Spatial Dynamics of Cropland and Cropping Pattern Change Analysis Using Landsat TM and IRS P6 LISS III Satellite Images with GIS

Md. Rejaur Rahman  S. K. Saha

Abstract  The study of the spatial patterns and temporal changes of cropland is important to understand the underlying factors and the functional effects of the agricultural landscape. On the other hand, crop dynamics mapping is essential to know the overall agro-spatial diversity of the area. Therefore, this paper addressed a spatio-temporal analysis of cropland and cropping pattern change in the Bogra district of Bangladesh over the last 16 years (between 1988/89 and 2004/05). In this paper, crop mapping from multi-temporal and multi-sensor satellite images was described. Landsat TM and IRS P6 LISS III satellite images were used with GIS for spatial dynamics of cropland and cropping pattern change analysis. First, seasonal cropland maps were derived from object-based classification of satellite images, then two-date classified image differencing with GIS overlay technique and decision rules were applied. Cropping pattern change was analyzed in a spatial and quantitative way for the 16 years and for this, Integrated Land and Water Information System (ILWIS) and Land Change Modular (LCM) of IDRISI Andes were used. The results showed that in the area, mono crop cultivation was found in summer, but in winter, areas under different crop cultivation had changed dramatically. Change analysis showed that the changes mainly occurred in the north northwest and southwest of the areas, and during the time the highest change area was found under the rice-potato pattern.

Keywords  cropland dynamics; gain and loss of cropland; spatial trend; cropping pattern change; Landsat TM and IRS P6 LISS III; GIS

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Introduction

Remote sensing and geographical information systems (GIS) are providing important tools for advanced ecosystem management. For the sustainable utilization of the land ecosystems, it is essential to know the natural characteristics, extent and location, quality, productivity, suitability and limitations of various land uses. The analysis of the spatial extent and temporal change of cropland and cropping pattern using remotely sensed data is of critical importance to agricultural sciences. 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. On the other hand, GIS technology can play a vital role in cropping system analysis of an area by spa-
tially integrating temporal crop inventory information of various crop seasons of that area.

The developments in GIS and remote sensing technologies and crop modeling have created promising opportunities for improving agricultural statistics systems[1-8]. The crop acreage estimation and change detection by using remote sensing was developed and tested for large areas in several countries[9-15]. In recent years, satellite technology has become extremely important due to its synoptic, repeated collection of data and multi-sensor data availability, which provides a cost-effective, reliable and critical mechanism for cropland mapping and change analysis[11,16]. In the literatures, a few examples of these applications can be found[17-21]. However, these studies either highlighted crop mapping for the agricultural statistics or cropping pattern/crop rotation identification by using different methods. Crop acreage estimation, gain and loss of cropland, exchanges of cropland, spatial trend of changes of cropland, cropping pattern identification and changes are essential to know the overall agro-environment and agro-spatial diversity of the area, which helps the planners and policy makers to assess the potential use of agricultural land, suitability analysis of crops and future cropping pattern planning of the area. Thus, this study was an attempt to analyze the crop dynamics from multi-temporal and multi-sensor satellite images using object-based classification of satellite data, and on the other hand, to identify the cropping pattern by using crop maps. Moreover, this study was also initiated to analyze the cropping pattern change in a spatial and quantitative way using two-date classified image differencing method with GIS and decision rules for better understanding of the crop environment of the area. Thus, the specific objectives of this study were: (1) to find out the seasonal (summer and winter) land use/land cover of the study area using Landsat TM and IRS P6 LISS III satellite images with object-based classification for the year 1988/89 and 2004/05, (2) to analyze the spatial dynamics of cropland, and gain and loss of the summer and winter cropland, (3) to find out the exchanges and spatial trend of changes between crops/cropland, and (4) to analyze the major cropping pattern/system and their changes between 1988/89 and 2004/05.

