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Possible impacts of land use change on eco-hydrology of Arial Beel

A.R. Siddique
Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

ABSTRACT: The study attempts to identify the possible impacts of land use change on eco-hydrology of Arial beel - a large depression between the Ganges and the Dhaleshwari rivers south of Dhaka. The satellite image based land-use maps of Arial beel as of six different points in time through 1984 to 2004 reveal that alteration in cropping pattern has been the predominant form of land use change during this period. Preliminary analysis shows urban and rural settlements and water bodies have remained stable at 1%, 17% and 2% respectively while cropped area and fallow land have fluctuated due to seasonality. Increase of crops and vegetables production required some increase in the amount of fertilizers and pesticides used - which has negatively impacted the aquatic lives of the beel and the livelihood of beel dependent fishermen. Cognizance of these impacts is essential in planning sustainable land use for the area with due consideration for bio-diversity and socio-economic characteristics of the wetland

1 INTRODUCTION

1.1 *Background*

Land-use change is a common term for the human modification of the earth's terrestrial surface. Instances of land use change include deforestation, road construction, agricultural development, change of land or soil, drainage, change of crop varieties, dam building, irrigation, coastal zone degradation, wetland modification, mining, the concentration and expansion of urban environments and other activities. Kashaigili et al. (2009) found that the sustainability of eco-systems requires proper use of land and management of water. This study highlights the importance of integrating remote sensing and local knowledge in understanding the catchment resources dynamics and ultimately informing the policy and decision makers on a need for proper land planning and improvement in agricultural practices for the sustainability of the catchment resources.

Bangladesh is one of the most densely populated countries in the world. Increased food demand and other growing national economic activities exert pressure on water resources of the country. Moreover, runoff from agricultural lands causes toxicity in the surface water, which can have adverse impacts on aquatic habitats (EGIS II, 2001). It has been observed in earlier studies that the reduction of biodiversity, aquatic and amphibian resources, and wildlife habitats lead to the change in wetland-based human occupations and shrinkage of socio-economic activities (Islam and Sadque, 1992).

1.2 *Study area*

The site chosen for the study is the Arial beel, one of the major wetlands of Dhaka and Munshigonj districts. As an agro-ecological zone (AEZ-15) (FAO, 1988) and part of Bio-ecological zone 4b (IUCN, 2002), the Arial beel has a great ecological, commercial and socio-economic importance. The significance of the area has been in the limelight in early 2011 due to a proposal of construction of an airport in the area (The Daily Star, Aug 2, 2011).

1.3 *Importance of sustainable land use change planning*

Studies of land use change have become an important field world-wide (Lovejoy, 1979). Land-use changes encompass one of the greatest environmental concerns of human populations today, including climate change, biodiversity loss and the pollution of water, soils and air. Patz et.al (2000) observed that human- induced land

use changes are the primary drivers of a range of infectious disease outbreaks and emergence events and also modifiers of the transmission of endemic infections.

Land use in Bangladesh is determined mainly by the monsoon climate and the seasonal flooding which affects the greater part of the country. These physical determinants are reinforced by high population pressure and increasingly, by alterations to the natural environment through flood protection, drainage and irrigation interventions. Dewan and Yamaguchi (2009) conducted a study on land use and land cover change in Greater Dhaka over the study period (between 1975 and 2003). The study observed significant decrease in the area of water bodies, cultivated land, vegetation and wetlands. Urban land expansion has been largely driven by population growth and economic development. They found that rapid urban expansion through infilling of low-lying areas and clearing of vegetation resulted in a wide range of environmental impacts, including degradation of habitat quality.

