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Change Detection of Winter Crop Coverage and the use of LANDSAT Data with GIS

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Abstract: The remote sensing technology in combination with geographic information system (GIS) can render reliable information on land use change detection. The analysis of the spatial extent and temporal change of cropland using remotely sensed data is of critical importance to agricultural sciences. This study described a method of using reflectance factor of multi-sensor data for identification and detection of change of the winter crop cultivated land. For this study the LANDSAT images (MSS, TM and ETM+) of Durgapur Upazila/Thana during winter season were acquired of 02 Feb., 1977, 11 Nov., 1998 and 17 Nov., 2000. For the recognition of feature from the images, supervised classification was followed. The images were classified into four significant land uses/land covers type viz. cropped area, current fallow (agricultural) land, water bodies and marshy land. These classification types were identified based on the land use classification scheme level-1. For generating the winter crop cultivated area map, pixels of winter crop area were extracted from the classified image of each date. Afterwards, winter cultivated area map of 1977 and 1998, 1989 and 2000 were crossed (overlay) to generate the map of winter crop change coverage for the respective date and to find out the changing pattern of winter crop cultivated area. Moreover map of cropped area and map of union boundary were crossed to calculate the area of union-wise winter crop coverage of different time period. The study reveals that the area under winter crop was changed significantly during 1977 to 2000. The study also identified that a large area of current fallow land comes under winter crop cultivation during 1977 to 2000 which is indicative of the expansion of agricultural scenarios in the study area.

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1. Introduction

Cropland has a close relationship to food production and appears to have a profound effect on the agricultural development. Therefore, understanding the changing pattern of cropland area has long been a major focus of research in agricultural science. Space-born remote sensing has a good potential for change detection and good data availability and is therefore, well suited for the monitoring of cropland change over a time period. Satellite images can show larger areas and, as a satellite regularly passes over the same plot of land capturing new data every time, shows a change in the land use and condition can be routinely monitored. In Land Monitor Programme, satellite images are being used to provide information on land condition and the changes in that condition through time, specifically the status of remnant vegetation to help farmers, environmental managers and planners for better management of the land. The effective agricultural mapping and monitoring are required for a variety of applications ranging from general inventory requirements to ecological studies. Remote sensing has shown great potential in agricultural mapping and monitoring due to its advantages over traditional procedures in terms of cost effectiveness and timeliness in the availability of information over larger areas (Murthy et al. 1998). The aim of this study was to incorporate the temporal dependence of multi-temporal image data to identify the changing pattern of winter cropped area and consequently enhance the interpretation capabilities. Moreover integration of multi-sensor and multi-temporal satellite data effectively improves the temporal attribute and the reliability of multi-data. Therefore, this paper discusses methods of the detection of winter cropland utilizing multi-temporal and multi-sensor remotely sensed data.

2. Spatial Extent

The spatial extent of this study is between $24^0 23' 06''$ to $24^0 31' 59''$ N latitude and $88^0 39' 56''$ to $88^0 51' 27''$ E longitude. This area is belonging to Durgapur *Thana/ Upazila* (hereafter *Upazila*) of Rajshahi District. Durgapur *Upazila* covers an area of 197.03 sq km, is bounded by Bagmara and Mohanpur *Upazilas* to the north, Puthia *Upazila* to the south and east and Paba *Upazila* to the west (Fig.-1). It consists of seven *Union Parishad*, 114 *Mauza* and 122 villages. Main crops of the study area are paddy, wheat, potato, brinjal, onion, garlic, betel leaf and mulberry plant. In the study area total cultivable land in the record is 15009.78 hectares. The area under double crop occupies 31% and triple crop 19% of the agricultural land. About 35% of the cultivable land is under irrigation (BBS, 2002). Temperature and rainfall in the winter season is shown in Table-1 and it is depicted that in winter insignificant amount of rain occurs which is supposed to be the main cause of dryness in the study area in winter.