1 Study area

The study was conducted in the Bogra District which lies in the Rajshahi Division of Bangladesh. This area is about 2 911.90 km² and located between 24°32'30" and 25°06'34" N latitude and 88°57'50" and 89°44'00" E longitude. It is bounded by the Gaibandha and Joypurhat districts in the north, Nator and Sirajganj districts in the south, Tangail in the east and Naogaon district in the west[22]. It consists of 11 upazilas/thanas (third order administrative units from the lower level) namely Shibganj, Sonatola, Sariakandi, Gabtali, Bogra Sadar, Dhupchanchia, Kalahoo, Adamdighi, Dhunat, Nandigram and Sherpur (Fig.1). It is situated in a tropical zone with a monsoonal and periodic thundershower climate. The summer begins from the middle of April and continues until the middle of June. The monsoon (rainy season) commences from the end of June and continues until the middle of October. The winter starts from the middle of November and continues until late February. The annual average minimum and maximum temperatures of the District are 21 °C and 31 °C, respectively. January is the coldest month (average winter low 11.7 °C) and April is the hottest month (average summer high 35.8 °C) in the area. The annual average precipitation is 2 095 mm, of which 70% occurs between May and September. The level of humidity is around 84% in the month of June and 67% in the month of March[22]. On the other hand, flooding in the study area is a common phenomena and it affects the area to a varying extent almost every year. Bogra District has experienced many severe floods that have devastated the area like other parts of Bangladesh in the past[23]. The main crops of the study

Fig.1 Map showing study area
area are rice, potato, mustard, wheat, and mulberry plant. Spatial pattern of agricultural landscape and cropping patterns of the area are influenced by the local climatic condition and natural disasters like flood.

2 Materials and methods

The methods which were followed in this study are shown in Fig.2 and their details are discussed in the following sections.

2.1 Remote sensing data processing and classification for land use/land cover

In this study Landsat TM and IRS P6: LISS III satellite images were used. Landsat TM and IRS-P6 images were acquired for the year 1988/89 (11-11-1988 for summer and 06-01-1989 for winter) and 2004/05 (01-11-2004 for summer and 05-02-2005 for winter), respectively. It may be mentioned here that the flood in the study area is a common phenomena, and therefore, the cultivation (sowing and harvesting) of summer crop mainly depends on the flood situation of the area. That is why, for the summer season, satellite images were acquired for November, and obviously, the unavailability of cloud free optical images before November of the area was another reason to acquire satellite data for November. In this study, to integrate, process and analyze the data, PC-based image processing package ERDAS Imagine, eCognition, IDRISI Andes and ILWIS (Integrated Land and Water Information System) were used. The imageries of Landsat TM were geocoded. Hence, after importing into ERDAS Imagine environment, they were first resampled according to the sensor pixel size (i.e. 30m) with Universal Transverse Mercator (UTM) projection. Afterwards, in the image-to-image registration procedure, IRS P6 LISS III images were geometrically corrected with the valid geocoded Landsat TM image, as referenced image. This method consists of collecting ground control point pairs from a split-screen display of the uncorrected and master image[24]. For IRS P6 images, root mean square (RMS) error was less than a quarter pixel (0.25) in the geometric correction. These images were then resampled by using the nearest neighbour algorithm with affine transformation and 23.5 m pixel size. On the other hand, the district boundary vector layer, which was extracted from the district boundary digital polygon map of Bangladesh (prepared by the Bangladesh Agricultural Research Council, Dhaka) was used. The data obtained by GPS was used as the ground truth information for the classification of the images.

