Characterization of tea plantations of Barak valley, Assam using remote sensing and GIS

CHAPTER – III

ESTIMATION OF AREA UNDER TEA PLANTATION OF AREA UNDER TEA PLANTATIONS USING REMOTE SENSING
Chapter 3

Estimation of area under tea cultivation using remote sensing

3.1. Introduction

Land cover is what covers the earth and land use describes how the land is used. Land use refers to man’s activity on earth which is directly related to land (Clawson and Stewart 1965). Land cover on the other hand, describes the vegetation and artificial constructions covering the land surface (Burley 1961). Land use is the manner in which human beings employ the land and its resources; it includes agriculture, urban development, grazing, logging and mining. In contrast, land cover describes the physical state of the land surface, which includes cropland, forest, wetland, pasture, road and urban areas (Jaiswal et al. 1999). The term land cover originally referred to the kind and state of vegetation, such as forest or grass cover, but it has broadened in subsequent usage to include human structures such as buildings, pavements and other aspect of the natural environment, including soil type, biodiversity, surface water and ground water (Cheng et al. 2010 and Meyer 1995). Land use /land Cover resources are the bases for various developmental activities on the earth. Land use /land cover assessment is one of the most important parameter to have a meaningful plan for land resource management. Land use/land cover inventories are very important in various resource sectors viz. agricultural, forestry, industries and mining perspective study. Information on land use /land cover in the form of map and statistical data is very useful for spatial planning, management and utilization of land for agriculture, pasture, urban, environmental studies, forestry and economic production etc. The timely, accurate and up-to-date information on land use /land cover can be obtained from various Remote Sensing satellite on a cost effective basis at the shortest possible time. Information on Land use/land cover is the basic prerequisite for land resource evaluation, utilization and management. A considerable
degree of land transformations is being witnessed as a result of growing population pressure and manmade activities on the finite land resources leading to deterioration of the environment. As a precursor, it is necessary to understand the cause and effect of the transformations through scientific studies.

Land cover mapping is a product of the development of remote sensing, initially through aerial photography (Colwell 1960). Some criteria for classification system to standardize the Landuse landcover (LULC) information that could be generated using remote sensing data were developed by Anderson et al. (1976). He proposed a multilevel landuse/landcover classification system i.e., level I, level II, level III and level IV that ranged from nationwide to regional level. The multilevel land use and land cover classification system described has been developed because different sensors will provide data at a range of resolutions depending upon altitude and scale. Some of these criteria apply to land use and land cover classification in general, but some of the criteria apply primarily to land use and land cover data interpreted from remote sensed data. It is hoped that, at the more generalized first and second levels, an accuracy in interpretation can be attained that will make the land use and land cover data comparable in quality to those obtained in other ways. For land use and land cover data needed for planning and management purposes, the accuracy of interpretation at the generalized first and second levels is satisfactory when the interpreter makes the correct interpretation 85 to 90 percent of the time. For regulation of land use activities or for tax assessment purposes, for example, greater accuracy usually will be required. Greater accuracy generally will be attained only at much higher cost. The accuracy of land use data obtained from remote sensor sources is comparable to that acquired by using enumeration techniques.

3.2. Review of literature

The conventional approach for collecting LULC information in the country was compilation of revenue records by the Directorate/ Bureau of Economics and Statistics (DES/BES) of respective states. Topographical maps representing very broadly mapped areas using mainly ground information on 1:50,000 to 1:25,000 scale is another source of LULC information. However this landuse information does not represent current situation of landuse and does not reflect changes as they are based on one-time survey.
However such studies provide the essential background of base data for further classification techniques (Sreenivasulu and Bhaskar 2010, Manonmani and Suganya 2010).