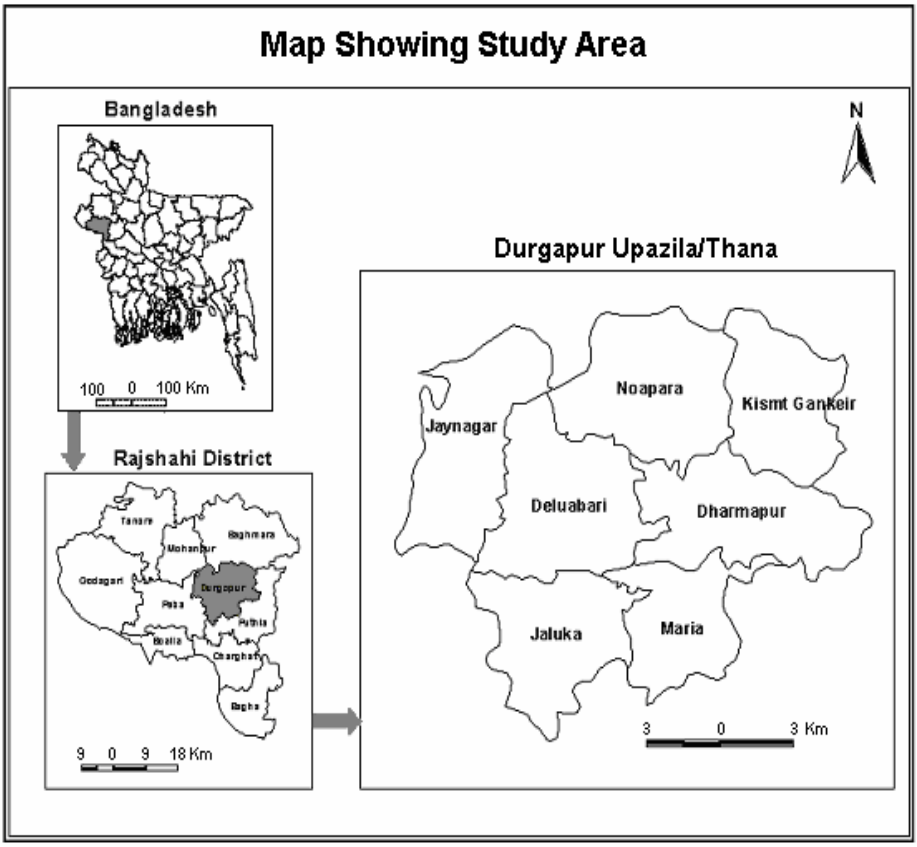

Fig.-1

3. Objectives

The main objectives of this study are as follows:

1) to identify the winter crop cultivated area and its spatial distribution in the study area using remotely sensed data.
2) to analyze the pattern of spatio-temporal change of the winter crop during the study period.

4. Materials

In this study geocoded LANDSAT imagery of different sensors were used. The main feature of LANDSAT data are as follows:

1) LANDSAT MSS:
   Bands: 3, 2, 1 (NIR, R. G)
   Data of acquisition: Feb. 09, 1977
   Saptial resolution: 80m

2) LANDSAT TM:
Bands: 4, 3, 2 (NIR, R. G)
Data of acquisition: Nov. 11, 1989
Saptial resolution: 30m

3) LANDSAT ETM+:
Bands: 4, 3, 2, (NIR, R. G)
Data acquisition: Nov. 17, 2000
Saptial resolution: 30m

The base map was initially prepared from the digital *Upazila* map of BARC (Bangladesh Agricultural Research Council) and was used for the purpose of the study. Union boundary was superimposed on to the *Upazila* map (Statistical Year Book of Bangladesh, *Mauza* Series). Some secondary data related to the study were also collected from the published reports such as Statistical Year Book of Bangladesh, Census of Population and the Statistical Year Book of Agriculture etc.

