed area is shown in blue.

4.4 Changes of Land cover areas

In Figure 8, area under each land cover has been shown from 2000 to 2008. It has been found that when the vegetation cover increases, the water body decreases. For example, the vegetation cover rises from 8880.892 sq. km to 10782.09 sq. km in 2001, 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 vegetation cover area changes increases 11% in 2006 from that of 2000.

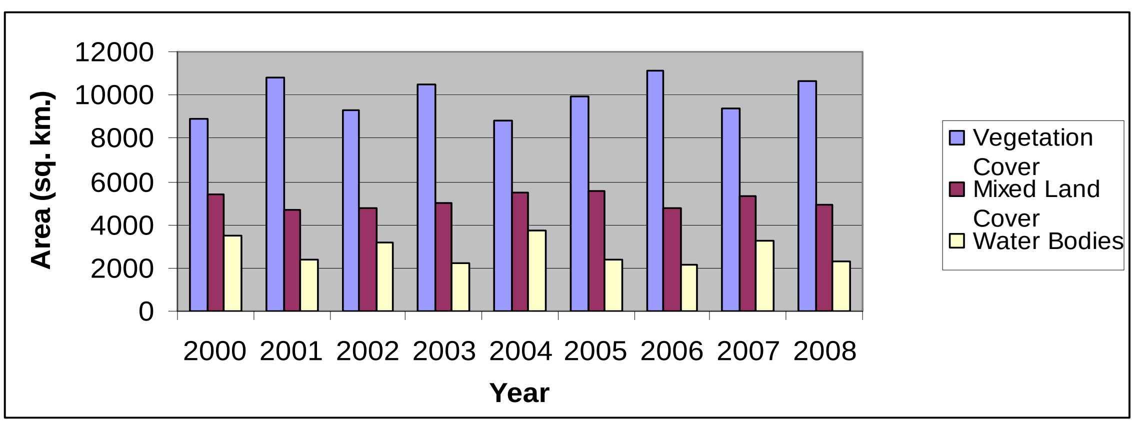

Fig. 8: Land Cover Change patterns of the Haor Area from 2000 to 2008

5. CONCLUSIONS

This study was able to detect the land cover changes of the haor area using MODIS satellite data. It has found that water bodies of the haor area has been reduced around 6.88% whereas vegetation (agricultural) area has been increased 8.35% during the 9 years period from 2000 to 2008. The change pattern of mixed land cover is somewhat unchanged except 2001 and 2006. Water bodies has been reduced greatly and converted to other land cover areas.

REFERENCES

Alphan, H. (2003). Land-use change and urbanization of Adana, Turkey. Land Degradation & Development 14(6), pp. 575-586.

Chilar, J. (2000) Land cover mapping of large areas from satellites: status and research priorities. International Journal of Remote Sensing, 21 (6&7), pp. 1093-1114.

EOS. (2006). NASA Earth observing system data gateway, from http://edcimswww.cr.usgs.gov/pub/imswelcome/

Fan, F., Weng, Q., Wang and Y. (2007) Land use land cover change in Guangzhou, China, from 1998 to 2003, based on Landsat TM/ETM+ imagery. Sensors, 7, 1323-1342.

Houghton R.A. (1994) A worldwide extent of land-use change. Bio-Science, 44, pp. 305–313.

Mas, J.F., Velazquez, A., Gallegos, J.R.D., Saucedo, R.M., Alcantare, C.; Bocco, G., Castro, R., Fernandez, T., and Vega, A.P. (2004) Assessing land use/cover changes: a nationwide multidate spatial database for Mexico. International Journal of Applied Earth Observation and Geoinformation, 5, pp. 249-261.

Meyer, W.B. (1995) Past and Present Land-use and Land-cover in the U.S.A. Consequences. Pp 24-33.

Muttitanon, W., Tiıpathi, N.K. (2005) Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data. International Journal of Remote Sensing, 26 (11), pp. 2311-2323.

NERP (1995) Specialist Study Wetland Resources, Final Report; Northeast Regional Water Management Project, FAP-6, Flood Plan Coordination Organization, October, 1995.

Reid, N. and Landsberg, J. (2000) Tree decline in agricultural landscapes: what we stand to lose, In R.J. Hobbs & C.J. Yates (eds) Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration pp 127-166. Surrey Beatty, Chipping Norton.

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J. and Dirzo, R. (2000) Biodiversity: Global biodiversity scenarios for the year 2100. Science, 287, pp. 1770–1774.

Vermote, E.F., & Vermeulen, A. (1999) MODIS algorithm technical background document, atmospheric correction algorithm: spectral reflectances (MOD09). NASA contract NAS5-96062.

Wilkie, D.S.; Finn, J.T. (1996) Remote sensing imagery for natural resources monitoring: a guide for first-time users. New York: Columbia University Press. pp. 295.

Zhao, G.X.; Lin, G.; Warner, T. (2004) Using ThematicMapper data for change detection and sustainable use of cultivated land: a case study in the Yellow River delta, China. International. Journal of Remote Sensing, 25 (13), pp. 2509-2522.