3.2.1. Application of remote sensing in LULC studies and agricultural sector

Remote sensing technology is principally appropriate for mapping land use and land cover as field-based mapping is practically difficult. First satellite-based global land cover maps have already been produced using AVHRR Global Area Coverage (GAC) data (DeFries and Townshend 1994, DeFries et al. 1998, Hansen et al. 2000, Loveland et al. 2000). National Landuse/Land cover Mapping using Multi-temporal Satellite Data was carried out by using IRS P6-AWIFS data of 1:250,000 scales for landuse/landcover mapping (NRSA, 2004). LISS I and LISS II images were used for LULC classification in regional level (Das et al, 2007, Singuluri et al 2008). Digital image processing was used on IRS-1C-LISS-III data to map the land use classes (Kumar et al. 2004), Pandey and Nathawat 2002). Several workers (Navalgund et al. 1991, Navalgund and Ray 2000, Dadhwal 1999, Dadhwal and Ray 2000 and Dadhwal et al. 2002) demonstrated the usage of Indian remote Sensing (IRS) satellite images for crop inventory, crop acreage and production estimation (CAPE) for the major agro-climatic zones of India. Crop classification has been carried out with Landsat Multi-spectral Scanner (MSS) or Thematic Mapper (TM) images (Lo et al. 1986, Badhwar et al. 1987, Tennakoon et al. 1992, Belward et al. 1990, Dwivedi et al. 2005). Some studies on minor crops in India using visual and digital analysis has also been studied (Sinha and Karale 1992, Sharma et al. 1993, Hedge et al. 1994, Panigrahy and Chakrabatry 1996, Kimothi et al. 1997, Païnaik et al. 1998).

3.2.2. Application of remote sensing in tea sector

As tea is a very important beverage, from both management and commercial point of view, an attempt has been made to predict tea yield using remote sensing and GIS and other key parameters in the GIS environment. A study was also carried out in Sri Lanka where LAI of the tea canopy and spectral reflectance of different types of tea clones for different pruning ages were studied in fifty tea fields in the estate and an empirical model
between NDVI and LAI of tea canopy was developed (Rajapakse et al. 2001). An attempt has also been made to develop a GIS anchored web enabled Decision Support System (DSS) for tea enterprises, introduction of precision farming, user friendly IT framework for collection of spatio-temporal data and efficient and smart Enterprise Resource and Planning (ERP) package for decision support at all levels for better management and profitability (Ghosh and Roy 2004). Some work has already been carried out in West Bengal, India where remote sensing has been used for finding the ground water availability in the tea growing areas of Terai Region. The study has revealed that satellite remote sensing combined with other conventional data has great potential for ground water exploration (Duarah et al. 1993). Attempts have also been made to model the influence of irrigation on potential yield of tea where the CUPPA Tea model was validated against the yield data from irrigation experiments carried out on contrasting soil types at Siliguri and Tezpore regions of North-East India (Panda et al. 2003). It was observed that water management is an important factor for augmenting the productivity of perennial crops like tea. A study was carried out on the landuse and ground water potential through remote sensing technique in the Darrang and Sonitpur District of Assam (Bordoloi and Borbora 1994).

An attempt has been made to estimate acreage and condition of tea plantations by using satellite based digital remotely sensed data in visible, near infra-red and middle infra-red spectral regions, in the Nilgiri district of Tamilnadu state. Landsat MSS and TM data, acquired on Dec. 26, 1990 were used in the analysis. Different spectral band combinations, Landsat MSS (1234), TM (1234), TM (2345) and TM (123457) were used for identification of tea plantations (Maruthachalam et al. 1993). A fuzzy knowledge-based image interpretation system for mapping of tea gardens from satellite images has also been carried out using IRS (Indian Remote Sensing Satellite) LISS (Linear Imaging Self Scanner) II geocoded images of a small area in the district of Cachar in Assam. The results obtained from the working of the system in each stage of its operation as well as from the experimental study show that the developed system provides sufficiently accurate information in each stage of its interpretation. It has been found that the performance of the system is better than the minimum classification accuracy required i.e., 85% to justify the operational capability of the system. Thus it can be concluded that
the developed system can be used reliably for mapping of tea gardens from satellite images. (Ghosh et al. 2000). A comparative study has been carried out to evaluate the performance of the narrowband NDVI derived from hyperion hyperspectral with that of derived from IRS LISS III for the estimation of LAI of some major agricultural crops in part of Guntur district, India. It has been found that the narrowband NDVI derived from hyperion has shown better results over the counterpart derived from LISS III (Rao et al. 2007). An approach has been developed for monitoring and assessing tea bush health using texture and tonal variations from Landsat, Aster and LISS III images. The Gray Level Co-occurrence Matrix (GLCM) categorizes the tea into healthy, moderately healthy and diseased tea. The study showed that the GLCM could be used for delineating the affected and non-affected tea patches at different resolutions (Dutta 2006). An attempt has been made to deal with mapping of forest cover and land use using Indian Remote Sensing (IRS) Satellite Linear Imaging Self-scanning Sensor (LISS) II sensor. The study was carried out using visual interpretation elements like tone, texture etc. The map thus delineated shows the spatial distribution of bio-climatic vegetation concentration and the land use patterns of a region of Barak valley, Assam (Ghosh et al. 1992).