5. Methods

The overall methodology for this study is presented in Fig-2. However, the details are as follows:

PC based image-processing package ERDAS Imagine version 8.6 and ILWIS version 3.2 were used for the processing, analysis and integration of spatial data to reach the objectives of the present study. The imageries of LANDSAT were geocoded. After importing into ERDAS imagine environment, those were first resampled according to the sensor pixel size i.e. 80m for MSS and 30m for TM and ETM+ data. For features recognition from the different time period images, supervised classification technique was used. Three bands i.e. near infrared, red and green band of LANDSAT data were used to generate the false colour composite (FCC). Using the digital map of Durgapur *Upazila*, study area was extracted from the FCC. In the procedure of supervised classification, training sites were chosen for each of the land use classes in the sample set according to the land use classification level-1 (Lillesand and Kiefer, 2002). For choosing the training sample of each land use types, ground truth information was incorporated and finally maximum likelihood classifier was used for classification of the image. For calculating the cropped area of different time period, the pertinent area pixels were extracted (reclassed) from the classified image. Later on, to identify the *Union* wise cropped area, the cropped area map was crossed (overlay) with *Union* boundary map in ILWIS environment. To find out the changing pattern of winter crop during 1977-89, 1989-2000 and 1977-2000, cropped area map of corresponding years were crossed (overlay) and

analysed. On the other hand, for NDVI prediction over cropped area, first NDVI image was generated for each of the three dates using following equation:

NDVI = (NIR-R) / (NIR+R)

Where, NDVI =Normalized Difference Vegetation Index
NIR = Near Infra-red Band
R = Red Band

Later on, cropped area map was extracted from the classified image, using a 'mask' over NDVI image to identify the NDVI value over the cropland. The areas under crop cultivation in the *Unions* were obtained by overlay (crossed) operation of *Union* boundary map and cropped area map. Then the change detection of cropland was computed from the attribute table and presented in the output map.