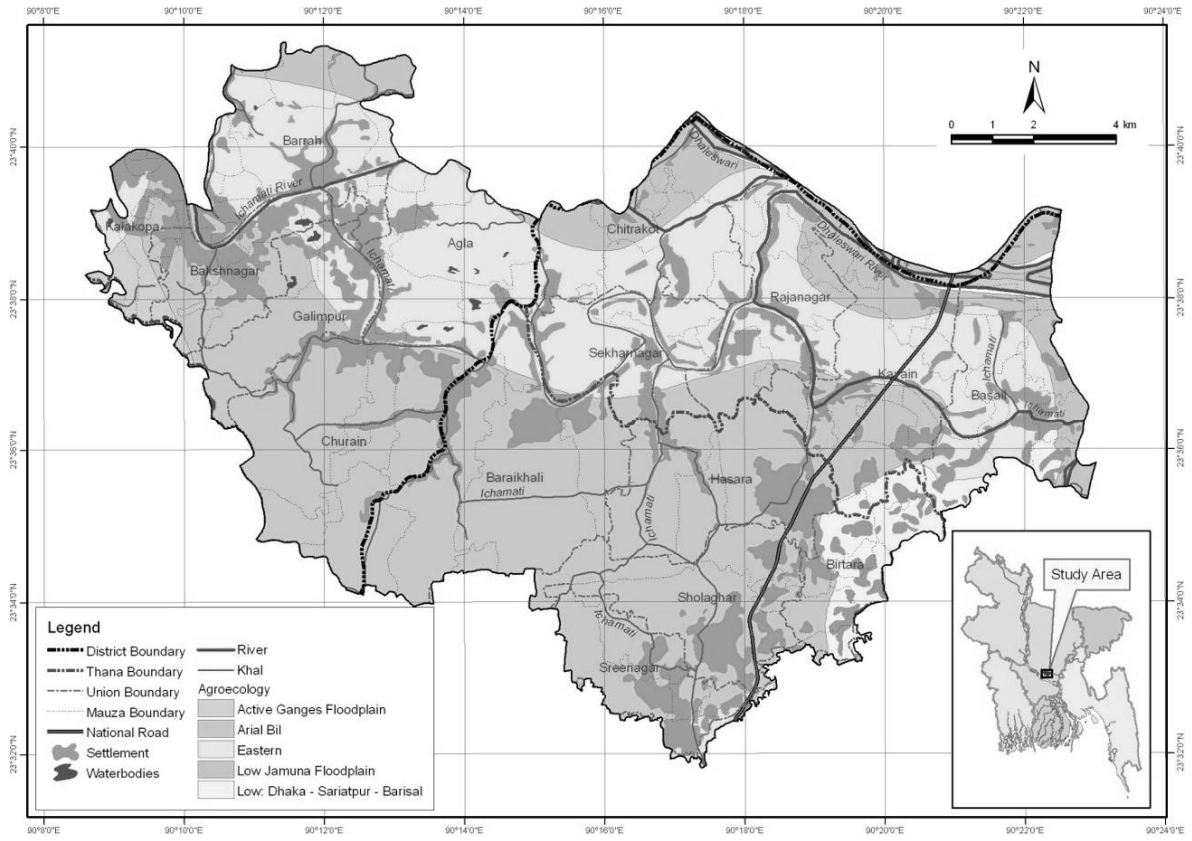

Figure 1. Arial Beel

2 LOCATION OF ARIAL BEEL

Discrete selection of study area is of paramount significance for any formal study. Arial beel is a large depression between the Ganges and Dhaleswari rivers south of Dhaka. The total area of the beel is about 14436 ha. It lies approximately between 23˚32´N to 23˚48´N latitudes and 90˚08´E to 90˚27´E longitudes. The Arial Beel belongs to Dhaka and Munshigonj districts and located at four upazillas namely Dohar, Nawabgonj. Sreenagar and Sirajdhikhan of which Dohar and Nawabgonj are in Dhaka district and Sreenagar and Sirajdhikhan are in Munshigonj district. The greatest portion (67%) of the beel belongs to Sreenagar upazilla which is followed by Nawabgonj upazilla (24%). The least portion of the beel (4%) belongs to Dohar upazilla and it is followed by Sirajdhikan upazilla (5%). Since Arial beel is not a well defined administrative unit – it was necessary to specify the exact dimension of the study area. With this objective the area under the following 15 unions was demarked as the study area: Churain, Galimpur, Baksnagar, Barrah, Kalakopa and Agla unions under Nawabganj Upazila in Dhaka district; Chitrakot, Rajanagar, Kaiyan and Basail unions under Serajdhikhan Upazila in Munshiganj district and Sreenagar, Baraikhali, Hasara, Birtara and Sholagar unions under Sreenagar Upazila in Munshiganj district.

