EVALUATION OF ASTER SPECTRAL BANDS FOR AGRICULTURAL LAND COVER MAPPING USING PIXEL-BASED AND OBJECT-BASED CLASSIFICATION APPROACHES

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ABSTRACT:

The ASTER sensor onboard NASA's Earth observing satellite Terra is an optical remote sensor comprised of 14 spectral bands ranging from the visible to thermal infrared region. With its multispectral bands the sensor bears the potential to provide data for both a detailed land use classification of heterogeneously vegetated areas. This study evaluates the potential of ASTER data for land use classification in a typical Bangladesh agricultural environment with its small-spaced fields. Land use in Bangladesh typically consists of small agricultural fields, complex vegetation covers, and scatteredly distributed residential areas, which have been problematic in terms of land cover mapping using satellite remote sensing data due to the complexity of the spatial structure. A pixel-based approach and a multi-scale object-based method are applied for agricultural land use classification using ASTER data in Sylhet district, Bangladesh. The supervised classification was performed using the Maximum Likelihood Classifier (MLC) with ERDAS Imagine software. On the other hand, object-based image analysis was performed through the eCognition software. The results show, that the phenological stages of the cultivars are the main factors influencing the separability of agricultural classes. To identify the best method, accuracy of each method was assessed using reference data sets derived from high resolution satellite data and ground truth field investigation data. Outcome from the classification works show that the object-based approach gave more accurate results (including higher producer's and user's accuracy for most of the land cover classes) than those achieved by pixel-based classification algorithms.

1. INTRODUCTION

Scientific support for land use planning must start with reliable information relating to current resource conditions. One of Bangladesh's most glaring gaps in that aspect is the lack of current, accurate, complete and accessible digital land cover information. Remote sensing is an effective technology to acquire information about geographic objects. Of the applications, the agricultural activities require a quantitative processing of remote sensing data with high accuracy and reliability. In the conventional pixel-based classification, the pixels are categorized separately into one of the pre-determined classes according to their spectral characteristics. However, in the case of agricultural applications, pixel-based classification techniques may cause problems due, for example, to the variations in soil moisture conditions, nutrient limitations or pests and diseases. The other problem may be caused by the mixed pixels that are located at the boundary of two or more land cover types (De Wit and Clevers, 2004). Therefore, when the classification is performed on a pixel basis, these factors may cause to assign a combination of the reflectance from two or more land cover types and, this causes misclassification (Smith and Fuller, 2001).

The basic idea behind an object-based classification is that the image is divided into homogenous objects using the knowledge of agricultural field boundaries. During classification, each pixel is assigned to a final class of the entire object according to their statistical properties, instead of determining the class label for each pixel separately. Therefore, object-based methods eliminate the effect of the spectral variability within the fields and the mixed pixels falling on field boundaries (A. Ozdarici and M. Turker, 2000,). As a result, for agricultural applications, object-based classification techniques produce more reliable results than the pixel-based classification techniques by overcoming the problems of misclassification. In this study, the potentiality of ASTER data for land use classification in a typical Bangladesh agricultural environment with its small-spaced fields is evaluated. In order to investigate an appropriate method for agricultural land classification, classical pixel-based and object-based classification techniques have been implemented.

2. OVERVIEW OF THE STUDY SITE

The study was carried out in Sylhet district, northeast part of Bangladesh (Figure1). The area is situated between $24^0 58'$ to $25^0 19'$ N latitude and $91^0 63'$ to $92^0 50'$ E longitude. Sylhet district with an area of approximately 3490.40 sq km. The study area has a tropical monsoon climate with annual average temperatures ranging from 13.6°C in January and 33.2°C in July. The mean annual rainfall 3632 mm which is concentrated in the months of June to September.

The main agronomical crops cultivated in this area are rice, mustard, potato, sweet potato, tomato, bean, groundnut and other vegetables (DAE 2003). Rice crops are dominated most parts of the study area and are grown in two different seasons called Kharif and Rabi. Rainfed Aman rice which is a major crop in this area of Kharif season. The crop calendar shows it is transplanted in June-July and harvested by November. Irrigated Boro rice is grown in Rabi season. It is transplanted in December-January and harvested by April-May (Perveen *et al*., 2007). The main horticultural crops are mango, pineapple, jackfruit, orange, litchi and citrus. Sylhet district is famous for tea plantation, the tea granary of Bangladesh. For miles and miles, the beautiful tea plantations spread like a green carpet over the plain land or on the sloping hills.