Flow Chart showing Methodology of the Study

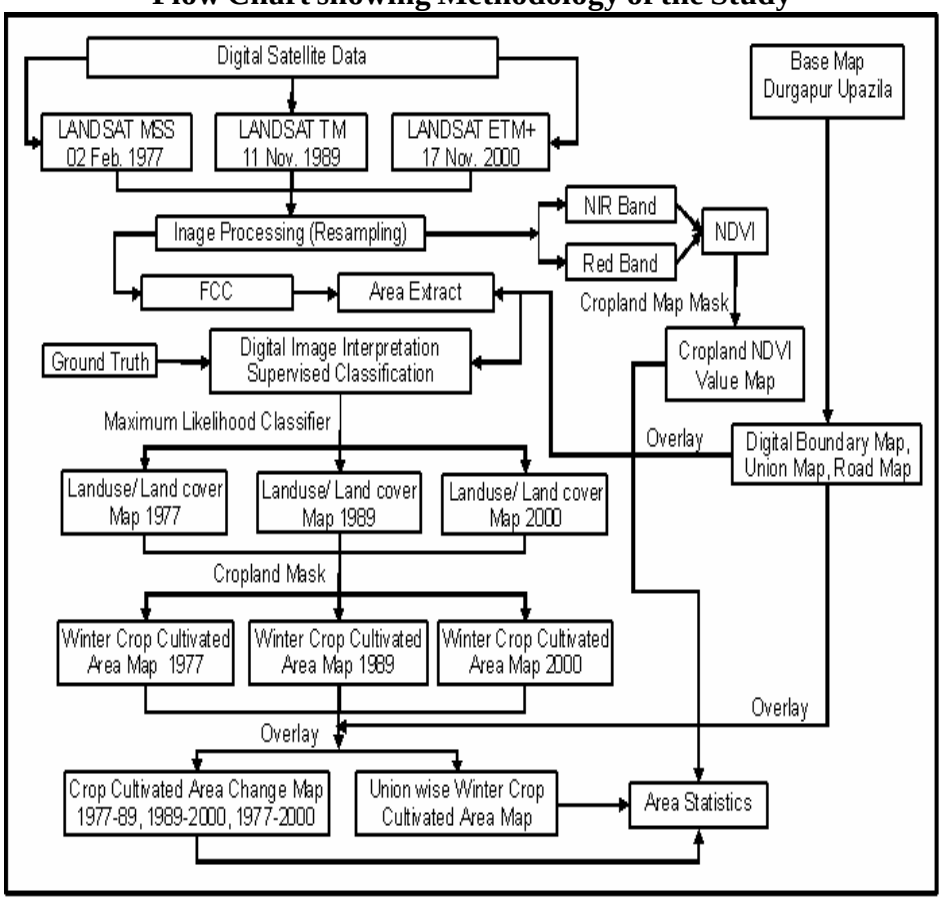

Fig.-2

6. Analysis

It had been mentioned earlier that detection of the change of area under winter crop cultivation was the main objective of this study. The temporal change detection, both spatial and quantitative, was accomplished with the help of GIS map manipulation functions as they provide a greater freedom for map handling. Table-2 shows the spatial extent of different land uses/land covers in the study area. The table reflected that area under winter crop was only 13.10% of the total study area in 1977, which increased to 17.37% in 1989, and further 23.85% in the year 2000. On the other hand, Table-3 depicted that area under winter crop was 16.92% of the total agricultural land in 1977, which increased to 22.28% and 31.82% in 1989 and 2000 respectively. Figure- 3 shows the spatial extent of winter cropped area in different time period. Table-4 shows *Union* wise distribution of area under winter crop cultivation and depicted that cultivation of winter crops was increased from the year 1977 to 2000 remarkably in all the *Unions* except Jaynagar Union (Fig-4). From the Table-3 and Figure- 3, it may be mentioned that though the area under winter crop increased from 1977 to 2000, but it covered only about 32% of the total agricultural land of the study area. So, about 68% of the total agricultural land was beyond the cultivation in winter season in the area. It was mainly because of less irrigation facilities and insufficient rainfall in winter season in the area (Table-5 and Table-1). Moreover, regression analysis shows a highly positive relationship between irrigated area (independent variable) and winter cropped area (dependent variable) and also for population (independent variable) and winter cropped area (dependent variable, Fig.-5, based on Table-5). So, it may be said that the area under winter crop cultivation mainly increased due to the increase of irrigation in winter season and also for population pressure in the area.

Table-1: Average maximum & minimum temperature and rainfall in winter season'2000

Name of Month	Temperature in Deg. Celsius		Rainfall (mm)
	Maximum	Minimum	
November	32.8	13.4	5
December	27.9	7.8	0
January	29.3	5.3	6
February	34	10.2	15