The Ichamati river flows through the beel area. It receives a large quantity of runoff during the monsoon from its territorial settlements. It is the drainage outlet of the Dohar, Nawabgonj, Sreenagar and Sirajdhikhan upazillas. Approximately 500 species of flowering plants, 150 of vertebrates and 400 species of vertebrates

are found in the beel area in addition to approximately 260 species of fin fishes and 25 shell fishes available in the beel (Islam, 2000).

2 METHODOLOGY

2.1 *Data sources*

Several published and unpublished materials and data were necessary for the present study and they were collected from various sources. This research uses both primary and secondary data. Information has been collected from primary sources through Focus Group Discussion (FGD). Information was also collected through the review of the previous studies on Arial beel and also through surveying recent published and unpublished materials. Other secondary information with spatial and non spatial dimensions was collected from Bangladesh Agricultural Research Council (BARC), Bangladesh office of International Union for Conservation of Nature (IUCN), Soil Research Development Institute (SRDI) and from other journals and publications. Satellite images and maps used for the study were collected from Center for Environmental and Geographic Information System (CEGIS). The types and sources of satellite images are given below:

Table 1. Types and sources of satellite images used in the study

Date and Year	Types of and Sources Data	Resolution
19-Mar-84	Landsat TM Satellite Image (CEGIS)	30m x 30m
7-Jan-90	Landsat TM Satellite Image (CEGIS)	30m x 30m
9-Feb-96	Landsat TM Satellite Image (CEGIS)	30m x 30m
18-Dec-98	Landsat TM Satellite Image (CEGIS)	30m x 30m
8-Feb-99	Landsat TM Satellite Image (CEGIS)	30m x 30m
29-Dec-04	Landsat TM Satellite Image (CEGIS)	30m x 30m

2.2 *Image classification*

The satellite images collected from CEGIS were already enriched with image classification. The numerous different color sheds seen in the images were lumped together and digitally classified into seven broad classes. The classification was done based on statistical classification techniques, knowledge of experts in various fields who have visited the study area and the ground truthed data collected at the time of image acquisition. The definitions of the seven classes are as follows:

Crop: Given the season of the image capture times the major part of the crops grown in the area consists of Boro. Hence this class is mainly Boro with some other Kharif corps.

Grass: This class includes fallow land with stubble and grass. This type of area is used as gazing area for domestic cattle heads.

Land: This class denotes fallow bare land or land areas used for seasonal vegetable production – not under regular cultivation.

Moist land: This class represents fallow land with relatively greater moisture content – usually seen in increased proportion after flooding.

Settlement: This class represents rural settlements recognized by large trees that usually surround villages and are digitized as feature objects which may include ponds, gardens etc. that are within the settlements.

Urban: Urban areas are recognized by higher density of settlements of more permanent nature including buildings and commercial structures.

Water: This class covers all water areas in the study area. It includes rivers, ponds and those areas within the beel which are perennially water covered.

2.3 *Image analysis*

For the purpose of quantitative analysis of the spatial classification included in the CEGIS images, it was first necessary to clip the images in the exact shape of the study area. As discussed in section 2, the study area has been defined as the collective geographic region denoted by 15 administrative unions. The clipping of CEGIS enriched Landsat TM satellite images was performed using ArcView GIS 3.2a – a commercial GIS analysis tool by Environmental Systems Research Institute, Inc. ArcView GIS software allowed to convert the satellite image file and a geo-coded administrative map of 15 unions selected as the study area into two shape files and clip the former based on the later.