3.3 Methodology

The present study was based on the digital image classification for preparation of landuse/landcover map. Various steps involved in the digital classification operation are described below:

3.3.1 Categories of Landuse/Landcover

In order to address the issues associated with classification like class definitions, multiple landuses on a single land parcel, minimum representable area and to standardize the LULC information that could be generated using remote sensing data. Anderson developed some criteria for classification systems. The classification criteria as developed by Anderson et al. (1976) are:- The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should
be at least 85 percent. The accuracy of interpretation for the several categories should be about equal. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another. The classification system should be applicable over extensive areas. The categorization should permit vegetation and other types of land cover to be used as surrogates for activity. The classification system should be suitable for use with remote sensor data obtained at different times of the year. Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible. Aggregation of categories must be possible. Comparison with future land use data should be possible. Multiple uses of land should be recognized when possible.

Land use and land cover classification system for use with remote sensing data as proposed by Anderson et al. (1976):

<table>
<thead>
<tr>
<th>Level I</th>
<th>Level II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Urban or Built-up Land</td>
<td>1. Residential</td>
</tr>
<tr>
<td>2. Agricultural Land</td>
<td>2. Commercial and Services</td>
</tr>
<tr>
<td></td>
<td>3. Industrial</td>
</tr>
<tr>
<td></td>
<td>4. Transportation, Communications, and Utilities</td>
</tr>
<tr>
<td></td>
<td>5. Industrial and Commercial Complexes</td>
</tr>
<tr>
<td>2. Rangeland</td>
<td>6. Mixed Urban or Built-up Land</td>
</tr>
<tr>
<td></td>
<td>7. Other Urban or Built-up Land</td>
</tr>
<tr>
<td>3. Forest Land</td>
<td>8. Cropland and Pasture</td>
</tr>
<tr>
<td>4. Agricultural Land</td>
<td>9. Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas</td>
</tr>
<tr>
<td></td>
<td>10. Confined Feeding Operations</td>
</tr>
<tr>
<td></td>
<td>11. Other Agricultural Land</td>
</tr>
<tr>
<td></td>
<td>12. Herbaceous Rangeland</td>
</tr>
<tr>
<td></td>
<td>13. Shrub and Brush Rangeland</td>
</tr>
<tr>
<td></td>
<td>14. Mixed Rangeland</td>
</tr>
<tr>
<td></td>
<td>15. Deciduous Forest Land</td>
</tr>
<tr>
<td></td>
<td>16. Evergreen Forest Land</td>
</tr>
</tbody>
</table>
In the present study, the analysis was carried out using level I and some level II classes of landcover classification following criteria for classification as adopted by Anderson et al. (1976). The LULC was classified into six classes: forest, tea plantation, other plantation, water and wasteland. As tea plantations is one of the important land use categories as well as important economic crop of Barak valley, Assam, this study was carried out with the specific objective of estimating the extent and spatial distribution of tea plantation using remotely sensed data.
3.3.2 Software and other instrument used

ERDAS IMAGINE 9.1 was extensively used for image processing and interpretation of satellite imagery in this study. Ground truth data was collected by use of Global Positioning System (GPS) Garmin.

3.3.3 Ground truth data collection

Ground truth data were collected by integrated use of global positioning system (GPS) and geocoded False Colour Composite (FCC) of AWiFS. The field survey was carried out from February 2009 to February 2010. This set of ground truth data was used for image classification and validation. GPS was used for taking the coordinates of the study area.

3.3.4 Satellite image acquisition

IRS P6-AWiFS image acquired on January 8, 2008, has been used for the mapping of tea plantations in Barak valley, Assam. IRS P6-AWiFS has a spatial resolution of 56 m, four spectral channels green (0.52-0.59 μm), red (0.62-0.68 μm), near infra-red (NIR: 0.77-0.86 μm) and short wave infra-red (SWIR: 1.55-1.70 μm) and a temporal resolution of 5 days with 740 Km swath width. The study area falls under path-row 115-51 according to the IRS P6-AWiFS image acquisition referencing scheme. Data were procured from National Remote Sensing Centre, Hyderabad.