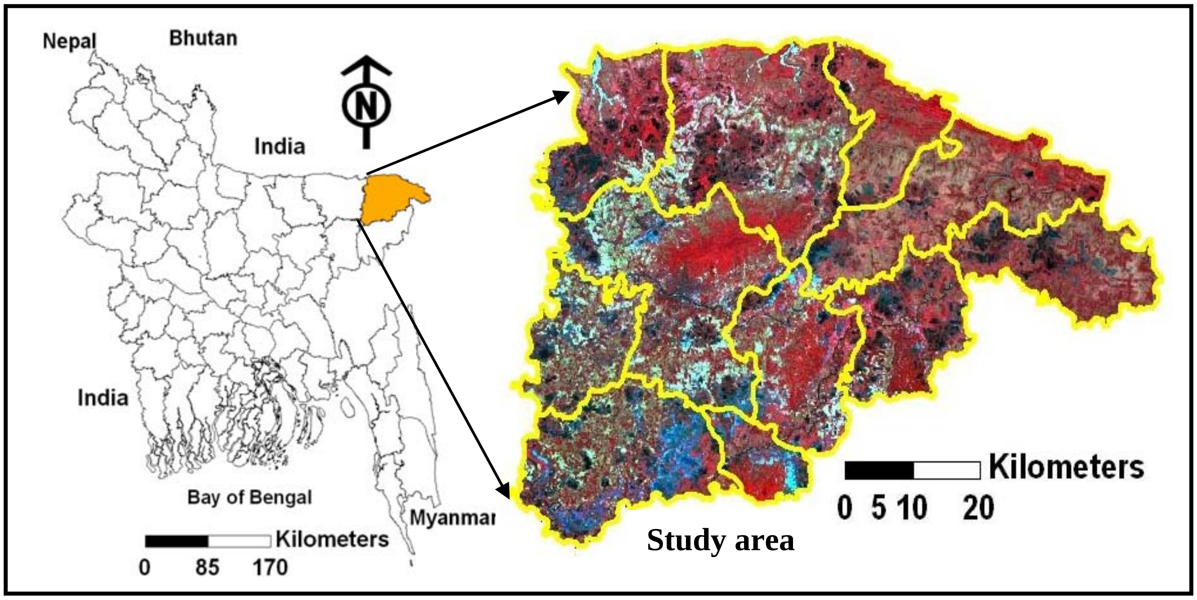


Figure 1. Location of the study site

3. METHODS

3.1 Image pre-processing

The visible and near infrared (VNIR) data of Terra/ASTER level 1B acquired on November 2003 with a spatial resolution of 15 m was analyzed for this research. ASTER scenes were selected based on the need to acquire a phenological records of the agricultural growing season. In agricultural land use studies, vegetation phenology is especially important due to the sudden changes in reflectance associated with crop planting and harvesting (Rundquist *et al*., 2002.) The image mosaicing of four scenes were performed using ERDAS Imagine version 9.1 software and masked the image by study area boundary. The study area boundary was digitized from the topographic map using Arc GIS 9.2 software. The images were georectified by locating the Ground Control Points (GCPs) and by applying a second order polynomial and the resampling algorithm was the nearest neighbor. The nearest neighbor resampling method was used to preserve the blocky structure of the agricultural fields and the original radiometry of the image (S. Eckert *et al*., 2004, Santos *et al*., 2005). Survey of Bangladesh topographical sheets on 1:50,000 scale were used as reference data for rectification of satellite images and selection of Ground Control Points (GCPs).

In this study geometric correction was carried out using Ground Control Points from topographic maps to geocode the ASTER image. A total of 25 GCPs were selected, which resulted in an RMS error of less than 0.5 pixels. The images were geocoded to Universal Transverse Mercator (UTM) coordinate system, zone no. 46 N of WGS 1984. The ASTER (VNIR) images contain three multispectral bands (0.52 – 0.86µm) corresponding to green (G), red (R) and near infra-red (NIR).

3.2 Pixel-based approach

Pixel-based classification was performed in two steps using ERDAS Imagine 9.1 software. Pixel-based classification methods, by using multi-spectral classification techniques, assign a pixel to a class based on spectral similarities (Casals-Carrasco *et al.*, 2000). In pixel-based image analysis, firstly unsupervised classification based ISODATA has been applied and thus, spectral clusters have been determined, which gives pre-knowledge about the study site. Then supervised classification was performed using the Maximum Likelihood Classifier (MLC).

