Study of the Spatio-Temporal Changes of Hail Haor using Remote Sensing and GIS Techniques

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Abstract

This paper has focused on the multi-temporal changes of the surface features of the Hail hoar wetland. The study was carried out using integrated technology of Remote Sensing (RS), Geographic Information System (GIS) and ground truth verification. Four sets of satellite data covering 1975-2014 time period were used for the study. The main wetland surface features identified in Hail hoar were water body and rice crops (Aman and Boro). The study revealed that the extents of all these surface features have been changed with specific trends. Extent of water area in dry season has been decreased and that in the wet seasons has been increased. The areas of Aman and Boro crops have also been changed with opposite patterns. These changes have upset the wetland characteristic of Hail hoar. Progressive increase of surface water in wet season made the hoar and its associate areas more vulnerable to flood. The decreasing tendency of dry season water area became alarming for the entire ecosystem of the haor region.

Keywords

Remote sensing, GIS, Hail hoar, Wetland, Change analysis, Aman, Boro

Introduction

Wetlands in Bangladesh have unique characteristics and have great importance in the country's socioeconomic, cultural and ecological aspects (Islam and Gnauck, 2007). Total area of wetland in Bangladesh is around 50% of the total land which covers an area of about seven to eight million hectares (Akonda, 1989; Khan et al., 1994). Wetlands in Bangladesh includes rivers, estuaries, swamps, haor, baor and beels, water storage reservoirs, fish ponds, and some other lands which suffer from seasonal inundation (Khan, 1993; Islam, 2008). Comparing with other major natural land forms, a wetland is young, dynamic and physically unstable. Over the period of time, wetlands have been drained, filled or otherwise altered (Dahl, 1990; Whittecar and Daniels, 1999). It changes with vegetation, sedimentation or geological subsidence. The key to vegetation development and community dynamics here is hydro-period, affected by topography, flooding and flood type, precipitation and water table fluctuations.

Hail haor is one of the largest natural freshwater wetlands of Bangladesh and is distinctive in Bangladesh for having much of its catchment within the country. Hail haor is located in the Sylhet basin bounded by number of tea gardens and low hills. Water from these low hills flows into the haor through 59 streams (Thompson, 2008). These small streams locally are known as charas (SPARRSO, 1981). Hail haor contains very rich components of biodiversity of all valuable ecosystems containing endangered and commercially important species of national and international interest. It has been listed in the Asian Wetlands Directory as of international significance on ecological grounds (Scott, 1989). It also has been listed as one of the nineteen Important Bird areas in Bangladesh (Bird Life International, 2004) and has been proposed as a Ramsar site. It is nationally recognized as an important fishery resource, and since 1999 has become a model of community-based co-management and restoration of wetland biodiversity and productivity. To ensure sustainable productivity of resources, Government of Bangladesh initiated many development projects for the Management of Hail haor.

Huge amount of sedimentation has been taken place in Hail haor area. Some study showed that sedimentation over a time period introduced new soil boundaries along with HYV rice crops which enhanced the shrinkage of the water body. The sedimentation process is accelerated with the flow of upstream water from the surrounding hilly areas which ultimately shrinking the bio-resources and extent of Hail haor wetland (Uddin *et al*., 2013). The loss/change of wetland resources in Hail haor shows an urgent need for up-to-date mapping and monitoring of the wetland components. Traditionally, wetlands are delineated using ground surveys. However, the surveys are difficult and time consuming (Yasouka et al., 1995; Lyon, 1993). Remote sensing is one of the technologies that can provide cost and time-effective solutions to mitigate these problems

(Goldberg, 1998). In addition, multiple date remote sensing images can supply information like extent of wetlands in different season, wetland land cover type, status of submerge and emergent wetlands and details about the wetland resource (Lyon and McCarthy, 1995). In this study time series remote sensing data and information collected through ground survey were used for studying the changing scenarios of wetland surface features of Hail haor.