AWiFS image has a large swath width and inclusion of spectral bands important to crop identification and monitoring, and cost effectiveness per unit area. The limitation of AWiFS data is it produces lower ground spatial resolution (56 m at nadir).

3.3.5 Map Projection and datum

Map Projection is the representation of the longitude and latitude on a flat map. Longitude are semicircles running north - south from one pole to the other. Latitude are circles running around the globe. Longitude measures the angle east to west from the prime meridian, and latitude measures the angle north or south of the equatorial plane. The angular measures of longitude and latitude may be expressed in degrees-minutes-
seconds (DMS), decimal degrees DD, or radians (rad). Some of the map projections used are cylindrical (universal transverse marker, UTM), conic (polyconic, Lambert conformal conic, LCC) and plane (Azimuthal) projections. A datum is a mathematical model of the Earth, which serves as a reference or base for calculating the geographic coordinate of a location. World Geodetic System (WGS) 84 is a referenced system or datum established by the National Geospatial-Intelligence Agency (NGA) of the US Department of Defense.

The projection and datum used for the study area were the Lambert Conformal Conic (LCC) and World Geodetic System (WGS) 84 zone 46 in north hemisphere.

LCC is projected on a cone which cuts at two parallels selected by the map maker. There are many advantages to using the Lambert conformal conic projection over other projections. One advantage for maps using this projection is that all angles are preserved (conformality). Also, shapes (especially small ones) are maintained, there is minimal areal distortion near the reference parallels, and distance is correct along the reference parallels; directions are also fairly accurate. The main limitation is an increase of distortion (of shape, distance, and area) away from the reference parallels.

### 3.3.6 Study area extraction

The study area has been extracted from the satellite imagery using the digitized district boundary of India. Subsequently, classification was carried out.

### 3.3.7 Data examination

This is a very important step required before any digital image processing is done because not all the satellite imagery/data are always good and they are subjected to various Radiometric and Geometric errors. The data acquired from the National Remote sensing Centre (NRSC) is initially examined and checked for Radiometric and Geometric errors. The methods adopted for correcting the Radiometric and Geometric errors is known as preprocessing.
3.3.8 Preprocessing (Data preparation for Digital Image Processing, DIP)

Digital Image Processing involves the manipulation and interpretation of digital images with the aid of a computer. The processing of remotely sensed data involves the following steps: -

3.3.8.1 Image to map rectification/ Base map preparation

Indian Tea Association (ITA) map of tea garden areas of Barak valley was digitally scanned and georeferenced to the satellite image giving same projection using second order polynomial transformation fit and the sub-pixel Root Mean Square (RMS) error was within the acceptable limit (0.03). The ITA map was used during verification of the tea gardens by superimposing over the geometrically corrected satellite image in the digital domain using the swipe tool available with the ERDAS IMAGINE viewer.

3.3.8.2 Digital image enhancement

Image enhancement deals with the individual values of the pixels in the image. The goal of spectral enhancement is to make certain features more visible in an image by bringing out more contrast. Initial display of LISS III data through ERDAS software revealed that the features were not clear/ visible as the contrast of imagery was dull. Linear contrast stretch technique was applied in order to improve the contrast of the image. Look Up Tables (LUT) was created that convert the range of data values to the maximum range of the display device. Based on these LUTs an enhanced image was produced.

3.3.9 False Colour Composite (FCC) generation

Any three bands can be combined to give a colour imagery. If images are taken in blue, green and red bands, they can be combined to give natural colour. In the case of vegetation, the maximum reflectance normally takes place in the IR – red. To take advantage of this, remote sensing data usually combines green, red and IR bands, representing blue, green and red respectively for image formation. This result in what is commonly referred to as False Colour Composite (FCC), since the colour represented is not the actual colour perceived by us (Fig.3.4).
3.3.10 Spectral signature analysis of the optical data

Spectral signature is the variability in the remote sensing data to identify the earth surface features spectrally. The proportions of energy reflected, absorbed, and transmitted will vary for different features, depending upon their material type and conditions. These differences permit us to distinguish features on an image. A graph of the spectral reflectance of an object as a function of wavelength is called a spectral reflectance curve.