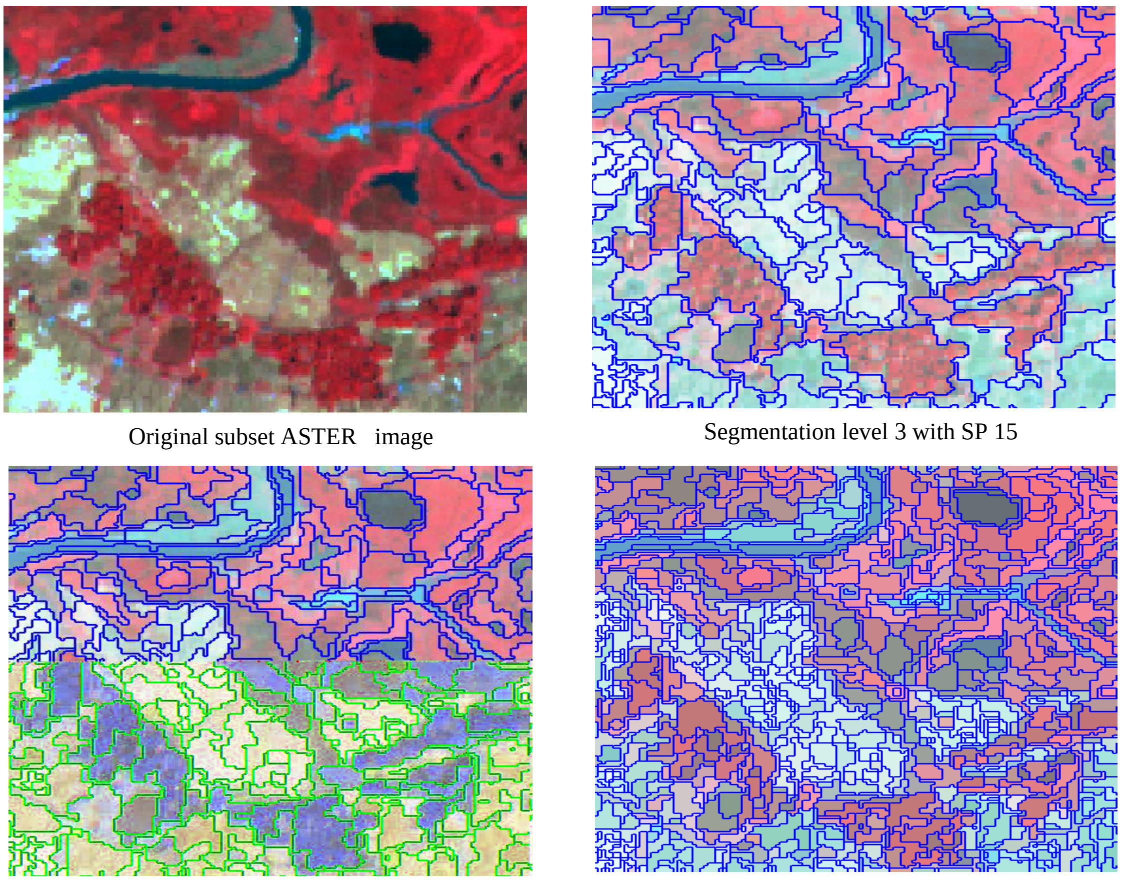
It is important that training samples be representative of the class that you are trying to identify. Great effort was spent during the training area selection since the training areas were collected from the most represented homogenous areas. Training data for the MLC classifier was collected from a variety of sources such as ground checkpoints, with the help of aerial photography, digital topographic maps, knowledge of the data, and visual interpretation of ASTER images. In addition to the spectral differences, the phenological characteristics of the crops were also taken into account during the selection of the training areas. Also, ancillary data such as DEM derived products (slope, elevation) and soil information were used as additional input to the classifier. The study site was classified into ten classes: Paddy fields, Mixed crops, Fallow land, Grassland, Tea plantation, Forest, Settlement, Urban, Water and Wetland. The false color composite of the ASTER (VNIR) bands Green, Red and NIR was used when selecting the training samples because they were found to be most informative bands (Perveen *et al*., 2007).

In this study, the accuracy assessment was carried out using 312 points from ground truth data. Then, error matrix was generated as given in Table 1 and Table 2. Pixel-based classified data often manifest a salt and pepper appearance due to the inherent spectral variability encountered by a classifier when applied on a pixel-by-pixel basis (A. Shalaby, 2007). Therefore, a filter 3x3 has been used to smooth the classified output to show only the dominant classification. The methodological flowchart of the pixel-based image analysis is shown in Figure 3.

