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Monitoring Land-use Changes by Remote Sensing and GIS Techniques: Case Study of Barind Tract, Bangladesh

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ABSTRACT : The Barind tract is threatened by desertification and undergoing rapid change. In view of this fact it is very much essential to manage this barind tract under proper land-use plan. The present study evaluates the effectiveness of high-resolution satellite data and computer aided GIS techniques in assessing land-use change detection for the period 1990 to 2007 within the study area, which is very much essential to manage this barind tract under proper land-use plan, and for proper land-use plan it is necessary to get reliable information. The present study found five major land-use such as current fallow, current agriculture, settlement, irrigation water and water bodies. From the result, it is found that current fallow and water bodies decrease while settlement and current agriculture increase. Study concludes that as Barind tract is threatened by desertification, decrease of water bodies is not a good sign for the study area.

Keywords : Land-use, Remote sensing, Geographical information system, Barind tract, Nandigram upazila, Bangladesh

INTRODUCTION

Land-use is obviously constrained by environmental factors such as soil characteristics, climate, topography, and vegetation. But it also reflects the importance of land as a key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchments and storage. Land is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled with economic growth. Often improper land-use is causing various forms of environmental degradation (Chaurasia *et al*., 1996; Lopez *et al*., 2001). Both human-induced and natural land-use changes can influence the global change because of its influence and interaction with terrestrial ecosystem (Houghton, 1994; Muttitanon and Tripathi, 2005), biodiversity (Sala *et al*., 2000), soil structure (Filgueira *et al*., 1999), soil erosion (Weng, 2001). It can also decrease biological activity of soil, the water storage capacity, soil organic carbon and nutrients (Lobe *et al*., 2001; Zalibekov, 2002; Su *et al*., 2004; Reid *et al*., 2000; Garcia *et al*., 1994; Masciandaro *et al*., 1998; Caravaca *et al*., 2002). Improper land-use can accelerate 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). For sustainable utilization of the land ecosystems, it is essential to know the natural characteristics, extent and location; it's (land) quality, productivity, suitability and limitations of various land uses. Land-use is a product of interactions between a society's cultural background, state, and its physical needs on the one hand, and the natural potential of land on the other (Balak and Kolarkar, 1993). In order to improve the economic condition of the area without further deteriorating the bio environment, every bit of the available land has to be used in the most rational way. This requires the present and the past land-use data of the area (Chaurasia *et al*., 1996).

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In recent years, land-use studies using remote sensing and GIS data have been received immense attention worldwide due to their importance in global change analysis (Cihlar, 2000; Alig *et al*., 2004). Therefore, accurate and up-to-date land-use information is essential for environmental planning and to achieve sustainable development (Alphan, 2003). Furthermore, timely and reliable data on land-use may facilitate the formation of integrated resource management policies (Dong *et al*., 1997). Application of remotely sensed data made possible to study the changes in land cover in less time, at low cost and with better accuracy (Kachhwaha, 1985) in association with GIS that provide suitable platform for data analysis, update and retrieval (Star *et al*., 1997; Chilar, 2000). 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). In Bangladesh a few studies (Islam and Quadir, 1988; Quadir *et al*., 1998; Islam *et al*., 2006; Hossain, 2005) on land-use change have been conducted. Though Bangladesh is predominantly a riverine country, northwestern region (mainly the barind tract) is threatened by desertification (Zuberi, 1998). It is very much essential to manage this barind tract under proper land-use plan and for proper land-use plan it is necessary to get reliable information. To prepare effective land-use plans it is necessary to monitor and mapping the land-use pattern and changing scenario of land-use of that particular area. Mapping, monitoring and land-use change analysis by field investigation is costly and very time consuming. Here, application of remote sensing (RS) and geographical information system (GIS) will be able to help in creating information system for judicious land-use planning and will, also help in national development policy. Considering this demand and urgency, the present study was conducted in Nandigram upazila in Barind tract to investigate the land-use change over a period of 17 years using RS and GIS, which will be helpful in creating dynamic information system for land use planning and also in developing national development policy

DESCRIPTION OF THE STUDY AREA

The study site

The study site, Nandigram upazila of Bogra district, was selected deliberately considering the availability of the satellite imageries, topo maps, and other secondary information. Fig. 1 shows the location of the study area. The Nandigram Upazila with an area of 26,861.96 ha is