In order to classify the satellite data, an object-oriented digital classification procedure was performed over FCC (false colour composite), which was generated by using NIR, red and green bands of the Landsat TM and IRS P6 LISS III images. In the object-based procedure, the first step of the classification is to identify the image objects. This was achieved by using a multiresolution segmentation approach as implemented in the software package eCognition[25]. During the segmentation process all generated image objects are linked to each other automatically. Therefore, the next step is to classify the segmented image into land use/land cover classes by generating a class hierarchy. The class hierarchy contains all classes of a classification scheme in a hierarchically structured form. After generating a class
hierarchy with inheritance hierarchy, the training sites are selected for each class on the basis of ground information. Then for each class of the classification scheme, a class description (i.e., standard nearest neighbour) is selected to classify the image which consists of a fuzzy expression allowing the evaluation of a specific feature and its logical operation\textsuperscript{[23]}. In this study for summer land use/land cover classification, five classes (viz. rice, current fallow, settlement, channel bar and water bodies) were recognized. On the other hand, six classes (viz. mustard, potato, current fallow, settlement, channel bar and water bodies) were recognized for winter land use/land cover classification. Finally, the accuracy assessment of the classified images was performed by using an error matrix and a Kappa statistics. It was found that for the Landsat TM images (1988/89), the overall accuracies were 90% (Kappa 88%) and 89% (Kappa 87%), respectively. On the other hand, for the IRS P6 images (2004/2005), the overall accuracies for the summer and winter were 92% (Kappa 90%) and 90% (Kappa 87%), respectively. A standard overall accuracy for land use/land cover map is set between 85% and 90\%\textsuperscript{[31]}. Thus, the accuracy is suitable for evaluating the land use/land cover change in this study.

2.2 Cropland dynamics and gain and loss of cropland

The spatial and temporal distribution and changes of cropland were analyzed by extracting cropland from the land use/land cover maps of the study area. For mapping the cropland from land use/land cover map, the pertinent area pixels were reclassed from the classified image in ILWIS (GIS) environment and area statistics were analyzed. On the other hand, in order to analyze the gain and loss of the seasonal cropland between 1988/89 and 2004/05, the summer land use/land cover map of 1988/89 and 2004/05 and winter land use/land cover map of 1988/89 and 2004/05 were overlayed (crossed). For overlaying the specific land use/land cover maps, “cross” operation of ILWIS was used. The cross operation performs an overlay of two raster maps, and the pixels on the same position in both maps are compared. The cross table includes the combinations of input values, classes or IDs, the number of pixels that occur for each combination and the area for each combination. From the cross table, different combinations were analyzed and reclassified as gain and loss of each category, and gain and loss maps were prepared by using ILWIS. In this study, the gain and loss were mainly concentrated to analyze the cropland (rice, mustard and potato) and current fallow land (agricultural land) over the stipulated time periods.

2.3 Exchanges of cropland and spatial trend of changes

The exchanges and spatial trend of the changes of cropland were analyzed by using \textit{Land Change Modular} (LCM) of IDRISI Andes software\textsuperscript{[26]}. The \textit{Map Exchanges} option in LCM was designed for the examination of exchanges between two types of land use/land cover category between two specific time frames. It follows the GIS overlay with reclass function. In contrast, the spatial trend of changes between two croplands was analyzed by using \textit{spatial trend of changes} option in LCM module of IDRISI. The analytical work using this option was achieved by a module called TREND. In the trend analysis, the surface was created by coding areas of change with 1 and areas of no change with 0 and treating them as if they were quantitative values. This was a best fit polynomial trend surface to the pattern of change. In this study, a 3rd-order surface trend (good for a very broad overview) was used to generate a spatial trend map of the changes between two types of cropland.

2.4 Cropping pattern/system mapping and their changes

The pattern of crops or sequence in which the crops are cultivated on a piece of land over a fixed period (ex. one year) defines a cropping pattern, i.e. the cropping pattern is the spatial representation of crops rotation in a year. Thus, the cropping pattern is understood in this paper as the spatial distribution of associations between crops, or crops and current fallow land (agricultural land that is uncultivated for one season of a year) in the same field(s) in a year. This is the same concept which was given by the Food and Agricultural Organization (FAO)\textsuperscript{[27]}. For cropping pattern mapping, the seasonal (summer and winter) cropland/crop maps were overlaid and derived i-
plicit spatial and temporal relationships between the crops grown in the area, i.e. the combination of crops between summer and winter. Here, by using GIS cross-tabulation operation of ILWIS, major cropping pattern maps were prepared for the year of 1988/89 and 2004/05. It may be mentioned that, in order to generalize the number of combination of crops, less than a 5-hectare area of combination of crops, or crop and other categories were not considered for the cropping pattern mapping. This generalization process reduced the number of classes of crop combination which were insignificant on the basis of the area occupied. For cropping pattern change analysis, the cropping pattern map of 1988/89 and 2004/05 were overlaid, analyzed and mapped and the area statistics were tabulated. For the cropping pattern change analysis, the ‘cross’ operation of ILWIS was used.