Source- Statistical Year Book of Bangladesh, 2001, BBS, 2003

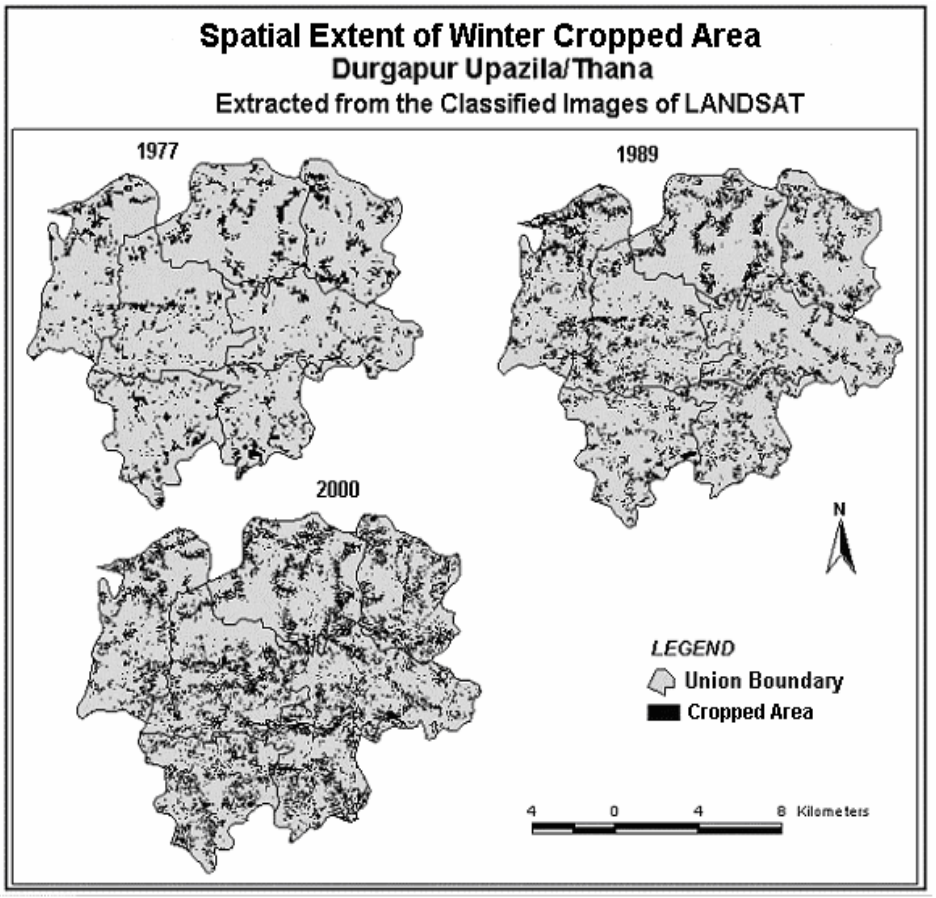

Fig.-3

Union-wise changing pattern of winter cropped area

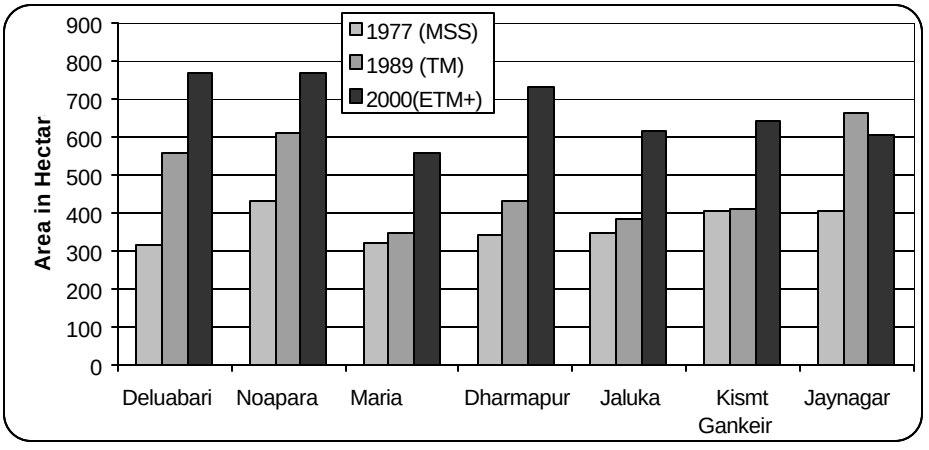

Fig.-4

In this study an attempt was also made to find out the NDVI value over the area under winter crop cultivation. NDVI is an excellent and widely used method of crops growth and condition assessment (Rahman, Islam and Rahman, 2004). For this study NDVI value was extracted over cropped area and shown in Table-6. The table depicted that NDVI value ranges from 0.17-0.57, 0.24-0.59 and 0.10-0.57 in the year 1977, 1989 and 2000 respectively. So it may be said that overall there was no change in the NDVI value of winter crop during 1977 to 2000 but it shows an overall goodness of the crops in winter season.

