Estimation of area under Agroforestry practices in Modhupur Sal forest using remote sensing

M. Golam Mahboob[1], G.M. Mujibar Rahman[2], M. Jinnahtul Islam[3], M. Abdus Salam[4]

[1]Scientific Officer, T&C Wing, Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur, [2]Professor, Department of Agroforestry, Bangladesh Agricultural University (BAU), Mymensingh, [3]Principal Scientific Officer, Bangladesh Space Research and Remote Sensing Organization (SPARRSO), Agargaon, Dhaka, [4]Associate Professor, Department of Aquaculture, BAU, Mymensingh

Abstract: The objective of this study was to detect and discriminate the area under agroforestry practices through satellite remote sensing in Modhupur sal forest. This study was conducted in the year of 2003 at Bangladesh Space Research and Remote Sensing Organization (SPARRSO) laboratory analyzing SPOT image of March 3, 1999 with bands 4, 3, 2 and 1 using ERDAS Imagine professional software. All individual bands and their different combinations of the imagery were tried for depicting the agroforestry areas. From the best combination of bands False Color Composite (FCC) was prepared. Extensive ground verification was conducted with the help of GPS and plantation journals. Unsupervised classification of SPOT image was conducted through the ERDAS Imagine and 15 landuse classes were derived. Similar landuse classes were merged together incorporating the ground truth information. Best FCC was obtained from the combination of SPOT spectral bands 3, 4 and 2 (RGB) for discrimination of the desired features in Modhupur sal forest. After merging similar landuse features incorporating ground data, a final map with four classes: sal forest, agroforest, rice field and depressed land were generated. The extents of agroforestry area were mainly found distributing around the peripheral zones of remnant sal forest. Some agroforestry practices were found scattered in all over the study area. The results of this study exhibit the way of depiction and estimation of agroforestry and other landuse features through remote sensing technique which could be refined in future with updated satellite images to study different aspects of forestry and agriculture in Bangladesh.

Keywords: agroforestry, remote sensing, landuse classification, sal forest, FCC, ERDAS Imagine, SPOT

Introduction

Forests are vital for maintaining the earth's ecological balance. The accepted standard according to the experts of environmental science is that a country must have at least 25 percent of its total land area covered with trees or forests

(Huda and Roy, 1999). Once covered by dense forests,

Bangladesh is now almost devoid of forested land, except in a few selected areas of the country (Giri and Shreshtha, 1996).

In Bangladesh, sal forests cover an area of about 121,000 ha, which is about 32% of the total forestland (Rahman, 2003). The Modhupur sal forest, the largest sal forest patch possesses a significant role in maintaining ecological balance situating at the center of the country. But unfortunately this forest area is severely denuded and heavily encroached by local people. Not only have mature trees been cut, illegal timber merchants have dug out stumps—leaving the areas barren without any regeneration potential (Chowdhury, 1999). More than 66 percent of the Sal forest is blank or under the possession of encroachers at present (UNEP, 2002). As Bangladesh is one of the most densely populated countries in the world, it is not possible to rehabilitate all the encroachers outside the forest. Moreover it is unkind to think about eviction of ethnic forest communities especially the Garos who lived in the Modhupur sal forest for centuries. Nowadays it is recommended to adopt an approach of reforestation involving nearby society. Being a land-hungry country, Bangladesh cannot undertake social forestry on a large scale (Rana, 2001). Agroforestry has become an effective tool to replenish degradation of forest as it offers direct benefits to the local community from its early stage of establishment. Government of Bangladesh (GoB) and Non Governmental Organizations (NGOs) launched several agroforestry programs by means of social forestry projects, throughout the country including sal forests. The study aimed at assessing the extent of agroforestry practices under Modhupur sal forest.

For efficient management of forests and also to prepare effective plans for afforestation programs, it is necessary to monitor and map the forest cover at certain intervals. The forest mapping and monitoring work through conventional field survey techniques is time consuming and involves high cost (Quadir *et al.*, 1998). Here the satellite remote sensing can play an important role. Data available from satellite remote sensing cover large areas in a single pass and are relatively cheaper. The sensors on board the resource satellites like Landsat Multispectral Scanner/Thematic Mapper