3 Results and discussion

3.1 Land use/land cover classification

It was mentioned that satellite images were classified by using object-based image classification technique for the land use/land cover mapping. Based on object-based classification technique, land use/land cover statistics are presented in Tables 1 and 2. Table 1 depicts that only rice (aman) was cultivated in the summer season in the area, and rice occupied 57.94% of the total area in 1988/89 and 62.74% in 2004/05, indicating that the area under rice increased by 4.80% of the total area from 1988/89 to 2004/05. The area under current fallow in summer occupied 23.20% and 10.61% of the total area in 1988/89 and 2004/05, respectively. Thus, in summer season the area under current fallow decreased by 12.59% of the total area from 1988/89 to 2004/05. The area increase under rice and decrease under current fallow in summer season were mainly due to the population pressure on land, the increase of rice production because of high yielding varieties (HYVs) and availability of irrigation facilities during the periods. Table 1 further shows that 18%, 0.48% and 6.13% of the total area under settlement, channel bar and water bodies increased from 1988/89 to 2004/05, respectively. The area under water bodies increased mainly due to the floods in the study area. In some areas flood water became stagnant over the time periods[23].

The winter land use/land cover statistics (Table 2) depicted that potato and mustard were the main crops in winter season in the study area and potato occupied 17.25% of the total area in 1988/89 and 26.81% in 2004/05, while the area under mustard was 5.48% and 7.27% of the total area in 1988/89 and 2004/05, respectively. So, the area under potato and mustard increased 9.57% and 1.79% of the total area from 1988/89 to 2004/05, respectively. The areas under potato and mustard increased mainly due to the increase of irrigation facility and demand of the winter crops in the market during the study periods. The land suitability should also have significant impact to increase the area under winter crops during the time[28]. Moreover, Table 2 depicts that more than 60% (61.80%) of the total area was under current fallow in 1988/89 and 48.96% in 2004/05, meaning that the area under current fallow declined 12.84% of the total area in the winter season from 1988/89 to 2004/05. The land use/land cover statistics of winter season further showed that the area under settlement and channel bar increased by 1.25% and 0.33% of the total area from 1988/89 to 2004/05, respectively, whereas the area under water bodies decreased by 0.10% of the total area during the time.

| Land use/land cover                  | 1988/89-Summer | 2004/05-Summer | Deviation (% of the total area) |
|--------------------------------------|---------------|----------------|--------------------------------|
| Rice (aman)                          | 168 726.79    | 182 713.11     | +4.80                          |
| Current fallow                       | 67 559.10     | 30 898.10      | −12.59                         |
| Settlement                           | 22 002.91     | 25 440.19      | +1.18                          |
| Channel bar                          | 7 338.68      | 8 735.91       | +0.48                          |
| Water bodies (river, ponds, etc)     | 25 563.96     | 43 404.13      | +6.13                          |
| Total                                | 291 191.44    | 291 191.44     |                                |
Table 2  Area statistics of land use/land cover -winter season

| Land use/land cover | 1988/89-Winter | 2004/05-Winter | Deviation (% of the total area) |
|---------------------|---------------|---------------|--------------------------------|
|                     | Area/ha       | % of the total area | Area/ha       | % of the total area |                                      |
| Potato              | 50 216.91     | 17.25          | 78 081.09     | 26.81            | +9.57                                |
| Mustard             | 15 953.84     | 5.48           | 21 175.19     | 7.27             | +1.79                                |
| Current fallow      | 179 962.91    | 61.80          | 142 560.49    | 48.96            | -12.84                               |
| Channel bar         | 9 655.80      | 3.22           | 10 608.11     | 3.64             | +0.33                                |
| Settlement          | 22 002.91     | 7.56           | 25 649.56     | 8.81             | +1.25                                |
| Water bodies        | 13 398.67     | 4.60           | 13 117.00     | 4.50             | -0.10                                |
| Total               | 291 191.44    | 100.00         | 291 191.44    | 100.00           |                                      |