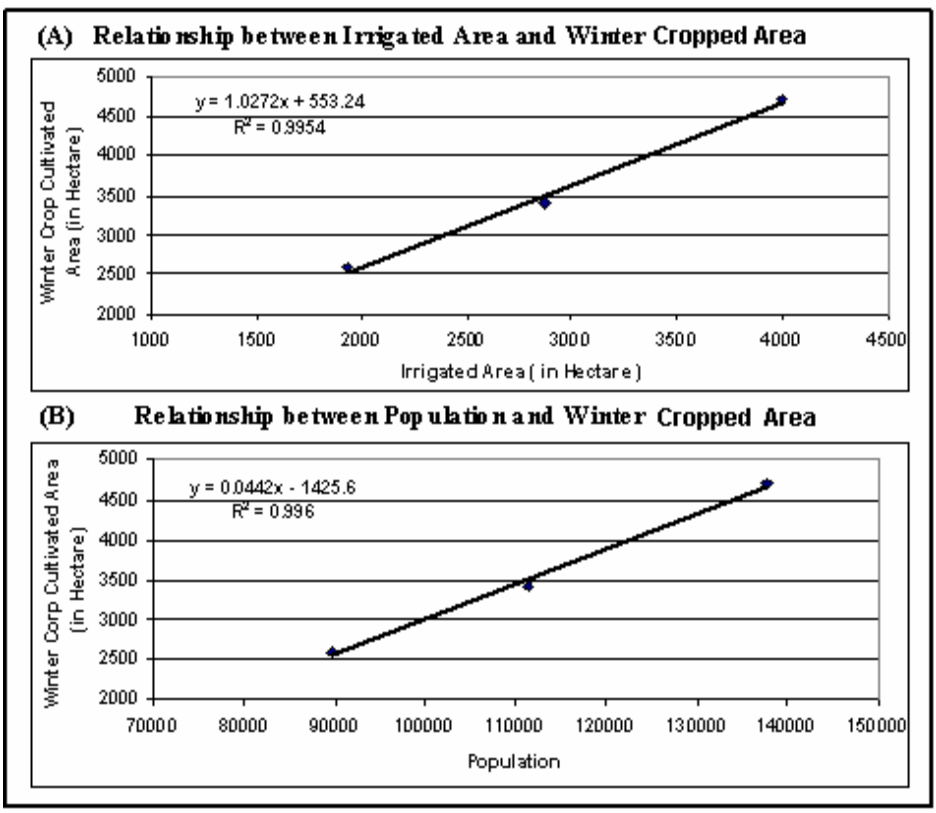

Fig.-5

On the other hand, Table-7 depicted that the changing pattern of winter cropped area during 1977-89, 1989-2000 and 1977-2000. It was clear from this table that during the year 1977 to 1989, about 1038 hectares of area under winter crop cultivation was unchanged i.e. remains under cultivation. But it was interesting to note that about 1544 hectares of area under winter crop cultivation was found changed to current fallow (no cultivation in winter) land whereas about 2385 hectares of current fallow land comes under winter crop cultivation from 1977 to 1989. If we see the changing pattern of winter cropped area from 1989-2000, it was found that about 1789 hectares of cultivated area was found

unchanged. Whereas about 1635 hectares of cultivated area was changed to current fallow land and about 2911 hectares of area under current fallow was changed to area under winter crop cultivation. Moreover, Table-7 depicted that about 1161 hectares area of winter crop cultivation was unchanged from 1977 to 2000. Whereas about 1421 hectares of area under winter crop was changed to current fallow land and about 3538 hectares of area under current fallow land was changed to area under winter crop cultivation during1977 to 2000. So from the Table-7 it may be said that during the year 1977 to 2000 a large area of current fallow land was changed to area under winter crop cultivation that highlighted the expansion of agricultural scenarios of the study area. Figure-6 showing the spatial pattern of change in winter cropped area during 1977-1989, 1989-2000 and 1977-2000.