(MSS/TM) and Le Systeme Pour l'Observation de la Terre (SPOT) High Resolution Visible (HRV) provide multispectral digital data with high ground resolution which can effectively be used for identifying various features of the earth surface including forests of different types. Studies conducted by Chawdhury *et al.* (1993) have shown that Landsat digital image of December 1990 could be successfully used to digitally classify and interpret the forests, homestead forests, shrubland and winter rice cover of some areas of the greater Dhaka and Tangail Districts in Bangladesh. Islam and Quadir (1988) used the TM image of February 1988 to generate the map for the Modhupur Forest. Singh (1989) has proposed a guideline for forest cover classification using remotely sensed data for Indian conditions. However, it may be noted that the identification and classification of forest classes are highly dependent on the characteristics of the sensors, type of data and objectives of the study. The forest biomass estimation using remote sensing technique was demonstrated by Rahman and Roy (1993) where forests were classified according to the various levels of biomass content using Landsat TM data. Zomer *et al.* (2001); Lefsky *et al.* (2001) used multitemporal Landsat images for detection analysis in forest cover change. Remote sensing studies conducted for crop forecasting (Chawdhury, 1999), crop inventory (Salam and Saha, 1998), pasture management (Lagunov, 1990; Knapp *et al.* 1990), aquaculture (Salam, 2000), forest nutrient status estimation (Ebbers *et al.*, 2000) etc. show the diversified potentials of remote sensing in the different fields of agriculture as well as forestry. Unruh and Lefebvre (1995) used the AVHRR 15 km-resolution, global vegetation index data obtained from the US National Oceanographic and Space Administration (NOAA) to estimate areas suitable for agroforestry in sabSaharan Africa.

Remote Sensing is the blessing of modern science, which has been used widely in the past decades and began to use as an effective tool for agriculture and forestry development studies. Agroforestry, as a newer discipline, has vast scopes to exploit its potential. So for the improvement of environment and advancement of our country with this state-of-the-art technology the study was conducted with the following objectives-

- to detect and discriminate the extent of existing agroforestry practices in Modhupur sal forest;
- to measure the area under agroforestry practices within the study region of Modhupur sal forest.

Materials and Methods

All laboratory-based operations were undertaken at GIS and Remote Sensing laboratory of Bangladesh Space Research and Remote Sensing Organization (SPARRSO) situated at Sher-e-Bangla Nagar, Agargaon, Dhaka. The database contained several raster images extracted from SPOT image of March 3, 1999, and digitised from a wide range of paper maps and tabular data from different sources. SPOT image of the seen J 301 (path), K 235 (row) band 432 and 1 was loaded to the computer equipped with the ERDAS Imagine professional software version 8.4. The software was run in the networked GIS Workstations powered by Windows 2000 version 5.00.2195 operating system (OS). SPOT multispectral images used in this study have a maximum resolution of 20m x 20m. The same is also capable to show a higher resolution of 10m × 10m in panchromatic mode. The image covers a vast area of Tangail, Mymensingh and Sirajganj districts. Geometric correction was made for the image. Image rectification was carried out using SPARRSO rectified Landsat TM imagery. Individual band of the imagery was studied for observing the reflectance characteristics of the Modhupur Sal forest area. Landuse features are distinguished in the image from their reflecting characteristics. It varies from vegetation species to species. Individual species shows their respective reflecting percentage. It also depends on spectral bands of radiation and resolution of the image. The image of the study area was visually analyzed with computer based RS software for its preliminary digital enhancement in order to enable its interpretation. For depicting the agroforestry area, every individual band alone and different combinations of the spectral bands of the imagery were tried. False Color Composite (FCC) was prepared from the best combination of bands. After visual interpretation of the FCC, a window of 7400 ha (1 km × .74 km) was chosen from the thickest part of the remnant sal forest for detailed study. Then the study area was cut from the imagery and saved to a different file. Unsupervised classification module of ERDAS Imagine Professional software was run over the image and 15 landuse

classes were obtained. Ground verification of the unsupervised classification was conducted.

Direct observations were made for land use and soil characteristics and GPS positions were recorded for each site visited. This was important for classification of the SPOT image. Points collected by GPS served as reference and verification points for the classification procedures. A hand held Global Positioning System GARMIN GPS III was used in the study to collect data including ground truth verification and other point data. The GPS-III is capable of receiving signals from up to 12 NAVSTAR satellites for positioning. Its accuracy level is about 9 to 18 m when there are 9 satellite signals being received.

Plantation journals were used to locate the BFD plantation area in Modhupur sal forest. Plantation journals are the books prepared by the local forest range offices to record the details of every plantation program. Each plantation journal contains a range of information including the location of the plantation area, map, list of the beneficiaries, their share percentage, duration of the program, name of the species and their number in details. Every plantation journal is prepared in two copies, one for the bit office and another for the range office. As the satellite image of March 3, 1999 was used in this study, field conditions were not found similar during ground truthing in 2003 for all the features shown in the image in many cases. There was a gap of four years in between satellite image acquisition and ground verification. Some of the woodlot plantations and agroforest gardens under social forestry program had chopped down during this interval, as they attained maturity according to the condition of social forestry program. So it was not easy for usual field data to satisfy all the conditions of absolute ground truthing. Subsequently similar landuse classes were merged together incorporating the ground truthing information in the labratory. For this reason, old plantation journals were used to locate previous woodlot plantations and agroforestry gardens existed in March, 1999 in the study area.