3.2 Spatial dynamics of cropland and gain and loss of cropland

In this study, for cropland mapping and determining the spatio-temporal dynamics of cropland, the cropland areas were reclassified and extracted from the classified image. Fig.3 and Fig.4 show the spatio-temporal distribution of seasonal cropland. The spatial distribution of summer cropland depict that the crop area was distributed almost in all the directions of the study area (Fig.3(a) and Fig.3(b)), whereas, the distribution of winter cropland was mainly concentrated in the north, east and southeast parts of the study area during the time periods (Fig.3(c) and Fig.3(d)). The analysis showed that in 1988/89 and 2004/05, about 168 726.79 hectares and 182 713.11 hectares of area were under summer (rice), and 66 170.75 hectares and 99 256.28 hectares, respectively, were under winter crops (potato and mustard) (Fig.4(a)). Hence, the seasonal cropland area statistics showed that the areas under both summer and winter crops increased from 1988/89 to 2004/05; especially, the winter crops area increased remarkably (Fig.4(b)). Therefore, it may be said that in the area, the cropping intensity increased over the periods.

The gain and loss of the cropland was also analyzed spatially and statistically in this study. Table 3 shows the statistics of gain and loss of the summer cropland and other categories of land use/land cover. The table depicts that between 1988/89 and 2004/05, the gain and loss areas under rice were 13.71% and 8.91% of the total area, respectively. So, the net gain of rice was 4.80% of the total area during the time. The gain area under current fallow was 4.58% and loss area was 17.17% of the total area, so a net loss of current fallow area was 12.59% of the total area between 1988/89 and 2004/05. The spatial distributions of gain and loss areas of rice and current fallow are shown in Fig.5. This type of map gives a general idea of the areas of gain and loss under specific crop. Fig.5 showed that the gain area under rice was mainly distributed in the north, northwest, southwest and central parts of the study area, whereas the loss area of rice was mainly located in the northeast and east parts of the area and near the river area (Fig.5(a)). These locations were mainly under the flood prone areas of the study area and it was the main reason for the loss of rice area during the time. In contrast, the gain area under current fallow (summer) was distributed in the
northwest part and concentrated within a few patches, whereas in this category the area under loss was distributed in a scattered way in all the directions of the study area and mainly concentrated in the north, northeast and southeast parts of the area (Fig. 5(b)). The changes of current fallow land to rice, settlement and water bodies were the main reasons to the loss of current fallow in summer season in the area.

Table 3  Summer cropland: gain and loss between 1988/89 and 2004/05

| Land use/land cover    | Gain/ha | % of the total area | Loss/ha  | % of the total area | Net gain & loss (as % of the total area) |
|------------------------|---------|---------------------|----------|---------------------|----------------------------------------|
| Rice                   | 39,926.11 | 13.71               | 259,397.9 | 8.91               | +4.80                                   |
| Current fallow         | 13,350.06 | 4.58                | 49,999.30 | 17.17              | -12.59                                  |
| Settlement             | 3,540.25  | 1.22                | 117.70   | 0.04               | +1.18                                   |
| Channel bar            | 6,500.56  | 2.23                | 5,096.99 | 1.75               | +0.48                                   |
| Water bodies           | 27,267.57 | 9.36                | 9,428.67 | 3.24               | +6.13                                   |
| Total                  | 90,584.55 | 31.11               | 90,582.45 | 31.11              |                                         |