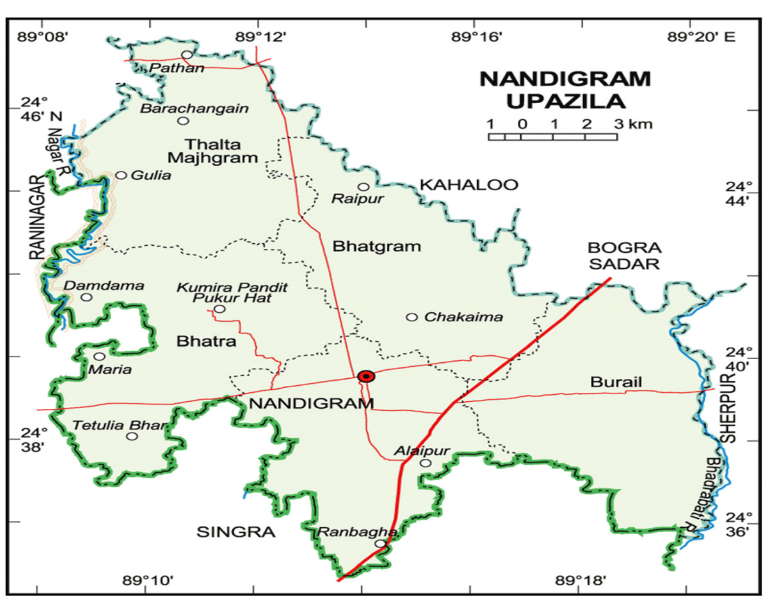

Fig. 1. Location of the Nandigram upazila

bounded by Bogra district and Kahalo Upazila on the north, Singra Upazila on the south, sherpur (Bogra) Upazila at the east, and Adamdighi, Raninagar and Singra Upazila at the west. Main rivers are Nagar and Bhadrabati (SRDI, 1995). Geographical location is 24°34' - 24°48'N and 89° 08' - 89°21'E. The Nandigram upazila is located 32 km from Bogra sadar. Nandigram upazila has 5 unions and 235 mouja (SRDI, 1995). According to population census 2001, total population of Nandigram is 1,68,520 with literacy rate of 29.1% (BBS, 2004). Main occupations includes: agriculture (62.61%), agricultural laborers (24.16%), wage laborers (1.06%), businessmen (5.20%), service holders (2.08%), and others (4.89%). Land-use single crop 40%, double crop 37%, and treble crop 23%. Arable land under irrigation 73% (Alam, 2004). Total area of settlement of this area is 1,298 ha which is 4.9% of the total area (SRDI, 1995). Main crops Boro, Aman and Aus paddy, wheat, mustard, potato, chilly, vegetables, pulses, etc. The climate of the upazila is in general warm and humid but the weather is very cool during winter which is 3.9°C in February and very hot during summer season. The temperature varies on an average from minimum 18.9°C in December and January to 43.9°C in April and May. The annual average rainfall is 1540 mm approximately, with maximum rainfall during June to October (SRDI, 1995).

Methods

Materials used

1) Satellite imagery:

A) Landsat TM FCC January 1990 (Band 5,3,4)

B) Landsat TM FCC January 2007 (Band 5,3,4)

2) Ancillary data comprised of Upazila map and topographic map (scale 1:50,000)

3) PC Based ERDAS IMAGINE software (8.7) was used to analyze land-use change.

Creation of GIS data base

The boundaries were digitized from topographic map sheets covering the study area. The imagery interpretations were digitized and all the coverage's were transferred into the real world coordinate system (Lambert conic conformal system, Everest projection). The polygon topologies were built for all the above coverage's.

Preprocessing of the satellite data

Geometric correction is necessary for image registration and also for extracting the study area. To make the images workable the data needed to be transformed to a uniform ground co-ordinate system of a chosen map projection. One of the images LANDSAT TM image-1997 was geometrically corrected to BTM (Bangladesh transverse Macerator) projection. The other LANDSAT TM image-1990 and LANDSAT TM image-2007 was corrected with references to this image. The ERDAS IMAGINE software was used for geometric correction. With the help of Upazila and topo maps (Scale 1: 50 000) and the reference image a good number of Ground Control Points (GCPs) were selected like Pond, road-river crossing etc. and the corresponding points were selected in the Source images. At least 11 GCPs were taken in Polynomial order 2.

Visual image interpretation

Interpretation deals with the examination of photographic images for the purpose of identifying objects and deducing their significance. Comparison of these images gave the change in the land-use over the period in different study

Table 1. Interpretation key of different land-use class

Feature ID	Feature	Sign in the image
1	Current fallow	Light red
2	Current agriculture	Light green
3	Settlement	Light green with coarse texture
4	Irrigation water	Dark blue or very light blue
5	Water bodies	Light blue or black

site. FCC (False color composite) image of LANDSAT TM- 1990 and 2007 were used for visual interpretation. The visual interpretation of land-use is mainly done by image characteristics. With the help of visual interpretation an interpretation key was developed (Table 1). Interpretation was 23 done using imagine with the help of available maps and field visits.