The ArcView GIS software also offers a “dissolve” function which aggregates features of a shape file that has the same value for a specified attribute. Using this feature the satellite images clipped against the study area were dissolved based on the class name attribute. Finally using the script interface of the software the aggregate land area of each class was determined. This same procedure was applied on each of the six geocoded satellite images listed in section 3.1 to quantify land use in the broad seven classes for the study area in the image capture periods.

2.4 *Ground truthing*

The ground truthing of the image analysis was performed through Focus Group Discussion (FGD) involving selected representatives of the communities in two selected unions within the study area – Churain Union under Nawabganj Upazila in Dhaka district and Baraikhali Union under Sreenagar Upazila in Munshiganj district.

Figure 2. Focus Group Discussion at Baraikhali Union

In the discussions, the participants were enquired about the land use change in their locality. Analyzing the responses of the two FGDs it can be concluded that about 30 yrs prior to the survey date, almost half of the area of Arial beel remained outside cultivation. At that time the main cultivated corp was aman and the production was 10-12 mound/bigha. Subsequently in the last 25 years, the beel community have gradually changed their cropping pattern. Now the position of the primary crop is taken by IRRI/29 and the production is 30-35 mound/bigha. Some of the fallow land has also been brought under cultivation. The FGDs also revealed that the local people have been growing many seasonal vegetables in fallow land since last 25 years. The agricultural production doesn’t span round the year because the beel area remains under deep water during the monsson season. During October-November, the local farmers prepare the seed-bed and in November- December they transplant the seeds for boro. Later on in April, they cut the crops. Once they raise the seeds from seed beds, then they plant different kharif corps including onion, garlic, wheat, oilseeds and mustard in the land used as seed beds.

Figure 3. Local people explaining the cropping pattern to the author

3 FINDINGS

3.1 *Generalized land use pattern in the study area*

Figure 4 shows generalized land use pattern of the Arial beel area in March 1984. The major part of agricultural land covered south-west section of the study area. On the other hand, fallow lands are found in the northern and the eastern sides. Scattered rural settlement areas stretch from north-west section to the south east section almost demarking between the areas predominantly covered with agricultural land from the area mostly remaining fallow. Urban settlements are concentrated in the north-west corner featuring Kalakopa union and in the south marking the center of Sreenagar union. Water bodies mostly demarking relatively lower areas in the region which perennially lie under water are scattered across the study area. The only discernible water body is the Ichamoti river flowing in the north-east corner of the study area.

Figure 5 illustrates generalized land use pattern of the Arial beel area in January 1990. The discernable change in land use from the 1984 image is that the vast fallow land area seen in the northern and eastern region earlier is now found to be under agricultural use. Figure 6 indicates the generalized land use pattern of the study area in February 1996. This image illustrates a lower density of crop area and higher propensity of moist land. Subsequent development in land use pattern in December 1998 is illustrated in Figure 7. The distinctive feature of this map is the relative absence of agricultural land and significantly higher propensity of moist land. Ground truthing confirmed that in December the crops are still at nascent stage and hence not detected in the satellite image. Furthermore the increased appearance of moist land can be linked to the devastating flood of 1998.

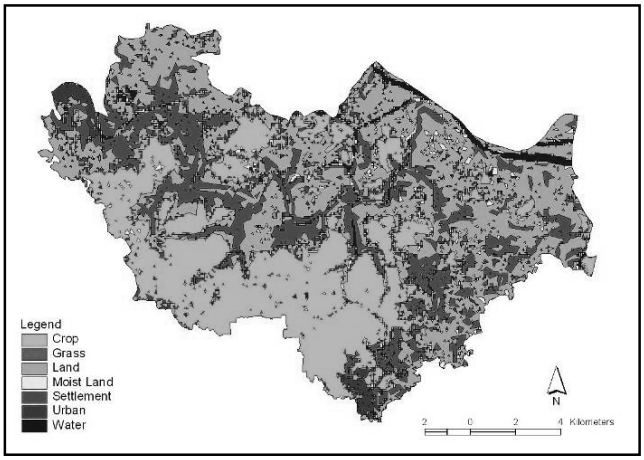

Figure 4. Land use map of Arial beel, Mar 1984.