Table 4 shows the statistics of gain and loss of the winter cropland and other categories of land use/land cover between 1988/89 and 2004/05. Table 4 depicts that the highest gain area was in potato and it was followed by current fallow and mustard, whereas the highest loss area was in the current fallow and it was followed by potato and mustard. Moreover, the statistics showed that the gain and loss areas under potato were 15.58% and 6.01% of the total area, respectively. Therefore, the net gain of potato was 9.57% of the total area during the time (Table 4). Whereas, the gain and loss areas under mustard were 5.90% and 4.11% of the total area, respectively, meaning that the net gain of mustard was 1.79% of the total area. On the other hand, the gain and loss areas under current fallow were 8.41% and 21.25% of the total area, respectively. Thus, in winter, the net loss of current fallow was 12.84% of the total area between 1988/89 and 2004/05 (Table 4). The spatial distribution of gain and loss of winter cropland (potato and mustard) and current fallow are shown in Fig. 6. Fig. 6 shows that the gain area of potato was distributed in a scattered way and concentrated mainly in the north, northwest and southwest parts of the study area, while the gain area of mustard was distributed only in the northwest part of the area (Fig. 6(a) and Fig. 6(b)). The gain of potato and mustard in these locations were mainly due to the increase of irrigation facility during the time. It may be mentioned here that the farmers introduced shallow tube-well irrigation scheme in the area during winter season and consequently the area under winter crops increased. On the other hand, the loss area under winter current fallow was distributed in the northwest and southwest parts of the area, while in this category gain area was distributed in the northeast and east parts of the area (Fig. 6(c)). The change of current fallow land...
Table 4  Winter cropland: gain and loss between 1988/89 and 2004/05

| Land use/land cover | Gain/ha | % of the total area | Loss/ha | % of the total area | Net gain & loss (as % of the total area) |
|---------------------|---------|---------------------|---------|---------------------|------------------------------------------|
| Potato              | 45 354.13 | 15.58               | 17 489.96 | 6.01               | +9.57                                    |
| Mustard             | 17 202.29 | 5.90                | 11 979.84 | 4.11               | +1.79                                    |
| Current fallow      | 24 484.07 | 8.41                | 61 866.49 | 21.25              | -12.84                                   |
| Channel bar         | 7 475.49  | 2.57                | 6 502.26  | 2.23               | +0.33                                    |
| Settlement          | 3 761.32  | 1.29                | 129.51   | 0.04               | +1.25                                    |
| Water bodies        | 7 134.99  | 2.45                | 7 434.26  | 2.55               | -0.10                                    |
| Total               | 18 371.8  | 36.20               | 14 066.03 | 36.20              |                                          |

to potato and mustard due to the increase of irrigation facility in these areas was the main reason for the loss of current fallow land in winter season.

3.3 Exchanges of cropland and spatial trend of changes between crops/croplands

The exchanges of cropland and spatial trend of changes between crops/croplands are important to know the agro-ecological environment of the area. It was stated earlier that in this study LCM module of IDRISI was used for the analysis of exchange and spatial trend of change between crops/croplands. The results of exchanges of winter croplands are shown in Fig.7. Fig.7 depicts that in winter, a good amount of current fallow land was changed to potato and also to mustard cropland. The changed areas from current fallow to potato and mustard were 38 224.85 hectares and 15 977.44 hectares, respectively (Fig.7(d)). The increase of irrigation facility in winter in the area was the main enforcement of the change of current fallow land to potato and mustard. The changed area from current fallow to potato and mustard were 38 224.85 hectares and 15 977.44 hectares, respectively (Fig.7(d)). The increase of irrigation facility in winter in the area was the main enforcement of the change of current fallow land to potato and mustard. The changed area from current fallow to potato and mustard was mainly concentrated in the northwest part of the area (Fig.7(a) and Fig.7(b)). On the other hand, a smaller amount of area was changed from potato and mustard to current fallow, and also from mustard to potato and vice versa (Fig.7(c), 7(d)). In contrast, the exchanges of summer cropland are shown in Fig.8(a). In the study area only rice was growing in summer season, and the exchange between rice and current fallow land showed that like winter season, a good amount of current fallow land was changed to rice area in summer and the changed area was 36 135.94 hectares, while the changed area from rice to current fallow was 12 172.82 hectares between 1988/89 and 2004/05 (Fig.8(b)).
of the area (Fig.9(a)) and northwest part of the area, respectively (Fig.9(b)). On the other hand, the changed area from potato to current fallow was mainly concentrated in the east part of the area (Fig.9(c)), and the changed area from mustard to potato was primarily concentrated in the north part of the area (Fig.9(d)). The spatial trend map of summer cropland shows that the area changed from current fallow to rice was mainly concentrated in the northwest part of the area (Fig.9(e)), while the changed area from rice to current fallow was concentrated