Objective

The ultimate aim of this study is to map and monitor the changes of wetland surface features of Hail haor using remote sensing data. To achieve this aim the following objectives were pursued:

1. Identification and estimation of the extent of main wetland surface features in Hail haor in temporal domain.
2. Analysis of the changes of Hail haor wetland and its surface features in temporal domain.

Location of the Study Area

The study area is Hail haor which is located in Sylhet basin and is bounded by the Brashijhura and Brashijhura hills in the east, the Atanmura rang in the south and Satgaon hills in the west. Fairly flat land with numerous small lakes and beels are in the north, extended up to the river Kushiyara (Thompson, 2008). The haor located in the administrative boundary of Sreemongal Upazila and Moulvi Bazaar Sadar Upazila of Moulvi Bazaar District. The geographic location is between the 24°18'-24°26'N latitude, 91°38'-91°45'E longitude. Figure 1 shows the location of the study area.

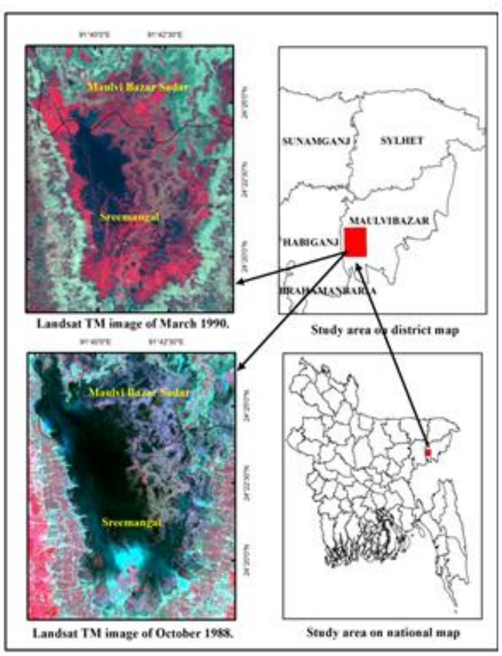

Figure 1: Location of the study area and example of satellite images used for the study.

Data Used

For studying the temporal and seasonal changes of wetland surface features multi-temporal remotely sensed datasets of wet (October) and dry (March) seasons were used. The remotely sensed data were grouped into sets as shown table 1. Two satellite images were included in each dataset to extract information of the two crop seasons (Aman and Boro) and to present the scenario of seasonal variation of water areas in Hail hoar. Figure 1 shows examples of satellite images of March and October used for the study. Dark portions in the images are water areas and red/reddish colors are vegetation areas.

Methodology

The study was carried out using integrated technology of RS-GIS-ground truth verification. Standard procedures of geo-referencing, image interpretation and on-screen digitization were used based on ERDAS Imagine software to generate the data layers mentioned in table 1. Refinement of the data layers based on field information were carried out. GIS analyses were carried out using ArcGIS software to reveal the seasonal and multi-temporal changes of the areas of water bodies and crops in the study area.

Table 1: Landsat images used for the study.

Dataset Name	Satellite /Sensors	Acquisition Date	Resolution	Information
1975	Landsat MSS	26-3-1975	80m	Water area, Boro crops
		28-10-1975		Water area, Aman crops
1990	Landsat TM	5-3-1990	30m	Water area, Boro crops
		9-10-1988		Water area, Aman crops
2000	Landsat TM	24-3-2000	30m	Water area, Boro crops
		28-10-2000*		Water area, Aman crops
		21-10-2000*		Water area, Aman crops
2014	Landsat TM	23-3-2014	30m	Water area, Boro crops
		30-10-2013		Water area, Aman crops
* The two images supplement each other to extract information under partly cloudy condition				