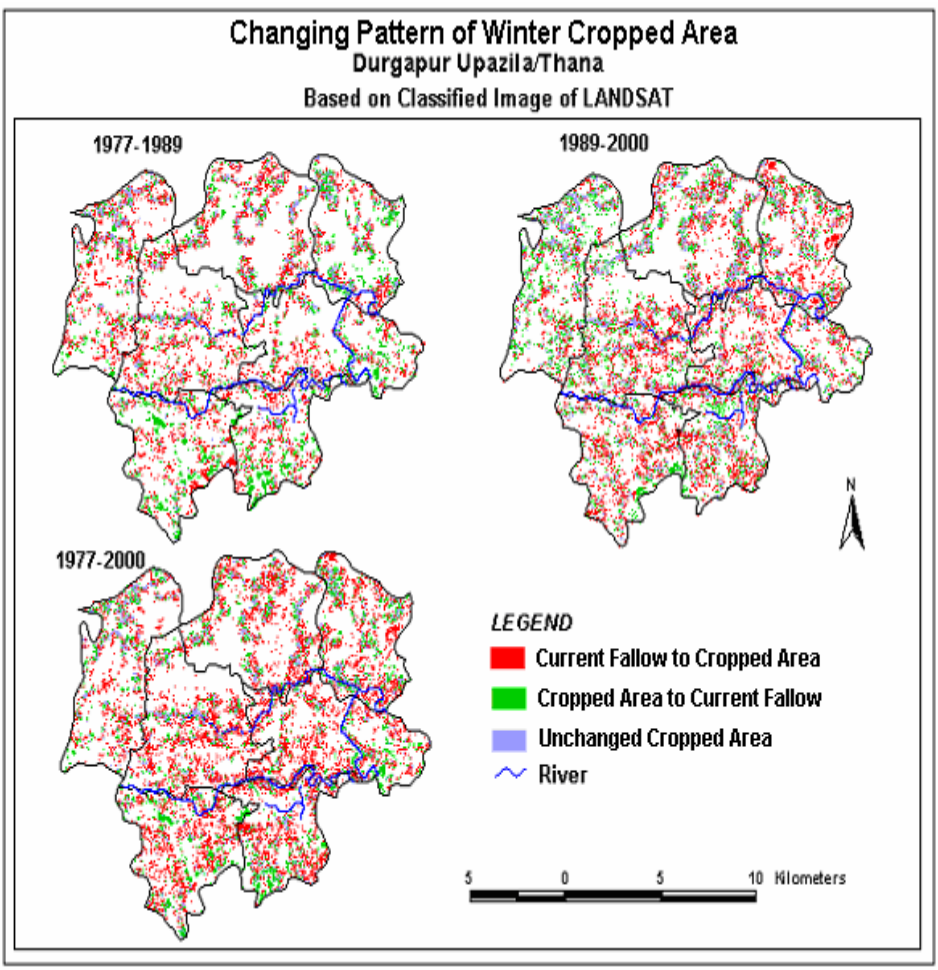

Fig.-6

Table-2: Spatial extent of land use/land cover according to supervised classification of LANDSAT data

(Area in hectare)

Landuse/ Land Cover types	1977 (MSS)	% of the total Area	1989 (TM)	% of the total Cropped Area	2000 ETM+	% of the total Cropped Area
Crop land	2582.00	13.10	3423.78	17.37	4699.80	23.85
Current Fallow land	12784.50	64.88	12000.78	60.89	10116.27	51.34
Marshy land	4061.34	20.61	2487.51	12.62	4046.67	20.54
Water Bodies	276.16	1.40	1797.21	9.12	841.95	4.27
Total	19704.00	100.00	19704.00	99.97	19704.00	100.00

Table-3: Area under winter crop cultivation -extract from the classified images of LANDSAT data.