mainly in the north part of the study area (Fig.9(f)). From this analysis it may be said that the north, northwest and east parts of the area were the most important in respect to the change of crop cultivation in winter and summer, and the cropping pattern of the area as well. Hence, for agricultural land use planning, priority should be given more in these parts of the area.

3.4 Cropping pattern and changes

It is mentioned that one of the objectives of this study was to analyze the major cropping patterns/systems and their changes between 1988/89 and 2004/05. The major cropping patterns and area statistics are given in Table 5. The result showed that in the study area, five major cropping patterns were identified in both the year 1988/89 and 2004/05. The rice-current fallow pattern was denoted the highest proportion, i.e., 42.56% and 36.67% of the total area in 1988/89 and 2004/05, respectively. The rice-potato pattern was in the second highest position and occupied 12.90% and 21.72% of the total area in 1988/89 and 2004/05, respectively. Table 5 also shows that the current fallow-potato pattern was the third highest pattern (3.65% of the area) in 1988/89, while the rice-mustard pattern was the third highest (4.28%) in 2004/05. Apart from these, the current fallow-mustard pattern occupied 3.39% and 2.69% of the total area in 1988/89 and 2004/05, respectively. In the study area, rain fed mono crop cultivation was mainly followed, i.e., rice was the main crop in the past, but from the year 1984 onwards, deep and shallow tube-well irrigation and HYVs (High Yielding Verities) had been introduced, and those were accepted by the local farmers. Consequently, the area under potato and mustard increased during

| Major cropping pattern (summer-winter) | 1988/89 | 2004/05 | Deviation from 1988/89 to 2004/05 |
|----------------------------------------|--------|--------|----------------------------------|
| Current fallow-mustard (single crop)   | 9 860.30 | 7 835.34 | -0.70 |
| Current fallow-potato (single crop)   | 16 022.95 | 8 443.95 | -0.75 |
| Rice-current fallow (single crop)     | 123 941.68 | 106 785.00 | -5.89 |
| Rice-mustard (double crop)            | 5 662.26 | 12 449.01 | +2.34 |
| Rice-potato (double crop)             | 37 554.08 | 63 243.43 | +8.82 |
| Total                                  | 187 641.30 | 198 756.70 | 68.26 |

Fig.9 Spatial trend of changes of cropland between 1988/89 and 2004/05
the winter season. It may be mentioned here that in 1984, the government had implemented a policy to install deep tube-wells for irrigation in the northwest part of the country, and the study area (Bogra District) belongs to this part of the country (Fig. 1).