Result and Discussion

Water Bodies

Seasonal and multi-temporal changing scenarios of water areas in Hail hoar is shown in figure 2 and the relevant statistics are presented in table 2. With reference to 1975, trends of change of water areas of wet and dry seasons were seen from table 2. Water areas in wet season had an increasing trend and water areas in dry season had a decreasing trend. The maximum wet season water area was 7496 hectare in 2014 and the minimum wet season water area was 3241 hectare in 1975. For dry season, year 2000 contained the maximum water area (2369 hectare) and year 2014 contained the minimum water area (949 hectare). Based on information collected from field, the reasons for the increasing trend of wet season water area were attributed to the lower discharge of water from the hoar due to congestion of drainage for construction of infrastructure and to the swallowing of haor depth due to sedimentation. Extended use of land and surface water for Boro cultivation was the cause of decreasing trend of water area in March. Because of the opposite trend of change of surface water areas mentioned above, seasonal fluctuation (March to October) of water area had an increasing trend since 1975 (table 2). The fluctuation was about 62 % in 1975 and increased to about 87 % in 2014.

Figure 2 shows the pictorial view of the extent of seasonal fluctuation of water area in 1975, 1990, 2000, and 2014. It is seen that water areas in March (common water area in dark blue color) were inclusive of the water area in October. Extended part of water areas in October (fluctuation between March to October) is shown in light blue color. Common areas of water were more or less stable up to 2000 but reduced significantly in 2014.

Maintenance of the extent of water areas is a major concern in sustaining the wetland characteristic of a landmass. Taking 1975 as the reference year, it is seen that the dry and wet season extents of surface water in Hail hoar have been changed in opposite patterns. Apart from upsetting the wetland characteristic of hail hoar, these changes brought another concern based on the increase of wet season water area in the haor zone. Calculating from table 2, it is seen that with reference to 1975, the increase of wet season water area in 2014 was 2244 hectare (42.73 %). The progressive increase of water area in wet season was disrupting the flood-water absorbing characteristics of the hoar and was making the hoar and its associate areas more vulnerable to flood.

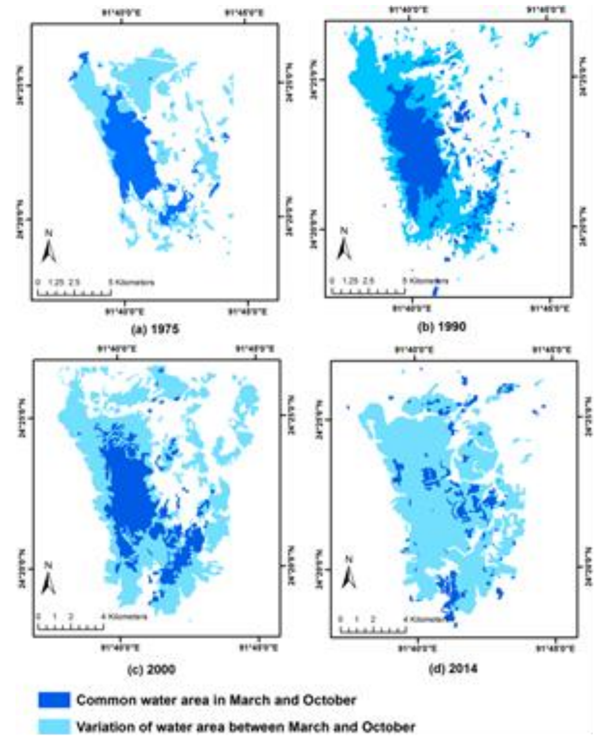

Figure 2: Water area change map

Table 2: Extents of surface water area.

Year	Water area		Seasonal changes	
	March, Hectare	October, Hectare	Area, Hectare	% w.r.t. October
1975	2011	5252	3241	61.71
1990	2235	6035	3800	62.97
2000	2369	7958	5589	70.24
2014	949	7496	6547	87.34

Crop Areas

Aman rice and Boro rice were cultivated in the Hail Hoar as the major crops. Changes of areas of these two crops in time domain were studied as wetland surface features. Table 3 presents the year-wise estimation of the areas of Aman and Boro crops.