Area measurement and Change analysis

From the IMAGINE attribute table areas from all the maps were calculated. The area obtained from the literature Nandigram Upazila, Bogra district of the study site was compared with the area obtained from the Landsat TM imagery of the year 1990 and 2007. Then different land-use change was analyzed.

Results and Discussions

The Fig. (2 and 3) are the geometrically corrected images of the study site presented in Lambert conic conformal system, Everest Projection. From the geometrically corrected images the maps were prepared (Fig. 4 and 5). Major land-uses of Nandigram Upazila are current fallow, settlement, current agriculture, irrigation water and water bodies. After measuring the area, the areas obtained from the image are matched with the area obtained from the literatures. The amount of error was 0.03% as measured. From the LANDSAT TM image of 1990 and 2007 of Nandigram upazila, calculated area is 26,855.16 ha which is a little bit deviated from the area obtained from literature (BBS, 2006) as 26861.96 ha. The areas of different maps were computed from the vector attribute table of the imagine. Results obtained from LANDSAT imageries of

Table 2. Area measured (in ha) from LANDSAT imageries of Nandigram upazila

Year	Current fallow (ha)	Current agriculture (ha)	Settlement (ha)	Irrigation water (ha)	Water bodies (ha)	Total (ha)
1990	17653.68 (65.73%)	2294.43 (8.54%)	5065.71 (18.86%)	1532.64 (5.7%)	308.7 (1.14%)	26855.16
2007	4628.26 (17%)	14237.4 (54%)	6843.71 (25%)	863.42 (3%)	282.36 (1%)	26855.15

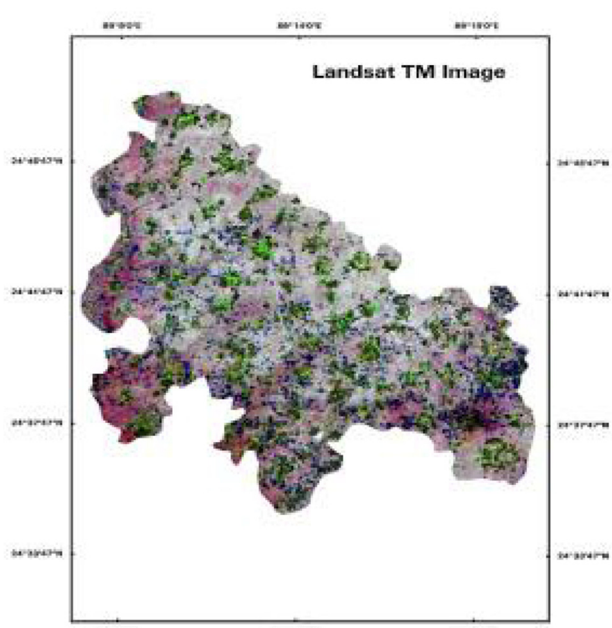

Fig. 2. LANDSAT TM image of Nandigram upazila of 1990

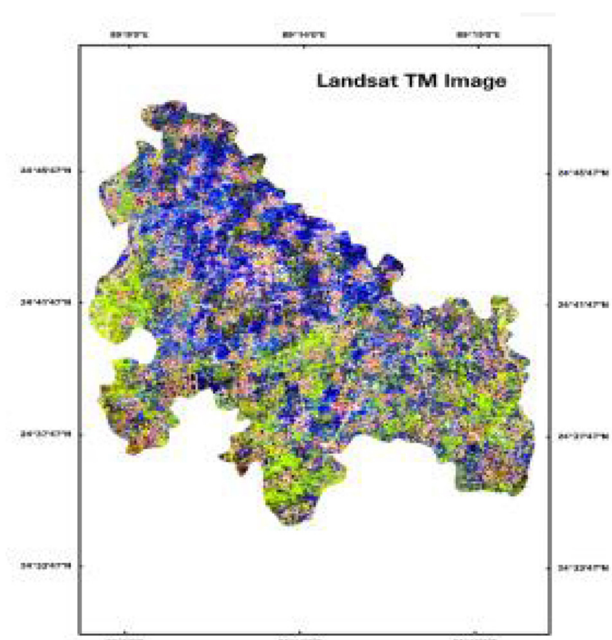

Fig. 3. LANDSAT TM image of Nandigram upazila of 2007

Nandigram Upazila is given below (Table 2)

The dominant land-use categories in 1990 were current fallow, which occupied 65.73% of the study area but in 2007, total area of current fallow is 17% of the total land use. That means the area of current fallow decrease. A reduction rate of water bodies is observed in Nandigram upazila. Water bodies occupied 1.14% in 1990 but in 2007 total area of water bodies found 282.36 ha, which is only 1% of the total area. It is because of extreme settlement pressure and navigability reduction of river. In 1990, settlement occupied 18.86% of the total Nandigram upazila while in 2007 it was found 25% of the total land, which shows the increasing rate. This is because of population growth.