On the other hand, the change analysis of cropping pattern of the area between 1988/89 and 2004/05 depicted that the highest change was found in rice-potato pattern (Fig.10) and 8.82% of the total area increased under this pattern. The changing pattern of rice-current fallow showed that 5.89% of the total area decreased between 1988/89 and 2004/05 which was the second highest changing pattern in the area (Table 5). Other than these, 2.34% of the total area increased in rice-mustard pattern, while 0.70% and 0.75% of the total area decreased in current fallow-mustard and current fallow-potato patterns between 1988/89 and 2004/05, respectively (Table 5). Furthermore, Fig.11 shows the changing cropping pattern (spatial) between 1988/89 and 2004/05 and this map was prepared by using two cropping pattern maps of the area with GIS. Fig.11 and Table 6 depict that about 52.04% of the total area was unchanged, out of which 38.56% and 13.48% were under single and double cropland, respectively (Table 6). In contrast, 12.52% of the total area was changed from single cropping pattern to double cropping pattern, while 3.70% of the total area was changed from double cropping pattern to single cropping pattern. Therefore, from this discussion it may be said that there was a change in the area under different cropping patterns and in the winter season, the crop area increased remarkably, especially the potato area. Though the double cropland was changed to the single cropland between 1988/89 and 2004/05, the changing pattern from single cropland to double cropland was much higher than that of the double cropland to single cropland, and the area under double cropped was about 26% of the total area in 2004/05 (Table 6), indicating the positive sign of agricultural scenarios of the area.

Table 6  Changing cropping pattern between 1988/89 and 2004/05

| Changing cropping pattern/system (1988/89~2004/05) | Area/ha | % of the total area |
|---------------------------------------------------|--------|---------------------|
| Double cropping (unchanged)                       | 39 225.35 | 13.48               |
| Single cropping (unchanged)                       | 112 300.90 | 38.56               |
| Single cropping to double cropping                | 36 467.09 | 12.52               |
| Double cropping to single cropping                | 10 763.35 | 3.70                |
| Total                                             | 198 756.07 | 68.26               |

4 Conclusion

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 an ideal tool for integrating the basic information sources such as maps, imagery and statistical data for effective resources management[29]. 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[30]. In this study, Landsat TM and IRS P6 LISS III images were used with GIS for spatial dynamics of cropland and cropping pattern change analysis. Crop acreage estimation, gain and loss of cropland, exchanges of cropland and spatial trend of changes, major cropping patterns identification and changes of cropping patterns between 1988/89 and 2004/05 were the main focuses of this study. To fulfill the objec-
tives of the study, first seasonal cropland maps were derived from object-based classification of satellite images, and then simple GIS overlay technique with decision was applied.

The study revealed that the multi-spectral and multi-temporal Landsat TM and IRS P6 LISS III images can be used satisfactorily for seasonal cropland and crop type’s area identification and monitoring over the time period. The cropland analysis showed that mono crop cultivation (rice) was found in summer season, whereas potato and mustard were cultivated in the winter season, and the gain area of cropland between 1988/89 and 2004/05 was higher in winter than in summer. The analysis also showed that mainly current fallow land was changed to cropland (rice, potato and mustard) in both summer and winter seasons. From the spatial trend analysis of changes of cropland, it was found that the changes mainly occurred in the north, northwest and southwest parts of the area. On the other hand, the cropping pattern analysis showed that, in the study area, five major cropping patterns were identified in both the year 1988/89 and 2004/05. The rice-current fallow, rice-potato and rice-mustard patterns were the important cropping patterns in the area, and the change analysis showed that the highest area change was found in the rice-potato pattern. The changing pattern (spatial) of cropland which was based on cropping pattern between 1988/89 and 2004/05 depicted that there was a change in the area under different cropping patterns, and in the winter season, the cropland increased remarkably, especially the potato area, indicating the agricultural development situation of the study area. In contrast, though there was a change in the area under different cropping patterns, about 42.26% of the total area was still under single crop cultivation (Table 6). Thus, for better management and overall agricultural development of the area, winter crop cultivation should be increased at a satisfactory level through proper planning. On the basis of the above discussions and findings, it is clear that the study followed a simple but effective way to use remote sensing and GIS for crop mapping, crop acreage estimation, identification of gain and loss areas of cropland, changes of cropland, spatial trend of changes, and also the major cropping pattern identification and changes. This study was initiated to analyze the crop dynamics and cropping pattern change in a spatial and quantitative way. The technique which was followed in this study was based on two-date classified image differencing method with GIS technique and decision rules. It was found extremely useful and can also be used for long term and multi-year cropland dynamics and cropping pattern change analysis in an agricultural areas.

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