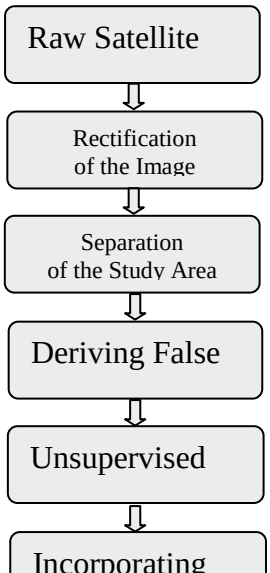

Figure 1. Schematic representation of the methodology of the study

Finally four classes were kept in the final map. Then a hard copy map was printed and area under different classes was derived from the raster attribute table of the software. A flow chart is given in Fig. 1 showing the methodology of the present study.

Results and Discussion

Different combinations of spectral bands of SPOT image were tried to prepare FCCs to depict the area under agroforestry practices in Modhupur sal forest. The best FCC was obtained from the combination of SPOT spectral bands 3, 4 and 2 (RGB) for discrimination of the desired features in Modhupur sal forest. FCC of Modhupur sal forest is given in Fig. 2. It was found difficult to identify the area under agroforestry practices using the individual band. Because the reflectance percentage of natural sal forest and agroforestry under different spectral bands were much closed. Salam (2000) used Landsat TM bands 2, 4 and 3 (visible green, near infrared and visible red respectively) to obtain a clear visual discrimination of the mangrove and non-mangrove boundary.

Unsupervised classification was conducted on the SPOT data of Modhupur sal forest through the automated classification tool available with ERDAS Imagine Professional software. The number of classes was assigned to fifteen. The classification for the landuse pattern in the sal forest produced adequate results for the purposes of the study. Similarly Salam (2000) derived nine mangrove classes and Xiao *et al.* (2002) distinguished seven different forest categories of boreal forests through unsupervised classification.

Data collected during ground truthing using GPS and from the records of the plantation journals were used to verify the classes. Incorporating the ground verification data, similar features of the landuse type were merged together. Finally four landuse classes namely sal forest, agroforestry, depressed land and rice field were generated. The final digital

map of the landuse classification is shown in Fig. 3. Mayaux *et al.* (2002) performed a similar classification and obtained the main land cover classes as: lowland rain forest, permanently flooded forest, periodically flooded forest, swamp grassland, and savanna for vegetation types of Congo basin.

The area under agroforestry practices was distributed over the study area around the peripheral zones of remnant sal forest. The result supports Bose's (1994) report: as the encroachers have been destroying the natural sal forest from the peripheral zones, so the foresters launched agroforestry practices on the governmental denuded forestland under several social forestry projects involving local community in a benefit sharing mechanism. Agroforestry practices were rarely found over large continuous land in the map. Two large patches of landmass under agroforestry, seen in the map (Fig. 3) are mainly juvenile woodlot plantations. Like most other woodlot plantations, agricultural crops were deliberately cultivated simultaneously with those plantations as intercrop at their early stages of development. This practice turned the plantation into an agroforestry system. Some scattered distribution of agroforestry practices was seen all through the study area. These fragmented agroforestry practices were the people's initiatives of raising trees in their crop fields (pineapple, aroids etc.) or at their homesteads.

The study was conducted over 7,400 ha area and sal forest was found existing over 3,037 ha, agroforestry practices on 1,747 ha, depressed land on 365 ha of land and remaining 2,251 ha of landmass was identified as rice fields. Proportional distribution of landuse classes is given in the pie chart (Fig. 4). It is worth mentioning that the study was concentrated just over an area of 1 km × 0.74 km of the thickest part of Modhupur sal forest and the above landuse data and Fig. 4 is not representative for the entire forest.

In unsupervised classification the depressed land and natural sal forest separated better compared to other categories. However maximum misclassification was observed with rice field (Fig. 3), which was followed by agroforestry. As this was not very close to the study concern, all sorts of agricultural and bare land were merged with the rice field category in the final map. Due to this

reason, BAF runway and firing range (L-shaped structure at the center) was misinterpreted as rice field. As the settlements structures in the area were very smaller, SPOT image having a ground resolution of 20m failed to depict them in the image. The difference in nature of reflection characteristics of depressed land or water bodies from the vegetation enhanced its easy discrimination from other features.