3.3 Object-based approach

Object-based classification was performed in eCognition, which is an object based image processing software program made available in 2000 from Definiens Imaging GmbH and was claimed to be user-friendly, multi-scaled, and fully functional (Blaschke and Strobl, 2001). Object-based classification does not operate directly on single pixels, but image objects which refer to homogeneous, spatially contiguous regions obtained by dividing image, namely image segmentation. eCognition segments a multispectral image into homogeneous objects based on neighboring pixels and spectral and spatial properties. Image segmentation is a preliminary step in object-based image classification. The accuracy of segmentation directly influences the performance of object-based image classification. Only good segmentation results can lead to object-based image classification out-performing pixel-based classification. Human interpretation and correction is considered as the best way to evaluate the segmentation output (Pal and Pal, 1993; J. Qian *et al*., 2007) and some methods have been developed to quantitatively measure the degree of over-and under-segmentation of regions, and to measure the discrepancy between the positions of the region boundaries.

Using eCognition software, a hierarchical segmentation was generated at three different scale parameters i.e., SP 5, SP 10, and SP 15 for the study area. Figure 2 shows three examples of the subset of the segmentation results with an original ASTER data. These three different scale parameters were tested on five sample areas, which represented the different types of land use classes found in each site. The segmentation algorithm was run for each test area and visually assessed to determine which set of parameters provided the best results for delineating spectrally unique regions while maintaining a naturally occurring shape of land use classes.



Original subset ASTER image

Segmentation level 3 with SP 15

Segmentation level 2 with SP 10

Segmentation level 1 with SP 5

Figure 2. Image segmentation using three different scale parameters

Segmentation results with SP 5 or SP 15 does not correspond to meaningful land use classes such as the apparent boundary between residential areas and surrounding agricultural fields. Instead, segmentation results with SP 10 show relatively good geometrical correspondence with basic land cover patches such as agricultural fields and residential areas, patches of grass lands and tea plantation etc. From the different levels, SP 10 was found to be a good compromise between number of objects and individual land cover representation. So, providing the complexity of the land use pattern in Bangladesh, the most suitable one, SP 10, was selected for the classification of ASTER image. The homogeneity criterion parameters were set as follows: color: 0.8, shape: 0.2, smoothness: 0.9 and compactness: 0.1. This level consists of optimal segments for agricultural land classification. However, individual but spectrally homogeneous fields are sometimes merged or fields are separated into several smaller segments due to spectral in field variation. The classifier of object-based image classification was nearest neighbor (NN), which is a soft classifier, based on fuzzy logic. The methodological flowchart of the object-based image analysis is shown in Figure 4.