Table 3: Year-wise areas of Aman and Boro crops

Year	Aman crop		Boro crop	
	Area, Hectare	%	Area, Hectare	%
1975	2819	72.00	4329	52.72
1990	527	13.46	3608	43.93
2000	932	23.81	5705	69.46
2014	933	23.84	5201	63.32

Aman Crop

Aman was the perennial rice crop in Hail haor. Table 3 depicted an overall decreasing trend of Aman area in Hail hoar starting from 1975. The highest Aman area was 2819 hectare in 1975 and lowest Aman area was 527 hectare in 1990. Total Aman cultivable area in Hail hoar estimated from the Aman areas of all the study years was 3914 hectare. It is seen from table 3 that with reference to the total cultivable area, Aman area was reduced from 72 % in 1975 to about 24 % in 2014.

Figure 3 shows time domain map of Aman areas and table 4 presents the relevant statistics. For making readable map classes 1 to 4 in table 4 were grouped as 'Crop areas in a year alone' (Dark brown color, 2767 hectare, 70.69 % of total Aman cultivable area), classes 5 to 10 were grouped as 'Common crop areas in two years' (blue color, 998 hectare, 25.50 %), classes 11 to 14 were grouped as 'Common crop areas in three years' (green color, 146 hectare, 3.73%). It is seen that common Aman area over the study period was very negligible (3 hectare, 0.08 % of total Aman cultivable area) and the dynamics of Aman crop areas was very high. Aman area alone in 1975 was 1814 hectare which was 46.35 % of the total Aman cultivable area; the significance of this statistics is that this 1814 hectare area was not used for Aman cultivation after 1975. On the other hand, Aman area alone in 2014 was 503 hectare which was 12.85 % of the total Aman cultivable area; the significance of this statistics is that this 12.85 % area was the latest extension of Aman crop in Hail hoar.

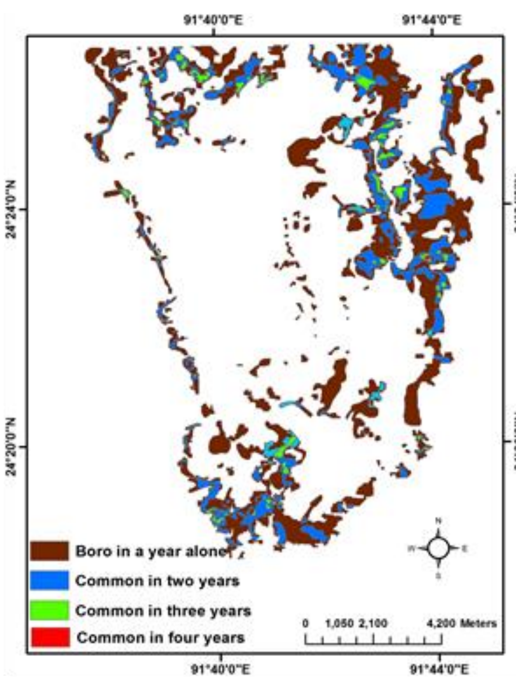

Figure 3: Time domain map of Aman crop.

Boro Crop

Table 3 presents the statistics of Boro crop areas in Hail haor. The overall trend of Boro area was increasing. Boro area was the highest in 2000 (5705 hectare) and the lowest in 1990 (3608 hectare). Estimated total Boro cultivable area in Hail hoar was 8212 hectare. It is seen from table 3 that with reference to the total cultivable area, Boro area was increased from about 53 % in 1975 to about 63 % in 2014, though in the year 2000 the highest percentage (69.46) of Boro area was cultivated. The increasing trend of Boro cultivation can be explained with the sedimentation process which has changed the duration and the depth of inundation in the haor area. This change had a positive impact on Boro cultivation. Similar findings were also reported by other researchers (Hoq and Shoaib, 2003; Sultana *et al*., 2009).

Figure 4 shows time domain map of Boro areas and table 4 presents the relevant statistics. It is seen that common Boro area over the study period was (23.13 % of total Boro cultivable area) much higher than that of Aman and the dynamics of Boro crop areas was comparatively lower: Common Boro area in two years was 23.48 %, Common Boro area in three years was 18.21 % and Boro area in a year alone was 35.18 %.