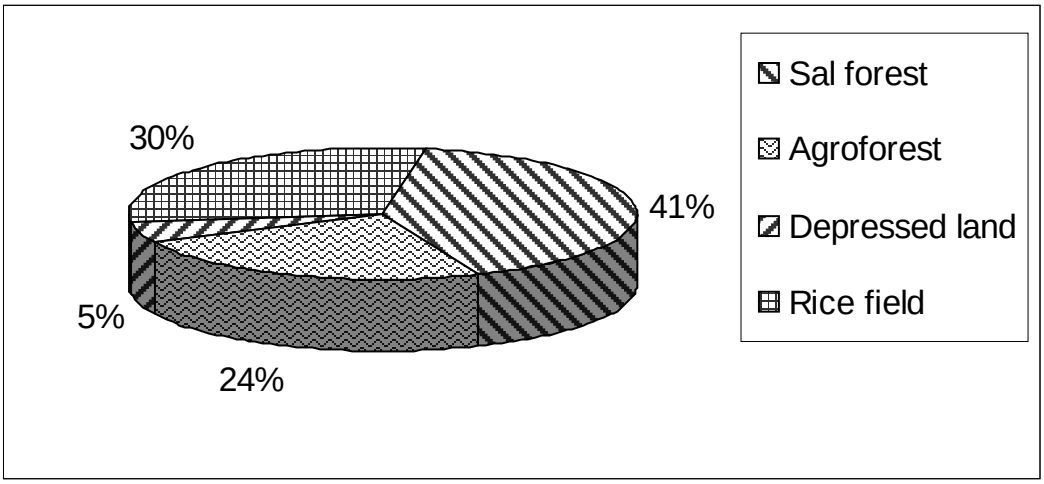

Figure 4. Distribution of landuse classes in the study area of Modhupur sal forest

There was a gap of four years between SPOT image acquisition (1999) and field verification of the study (2003). During ground verification it was found difficult to collect previous landuse information of agricultural fields at the time of image acquisition. Land cover is a dynamic feature that can be changed rapidly across the landscape, which adds to the difficulty of making generalization and extension of sparse data over a large area. Rice field, other agricultural land and bare soils are interchangeable in between categories over times. Moreover, the satellite image was taken on March 3 and ground truthing was conducted during the month of April and May. It was also a source of errors, as the vegetation attained different colors with the variation of seasons. Using a recent image for study and conducting ground truthing during or immediate after image acquisition by the satellite could help in discrimination of the real feature of the study area. Nowadays the RS satellite operating authorities offer some unique opportunity like fixing the schedule of ground verification on the same date and time of image acquisition. Using a single image often causes error in interpreting the earth's feature as clouds

may hamper in acquisition of real image. Image used in the current study was taken in dry season. Another different date image of wet season could help in generating more clear conception on landuse classes.

With the maturity of rotation period of social forestry program, some of the woodlot plantation and agroforest garden were chopped down in the interval period of image acquisition and ground study. Plantation journals were found useful to locate the then status of agroforestry practices as per the satellite image. Cutting the social forestry plantations did not cause so much harm in RS estimation of agroforestry area, because new plantation has been launched on the same piece of land.

The results of the landuse classification and inventory of agroforestry showed that the satellite remote sensing image could be a valuable tool to classify and update the thematic maps and to locate and inventory of agroforestry practices and forest monitoring. Langford and Bell (1997) and Kamimura and Rinny (1998) succeeded in detection of agroforestry practices through satellite image. Salam (2000) reported the similar result in mangrove and landuse classification in southern Bangladesh.

Present study suffered from several constraints including fund, equipment, laboratory facilities and time. Adequate fund could help in using recent satellite images. Some essential tools like spectrometer, Differential Global Positioning System (DGPS) could enhance the accuracy of the study. Supervised classification through collection of sufficient data on adequate training sites could classify the study area more sophisticatedly. Salam (2000) conducted both unsupervised and supervised classification for Mangrove forest.

Conclusion and Recommendation

Remote Sensing has become an effective tool for mapping and monitoring agriculture, forestry and other environmental features by the grace of modern photogrammetry and ICT. The success of the study was to derive the way to assess the extent and amount of the agroforestry area in the sal forest using SPOT image. The study covered only an area of 7,400 ha of land from the thickest part of the Modhupur sal forest due to time and fund constraints. A similar study

on the entire area with adequate time and resources could give us the detailed inventory of Modhupur sal forest. The results of this study are indicative of discriminative power of Remote Sensing which could be refined in future with most updated satellite images and can also be used for other type of landuses such as forestry as well as agriculture.

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