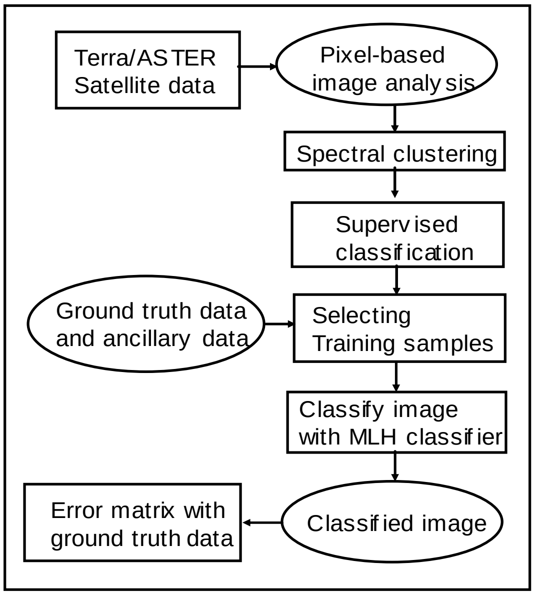


Figure 3. Methodological flowchart of pixel-based approach

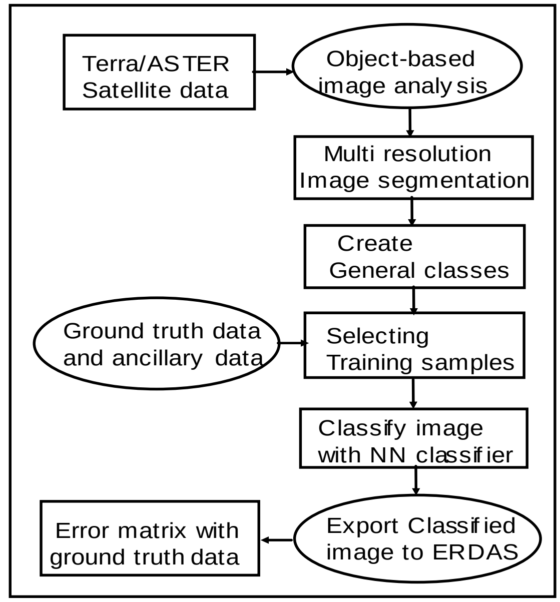


Figure 4. Methodological flowchart of object-based approach

4. RESULTS AND DISCUSSIONS

The classification results of the MLC and object-based method is shown in Figure 5 and Figure 6 respectively. The accuracy assessment of these two classifiers can be found in Table 1 and Table 2 respectively. The MLC method provided an overall accuracy of 71.47%. On closer examination of the error matrix, it was found that paddy fields were mainly misclassified as mixed crop and grass land or fallow land (stubble fields). The main reason for this would be that due to mixed fields, the statistical values calculated for each field may not represent the actual crop information within the fields. The other reason for this would be some paddy fields were already harvested and stubble fields/bare soil plots were found in the test area and after harvesting, paddy fields were covered by the sparse grass. The same misclassification occurred between forest and tea plantations. The reason for this might be similar spectral reflectances. The kappa coefficient, which is 0.6714, is quite low too, indicating the MLC method is still an unsatisfactory one to classify remotely sensed images of the typical Bangladesh agricultural environment with its small-spaced fields.

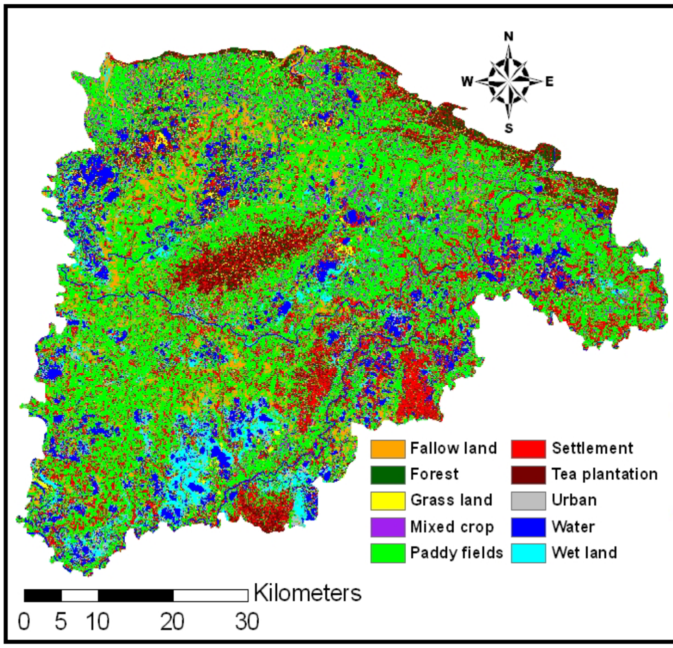


Figure 5. Results of Maximum Likelihood Classifier (Left)

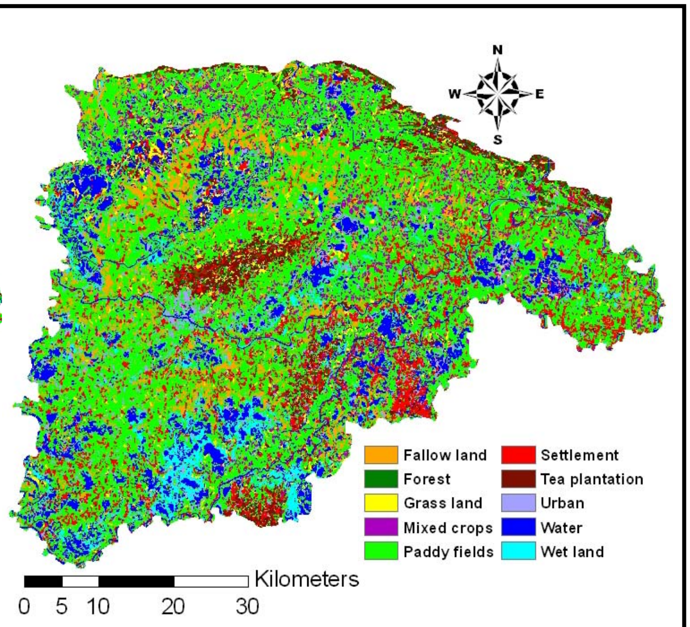


Figure 6. Results of Object-based classifier (Right)

The overall accuracy of the object-based classifier reaches 80.45%. The kappa coefficient, which is 0.7747, is quite high too, especially for a classification containing as many as ten types of land covers. The object based classification approach has the advantage to prevent from the "salt and pepper" effect as it can be observed in pixel-based classification approaches (Figure 5). Nevertheless, if the developed class hierarchy is instable, whole segments (groups of pixels) are misclassified which results in a low accuracy compared to the ground truth data.