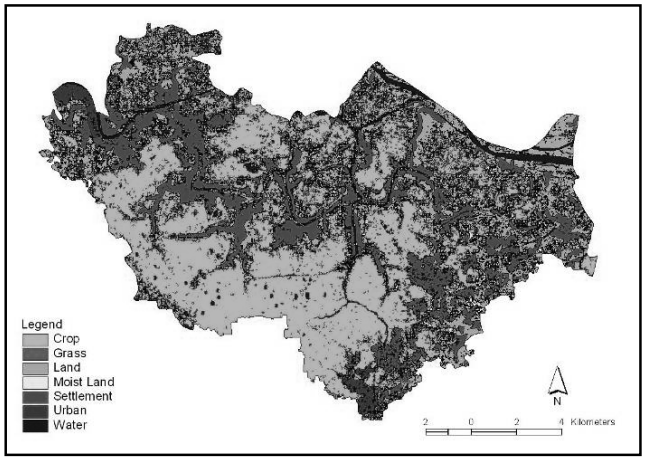

Figure 5. Land use map of Arial beel, Jan 1990.

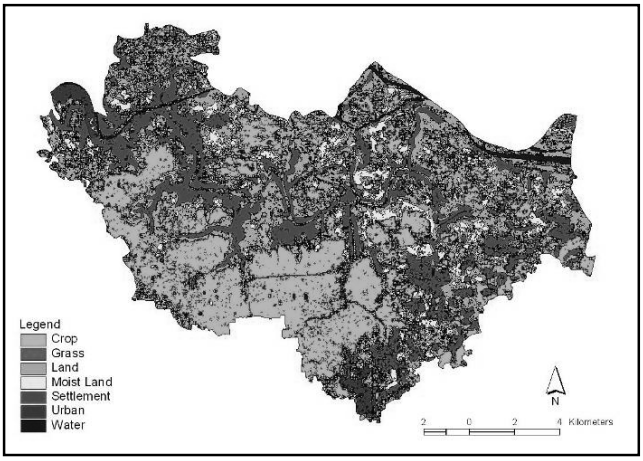

Figure 6. Land use map of Arial beel, Feb 1996.

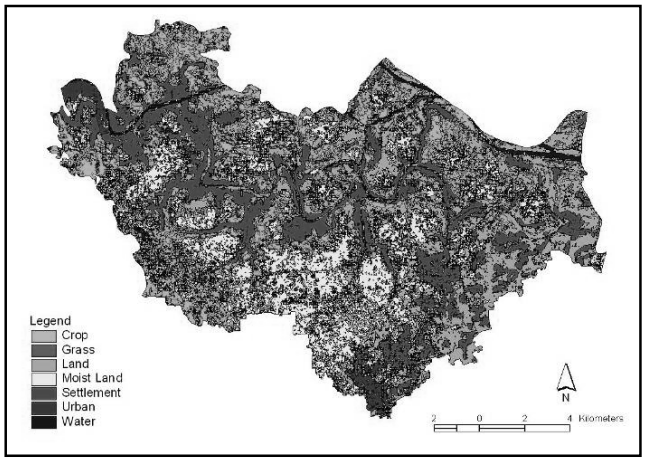

Figure 7. Land use map of Arial beel, Dec 1998.