Land covered by irrigation water showed a significant reduction. In 1990, irrigation water was 1532.64 ha which is 5.7% of the total area and in 2007 it was found 863.42 ha, which is 3% of the total Nandigram Upazila. In 1990 current agriculture covering 2294.43 ha (8.54%) and in 2007, it occupied 14237.4 ha (54%) of the total Nandigram Upazila. It shows an increasing rate.

From the above result it is found that water bodies decrease while settlement and current agriculture increase. In short the most common variable explaining the changes in land use in Nondigram upazila is population growth. Another thing is that agriculture of Nandigram Upazila is mainly dependent on irrigation water. According to 1990 census, about 19713 ha agricultural land is under irrigation system (SRDI, 1995; Alam, 2004). So irrigation water is an important part of land use of Nondigram upazila that we found in Nandigram upazila. According to SRDI (1995) report total area of settlement is 1298 ha. But in 2007, total area of settlement in Nandigram upazila is 6843.71 ha which shows an increasing rate. Study shows that current agriculture practice increase. During Rabi season, Boro is the main crop in that area and significant amount of land left as fallow due to deficient or limited rainfall (SRDI, 1995). Present study also shows similar scenario. In the study LANDSAT image that is used for analyzing 1990's land-use was an image of January (Rabi season) and total area of current fallow found 17653.68 ha which is 65.73% of the total land-use. Another reason is during that time people were not so conscious about how to use fallow land. But in 2007 current fallow land was only 17% of total land use. This is because now people are more conscious about different types of agricu-

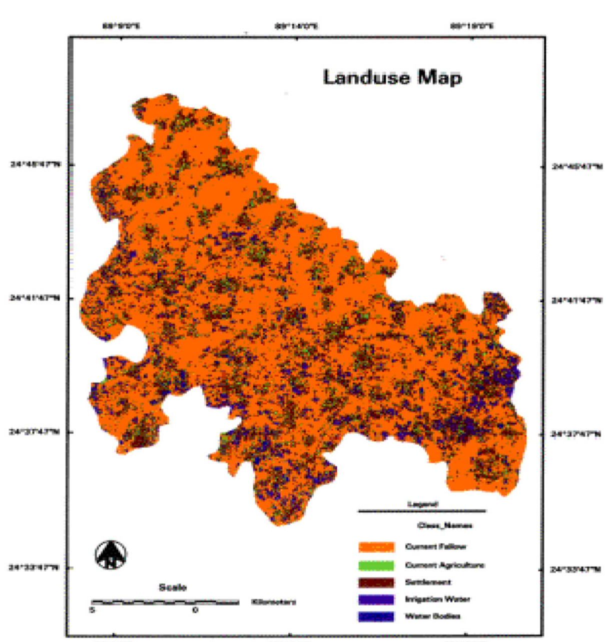

Fig. 4. Classified image of Nandigram upazila of 1990

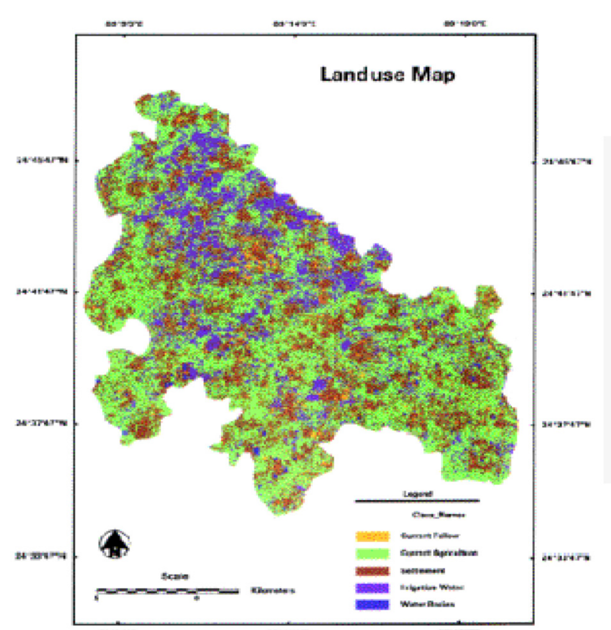

Fig. 5. Classified image of Nandigram upazila of 2007

ltural practice and for this reason they practice different agricrops in the fallow land which is suitable with less water.

CONCLUSION

The study has revealed that satellite data has the unique capability to detect the changes in land-use quickly and accurately. From the analysis it has been found that the satellite data is very useful and effective for getting the results of temporal changes, with this effective data it has been found that settlement, current agriculture, current fallow, irrigation water and water bodies are the major land-uses of Nandigram upazila. As the study area is threatened by desertification and water bodies also decrease, this study might be helpful to prepare an effective land-use plan for Nandigram upazila for combating desertification.

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