3.3.10.1 Generation of spectral profile from AWiFS image

Using the AWiFS image, the spectral reflectance profiles were generated. The classes were identified from the image and then the profiles were generated using the mean digital number (DN) values. The variations in the bands show the reflectance of different classes present in the image.

3.3.11 Digital image classification

Digital techniques facilitate quantitative analysis, make use of full spectral information and avoid individual bias. Simultaneous analysis of multi-temporal and multi-sensor data is greatly facilitated in digital methods. In digital classification, the computer analyses the spectral signature, so as to associate each pixel with a particular feature of imagery.

Multi-spectral classification can be broadly clubbed under two broad categories, viz., supervised classification and unsupervised classification.

In Supervised classification, the analyst, based on the prior information on the spectral characteristics of the classes, trains the computer to generate boundaries in the feature space within which each class should lie. Then each pixel lying within a class boundary is assign to that class. In contrast to this, in the unsupervised classification, the computer is asked to group (cluster) each pixel in the data into different spectral classes on the basis of natural spectral groupings present in the image grey values. Subsequently, the image analyst determines the land cover class associated with each spectral cluster from the prior knowledge already available from ground reference data.
In the present study unsupervised classification technique was adopted. The heterogeneous nature of the study site where no clear demarcation of landuse/landcover type is observed and was not suitable for supervised classification since it resulted in mixing of pixels.

Hence unsupervised classification technique with post classification processing was used for mapping the study area in order to avoid introduced bias in classification process. This technique has been effectively used by several workers in other parts of the world (Singh et al. 2011, Panigrahy et al. 2005a, Soares et al. 2008, Wardlow and Egbert 2008).

3.3.11.1 Unsupervised classification

This type of classification does not utilize training data as the basis of the classification. This classifier involves algorithms that examine the unknown pixels in the image and aggregate into a number of classes based on the natural grouping or cluster present in the image. The classes that result from this type of classification are spectral classes. Unsupervised classification is the identification, labeling and mapping of this natural classes. This method is used when there is less information about the data before classification. The present study adopted the Isodata clustering technique using the ERDAS IMAGINE 9.3 classifier module. ISODATA (Iterative Self-Organizing Data Analysis Technique) is a standard unsupervised classifier (Jensen 1996) that uses minimum spectral distance to assign a cluster for each candidate pixel through a number of iterations (Erdas 1999). The user specifies a convergence threshold, number of desired classes, and number of iterations. Iterations cease when either the convergence threshold or the maximum number of iterations is reached. While avoiding the subjectivity and autocorrelation effects inherent in pre-classification training selection (Campbell 1981, Jensen 1996), the ISODATA method is not completely automated, as it requires that the analyst manually label the resultant spectral classes to information classes. Unsupervised methods, especially ISODATA, continue to be a popular choice for analysts without extensive a priori field knowledge (e.g., for classifying historical or time-series data.
(Lucas et al. 2000, Wang et al. 2002), or for those wanting to avoid introduced bias in classification analysis.

3.3.11.2 ISO Data clustering (Iterative Self Organising Data Techniques)

It repeatedly performs an entire classification and recalculates the statistics. The procedure begins with a set of arbitrarily defined cluster means, usually located evenly through the spectral space. After each iteration, new means are calculated and the process is repeated until there is some difference between iterations. This method produces good result for the data that are not normally distributed and is also not biased by any section of the image.

In the present study six classes have been identified. The higher number of classes ensures maximum spectral separation between the classes. These classes are identified and named after post classification processing.

3.3.12 Post classification processing

The classified information has to be presented suitably for further utilization of the information. For this thematic image is generated after classification. The classified images have speckle like noise (salt and pepper noise) due to misclassification, or scattered isolated classes among dominant classes. When one looks for dominant classes (for planning purpose), a smoother image is desirable. This is generally achieved by smoothing technique.

3.3.13 Accuracy assessment

A major advantage of the remote sensing technology is its ability to quantitatively assess the spatial extent of the ground features. To use this methodology, it is necessary to quantitatively assess the accuracy of the classification. Story and Congalton (1986) have coined two accuracy terms - producer’s accuracy and user’s accuracy. As per this, the number of correctly classified samples of a category, divided by the total number of category observed on ground is called producer’s accuracy. The producer of the classified map is interested in how well a specific area on earth can be mapped.
When the number of correctly classified samples of a category are divided by the total number of samples that were classified as a category, it is called user’s accuracy, because a map user is interested in the reliability of the map, or how well the map represents what is really on the ground.