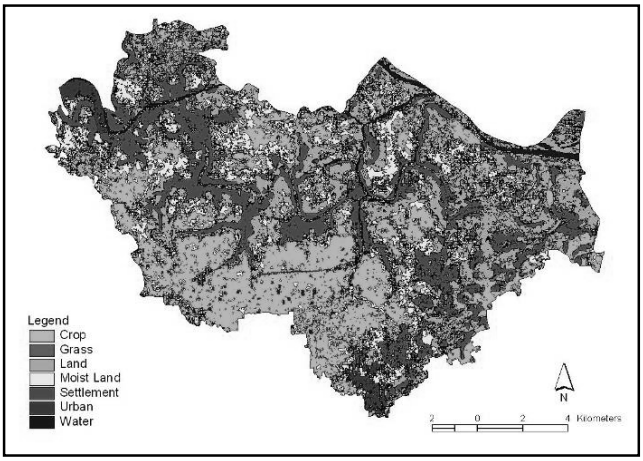

Figure 8. Land use map of Arial beel, Feb 1999.

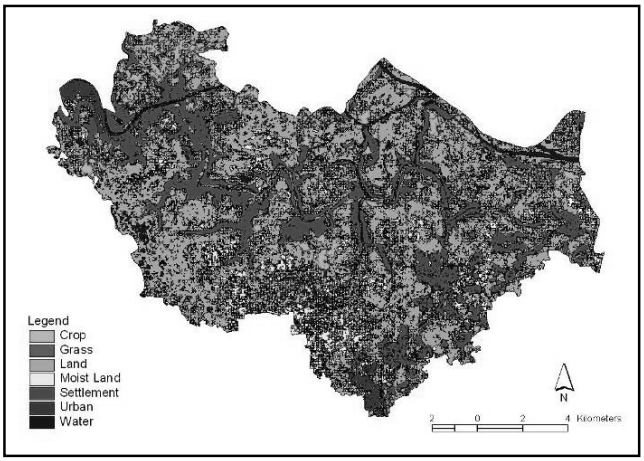

Figure 9. Land use map of Arial beel, Dec 2004.

Figure 8 displays generalized land use pattern of the Arial beel area in February 1999 – less than a year later than the earlier image. This image again shows the agricultural production restored in the south-west region although the propensity of moist land continues to be high. Lastly, the most recent of the available generalized land use pattern maps of the study area as of December 2004 is presented in Figure 9. This image features remarkable low propensity of agricultural land due to the seasonal variation discussed earlier. A highly

remarkable observation from these chronological images is that there is almost no change in rural or urban settlement areas throughout the study period spanning 20 years.

3.2 *Analysis of land use change*

The quantitative analysis of the seven different classes across the six images is presented in Table 2 and 3, which has been further discussed class by class later.

Table 2. Distribution of the land cover classes within the area as derived from image classification (area in hectares)

Class name	Mar-84	Jan-90	Feb-96	Dec-98	Feb-99	Dec-04
Crop	7183.18	10,353.32	7372.74	4215.56	7654.81	3731.38
Grass	1149.04	1295.95	1017.00	1227.51	469.10	2406.82
Land	9082.57	4938.20	7109.78	8127.14	5672.90	10,227.91
Moist Land	683.96	1231.80	2767.32	4768.19	4477.02	1606.31
Settlement	3828.96	3799.45	3849.75	3841.80	3840.30	3840.83
Urban	301.67	293.19	296.91	301.18	300.72	297.80
Water	462.25	552.50	334.75	266.32	332.14	628.35

Table 3. Distribution of the land cover classes within the area as derived from image classification (area in percentage)

Class name	Mar-84	Jan-90	Feb-96	Dec-98	Feb-99	Dec-04
Crop	32	46	32	19	34	16
Grass	5	6	5	5	2	11
Land	40	22	31	36	25	45
Moist Land	3	6	12	21	20	7
Settlement	17	17	17	17	17	17
Urban	1	1	1	1	1	1
Water	2	2	2	1	1	3

Crop: Due to seasonal variation agricultural crops are relatively less discernible in December images when the crops are at an early stage of growth. Ignoring the two December images as outliers it can be concluded that the aggregate area under agricultural production has remained relatively constant across the year. However, the FGDs clearly established that the crop production has gradually increased. Such increase of production keeping agriculture area constant was possible through higher production of high yielding varieties of rice, IRRI/29.