Table 1. Error matrix of image classification by Maximum Likelihood Classifier

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	kappa (K^)
No data	0	5	0	---	---	0
Water	17	19	14	82.35%	73.68%	0.7217
Forest	17	16	11	64.71%	68.75%	0.6695
Urban	28	30	21	75.00%	70.00%	0.6704
Paddy fields	78	84	59	75.64%	70.24%	0.6032
Tea plantation	29	29	21	72.41%	72.41%	0.6959
Settlement	38	35	26	68.42%	74.29%	0.7072
Grass land	35	31	24	68.57%	77.42%	0.7457
Fallow land	27	34	22	81.48%	64.71%	0.6136
Wet land	14	10	8	57.14%	80.00%	0.7906
Mixed crops	29	19	17	58.62%	89.47%	0.884
Totals	312	312	223			

Overall Classification Accuracy = 71.47%, Overall Kappa Statistics = 0.6714

Table 2. Error matrix of image classification by Object-based Image Classifier

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Kappa (K^)
No data	0	5	0	---	---	0
Tea plantation	29	29	25	86.21%	86.21%	0.8479
Paddy fields	78	84	63	80.77%	75.00%	0.6667
Mixed crops	29	19	18	62.07%	94.74%	0.942
Grass land	35	31	29	82.86%	93.55%	0.9273
Fallow land	27	34	24	88.89%	70.59%	0.678
Forest	17	16	13	76.47%	81.25%	0.8017
Urban	28	30	23	82.14%	76.67%	0.7437
Settlement	38	35	31	81.58%	88.57%	0.8699
Wet land	14	10	10	71.43%	100.00%	1
Water	17	19	15	88.24%	78.95%	0.7773
Totals	312	312	251			

Overall Classification Accuracy = 80.45%, Overall Kappa Statistics = 0.7747

Paddy fields were classified as mixed crop, settlement or tea plantation. Due to similar spectral reflectances, paddy fields might be misclassified as mixed crops. In Bangladesh, only urban settlement areas are with concrete buildings and other structures but most of the rural settlements are constructed tin shade bamboo, wood, straw etc. and usually surrounded by fruit tree/shrubs. Due to this complex cover types, settlement areas also were misclassified with other land cover types such as, mixed field crops, grass land and forest. Urban areas were also misclassified as wetland or water. The reason for this would be the effect of training pixels. It should be noted that when selecting the training areas for urban and wetland, some confusion was raised.

In particular, relatively high accuracy for agricultural area, especially the paddy fields, both producer's one and user's one, is achieved by the object-based approach. The producer's accuracy and user's accuracy for agricultural area by the object based method are 80.77% and 75.00%, respectively. While the corresponding producer's accuracy and user's accuracy by the MLC method are 75.64% and 70.24% respectively. However, Object-based classification has a higher accuracy than pixel-based classification from the viewpoint of overall accuracy because it can group pixels into objects with spatial and texture information. So, obviously the object-based method is more reliable to delineate small-spaced fields of agricultural land use in Bangladesh.

5. CONCLUSIONS

In this paper, new object-based image analysis technique has been compared with the classical pixel-based image classification methods with the Terra/ASTER images covering an agricultural area in Sylhet district Bangladesh. However, the classification assessment presented in this paper concludes that, the object-based classification produces better land cover mapping, with the seasonal (Rabi) dataset of Terra/ASTER images, than the traditional pixel-based classification techniques. Therefore, it can be stated that by using an object-based approach, the mapping of the agricultural land with its small-spaced fields in Bangladesh can be carried out more reliably when compared with the conventional pixel-based classification techniques. Both methods suffer from low spectral variations among the different agricultural land cover types and a common problem of mixed pixels.

The study area has a complex heterogeneous land use types. As it was possible to classify this complex land use types, it is expected that other parts of the country, where less complexity in land use found could also be classified using ASTER images. Hence, this study has demonstrated the potential of using ASTER data in Rabi season.

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