(Area in hectare)

Year	Cropland	Total Agricultural Land	% of the total Agricultural land
1977 (MSS)	2582.00	15387.75	16.92
1989 (TM)	3423.78	15440.58	22.28
2000 (ETM+)	4699.80	14836.68	31.82

Table-4: Changing pattern of winter crops area based on classified images of LANDSAT data

(Area in hectare)

Union Name	1977 (MSS)	1989 (TM)	2000(ETM+)
Deluabari	315.27	560.34	769.86
Noapara	435.06	612.54	769.41
Maria	323.01	351.36	562.14
Dharmapur	344.88	434.7	733.14
Jaluka	347.58	385.83	617.22
Kismt Gankeir	405.54	412.29	641.52
Jaynagar	405.54	666.72	606.51
Total	2582.00	3423.78	4699.80

Table-5: Area under irrigation and winter cultivation along with population

(Area in hectare)

Year	Irrigated Area	Winter Crop Cultivated Area	Population
1977	1931.04 (12.55%)	2582.00 (16.92%)	89677
1989	2875.50 (18.69%)	3423.78 (22.28%)	111427
2000	3999.80 (25.99%)	4699.80 (31.82%)	137740

N.B.- Value in parenthesis shows % of the total Agricultural Land

Source: i) Upazila Statistics (1979-80 to 1982-83), Vol-One, Basic Statistics, Land Utilization and Irrigation, BBS, 1985,
ii)Thana Statistics, Vol-1, Basic Information, Land Utilization & Irrigation (1974-75 to 1978-79), BBS, 1981 and
iii) based on Table-3 (winter crop cultivated area).

Table-6: NDVI value over winter cultivated area based on LANDSAT data

	NDVI Value for crops area	
	Min.	Max.
2000 (ETM+)	0.17	0.57
1989 (TM)	0.24	0.59
1977 (MSS)	0.1	0.57

Table-7: Changing nature of winter cropped area based on LANDSAT data

(Area in hectare)

Nature of Change	1977-1989	1989-2000	1977-2000
Unchanged Crop Cultivated Area	1038.15	1789.02	1161.36
Crop Cultivated Area to Current Fallow	1543.86	1634.76	1420.65
Current Fallow to Crop Cultivated Area	2385.63	2910.78	3538.44

7. Conclusion

Crop acreage estimation and change detection of area under crop based on remote sensing was developed and tested for large areas in several countries in the world. Appraisal of the resources and obtaining timely and accurate knowledge of the resources is very essential to plan an optimal resource management strategy for a country's development. Geographic information system with a remote sensing component is the ideal tool for integrating the basic information sources such as maps, imagery and statistical data for effective resources management. (Goodenough, 1988). In this study LANDSAT images were used satisfactorily for winter cropped area identification and change detection over specific time period. Medium spatial resolution (30m) data like LANDSAT, TM and ETM+ can be used for monitoring cropped area dynamically. The resolution of LANDSAT MSS (80m) is not high enough for cropped area identification in small area like Durgapur *Upazila*. In the earlier stage of satellite data, there was limitation of high-resolution data availability. So it may be considered a limitation that high-resolution data availability for that time was absent. However, the study indicated the right use of LANDSAT data and integration of GIS for monitoring the cultivated area under winter crop and its change detection over a time period. In this study effort was made to highlight on the changing pattern of cultivated area under winter crop using LANDSAT multi-sensor data. It was observed that the area under winter crop changed remarkably during 1977-2000 (about 32% of the total agricultural land). Increase of winter crop area means the increase of area under irrigation in winter season and it effect directly to the increase of cropping intensity in the area. So this study indicates the development situation of agriculture in the study area in a particular, it also highlights that about 68% of the total agricultural land was beyond the cultivation in winter season and remains fallow. Thus for better management and overall agricultural development in the study area, winter crop area should be increased at a satisfactory level through different mode of irrigation. In conclusion it may be said that for the current study on detecting the changing pattern of cultivated area under winter crop in a span of 23 years both spatial and in quantitative way, integration of remote sensing data with GIS was found extremely useful.

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