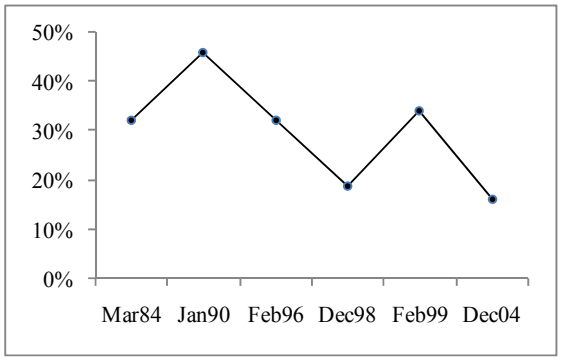

Figure 10. Share of crop areas in different years.

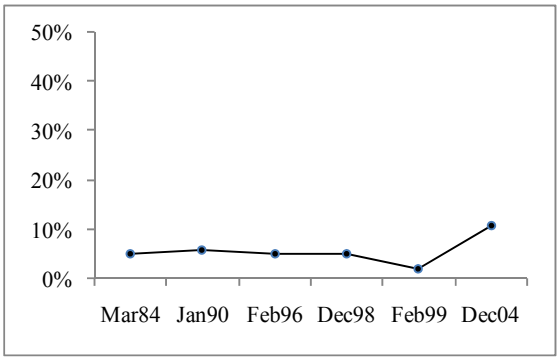

Figure 11. Share of grass areas in different years.

Grass: As discussed earlier fallow land with stubble and grass is used as gazing area for domestic cattle heads. Such areas have remained relatively constant over the years only slightly increasing in the final year of observation.

Land: Fallow bare land not under regular cultivation may be used for seasonal vegetable production. In the analyzed data the area under this class is seen to be inversely related to the area under land class. This is be-

cause in December images much of the land under crop and vegetable production is technically classified as fallow land due to the limitations in image classification technique.

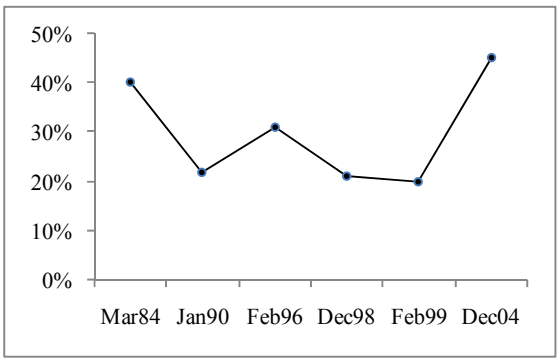

Figure 12. Share of fallow land areas in different years

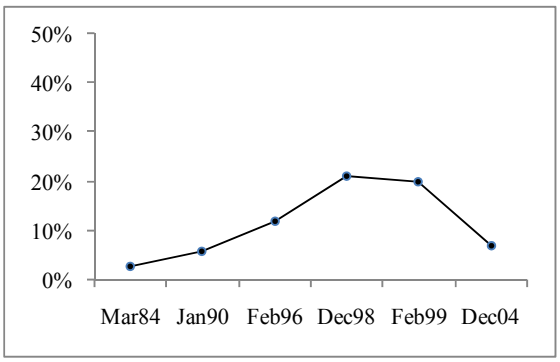

Figure 13. Share of moist land areas in different years

Moist land: As explained earlier, this class represents fallow land with relatively greater moisture content. The relative increase of moist land in 1998-99 can be attributed to the flood of 1998.
Rural and urban settlement areas: Rural and urban settlements have remained constant over the period at 17% and 1% of total land area under study during the observed period. This signifies low level of urbanization in the study area between 1984 and 2004.