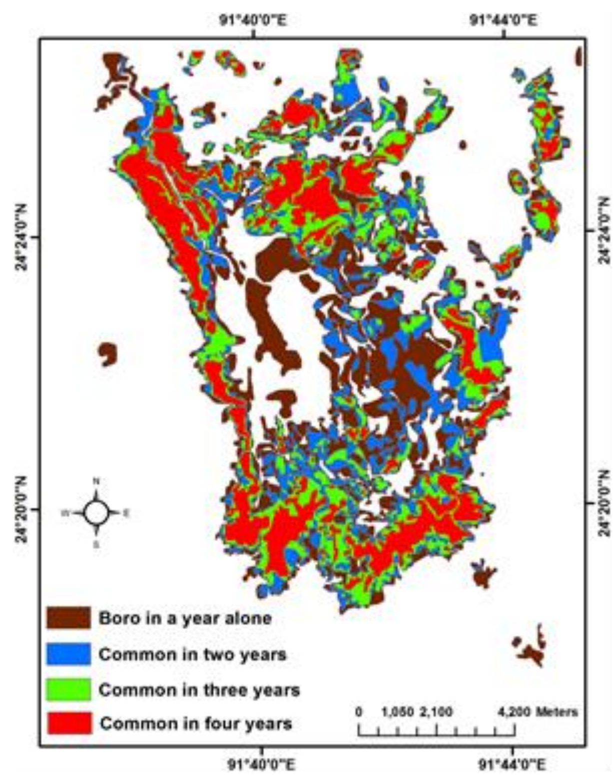

Figure 4: Time domain map of Boro crop.

Table 4: Changes of crop areas in time

Class No.	Change class	Aman		Boro		Broad class category
		Area, Hectare	%	Area, Hectare	%	
1	1975 alone	1814	46.35	465	5.66	Crop areas in a year alone
2	1990 alone	267	6.82	196	2.39	
3	2000 alone	183	4.68	1127	13.72	
4	2014 alone	503	12.85	1101	13.41	Common crop areas in two years
5	1975 and 1990	117	2.99	139	1.69	
6	1975 and 2000	505	12.90	477	5.81	
7	1975 and 2014	246	6.29	250	3.04	
8	1990 and 2000	46	1.18	273	3.32	
9	1990 and 2014	8	0.20	126	1.53	
10	2000 and 2014	76	1.94	663	8.07	
11	1975, 1990 and 2000	48	1.23	337	4.10	Common crop areas in three years
12	1975, 1990 and 2014	26	0.66	233	2.84	
13	1975, 2000 and 2014	59	1.51	524	6.38	
14	1990, 2000 and 2014	13	0.33	401	4.88	
15	1975, 1990, 2000 and 2014	3	0.08	1904	23.13	Common crop areas in four years (No change areas)

Conclusion

The study revealed that the major wetland surface features in Hail hoar were water body and rice crops (Aman and Boro). The extents of all these surface features of Hail hoar were seen to changes with specific trends. The dry season water area has been decreased while the wet season water area has been increased. Due to continuous siltation processes, the haor area has been being filled up and perennial water area of the haor has been changed. Apart from disturbing the wetland characteristic of hail hoar these changes, particularly increase of wet season surface water, has been making the hoar and its associate areas more vulnerable to flood. The decreasing tendency of dry season water area has been becoming alarming for the aquatic species and for the entire ecosystem of the haor region.

It is seen that the area of Aman rice had a decreasing tendency while the Boro rice area had an increasing tendency. Filed information supported that there are relationship between the changing patterns of water and crop areas. The increase of wet season water area has been disrupting the perennial Aman fields and reducing the Aman cultivation area. The reduction of dry season water area has been making available more areas for Boro cultivation. However, surface water of the hoar has been being used for Boro cultivation which, in turn, reducing the dry season water area of the Hail hoar.

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