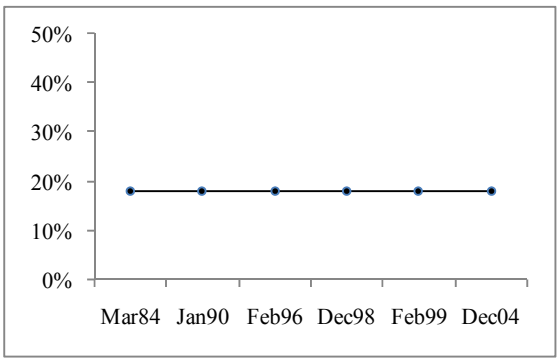

Figure 14. Share of settlement areas in different years

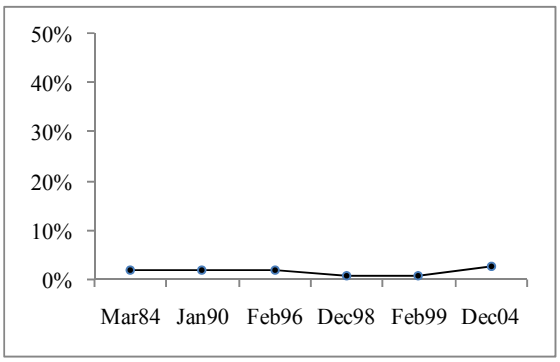

Figure 15. Share of water bodies in different years

Water: Share of water bodies have also remained fairly constant fluctuating between 1% and 3% over the period under study.

3.3 *Possible implications of detected land use change*

Alteration in cropping pattern has been detected as the only significant instance of land use change in the study area between 1984 and 2004. A gradual shift to high yielding varieties of crops has been evident. In recent years, the eco-hydrological effects of landscape pattern change have been discussed intensively, in particular with respect to runoff (Bellot et al. 2001; Felix et al. 2002), water quality (Basnyat et al. 1999), soil quality (Sheng et al. 2003), and climate (Taylor et al. 2002). Intensified agriculture accompanied with wide application of chemicals including pesticides, fertilizer is identified as one of the major sources of water pollution (Fu et.al. 2005). Although compared to other parts of Bangladesh, people of this area use less amount of fertilizer, the increase of crop and vegetables production has resulted in some increase in the amount of fertilizers and pesticides used- which could have negatively impacted fishing sector and other aquatic lives of the beel. In fact through interview of local fishermen it has been verified that some native fish species like-boal *(wallago attu),* shoal *(channa striata),* koi *(anabas testudineus)* are now endangered. As a consequence of depletion of aquatic resources, beel dependent fishermen have lost their occupations and in some cases have engaged in illegal works. The records of police stations in the beel area show that about 25 people have died from 1980 to 2006 due to conflicts in the beel area (Hossain, 2009).

3.4 *Emerging trends of land use change in the Arial beel*

One of the limitations of this study is that the satellite image of the latest years was not available for comparative study. Some emerging trands in land use change pattern in the study area were identified from the field

visits to the Arial beel area. Some industrial units including brick fields have emerged in the central region of the study area. It was even seen that some real estate developers have earmarked certain section of the beel area for development of residential projects.

Figure 16. Real estate developers have earmarked section of the Arial beel area for development of residential projects

Unplanned urbanization initiatives like these could cause further disturbance to the eco-hydrological balance of Arial beel. The concerned authorities should take into consideration the possible impacts of land use change on the bio-diversity and the socio-economic environment of the area.

4 CONCLUSION

This paper has mainly analyzed the land use changes of Arial Beel from 1984 to 2004. From 1980s, the major part of the crops grown in the area consisted of Boro. Analysis of the images has revealed that alternation of cropping pattern is the only noticeable instance of land use change during the analysis period. The gradual shift to high yielding varieties of crops could lead to more intensive use of chemical fertilizers and pesticides negatively impacting the aquatic habitat of the beel area. Further eutrophication studies may be conducted to highlight the changes in the quality of surface water of the area. Loss of fisheries resources could also adversely impact the livelihood of the beel dependent people. Cognizance of these impacts is essential in planning sustainable land use change of Arial Beel area with due consideration for bio-diversity and socio-economic characteristics of the wetland.

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