3.3.13.1 Kappa statistics:

The K (Khat) statistics is a measure of the difference between the actual agreement between reference data and an automated classifier and the chance agreement between the reference data and a random classifier. Conceptually, K can be defined as

\[
K = \frac{\text{observed accuracy} - \text{chance agreement}}{1 - \text{chance agreement}}
\]

This statistics serves as an indicator of the extent to which the percentage correct values of an error matrix are due to true agreement versus chance agreement approaches 0, k approaches 1. In reality, k usually ranges between 0 and 1.

3.3.14 Final map generation

The final map i.e., Landuse/landcover map of Barak Valley was prepared using the Map Composer Module of the ERDAS IMAGINE 9.1.
The detail techniques of LULC classification has been depicted in the form of a flowchart as follows (Fig. 3.1):

Fig. 3.1 Flowchart of the methodology of Landuse/ Landcover classification
Plate: Indian Tea Association Map showing tea growing areas of Barak Valley, Assam
3.4. Results

3.4.1. Analysis of spectral signature analysis of the optical data

The primary objective of spectral signature analysis was to check the separability or to evaluate the spectral separation between landcover classes. The reflectance curve for all the bands were generated to study the spectral response pattern of each landcover classes. In an optical image, vegetation can be easily distinguished from its unique spectral signature. The reflectance of the tea patches and other vegetation classes showed high peak in the NIR band. The low peak shown at the red region of the spectrum are mainly due to the absorption of chlorophyll. Forest give highest reflectance in NIR region as compare to other landuse/landcover classes and low reflectance in visible regions. Tea patches gives lower reflectance value in NIR region in comparison with forest. Other plantation shows lower reflectance than tea patches while agricultural areas shows lower reflectance than other plantation areas. Wasteland patches gives a low reflectance value in NIR region and higher reflectance in visible region as compare to other classes. It may be due to less chlorophyll content in wastelnd area as it has less vegetation. Water gives low reflectance in visible and almost nil reflectance in near-infrared region.

Since the maximum separability was obtained in the NIR region as depicted in Fig. 3.2 and 3.3, above, the analysis was mainly done by extracting data from this band inorder to ensure effective classification of landuse categories.
The following graphs depict the spectral responses of forest, tea and other plantations.

![Graph of spectral responses of forest, tea and other plantations.](image)

**Fig. 3.2:** Spectral response plot of mean digital no. (DN) value of Forest, Tea and Other plantation of AWiFS data

![Graph of spectral responses of Agriculture, Wasteland and Water.](image)

**Fig. 3.3:** Spectral response plot of mean digital no. (DN) value of Agriculture, Wasteland and Water of AWiFS data
3.4.2. Analysis of digitally classified map

The landuse/landcover classes were classified into six classes i.e., forest, agriculture, wasteland, water, other plantations/orchards and tea plantations using unsupervised classification. The classified map is shown in Fig 3.5. The distribution of various landcover classes are shown in Fig. 3.6. It shows forest to be the largest and wasteland to be the smallest landcover categories with 52.2% and 0.1% respectively.

Since the main objective of the study was to delineate and characterize tea plantations, the other vegetation classes which include natural forest, forest plantations, home gardens etc. were merged and classified as forest. The area of this comes to be 52.2% of the total geographical area. Tea plantation was found to occupy 4.2% of the total geographic area of the study area. The forest have thus been represented as open and closed forests depicting that it includes all major vegetation categories. The area statistics of landuse/landcover classes are shown in Table 3.1.

Table: 3.1 Area statistics of landuse/landcover classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Area in ha</th>
<th>Area in km²</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>361476.95</td>
<td>3614.77</td>
<td>52.2</td>
</tr>
<tr>
<td>Agriculture</td>
<td>185839</td>
<td>1858.39</td>
<td>26.8</td>
</tr>
<tr>
<td>Wasteland</td>
<td>898.15</td>
<td>8.98</td>
<td>0.1</td>
</tr>
<tr>
<td>Water</td>
<td>14605.6</td>
<td>146.06</td>
<td>2.1</td>
</tr>
<tr>
<td>Other plantation/Orchard</td>
<td>100786</td>
<td>1007.86</td>
<td>14.6</td>
</tr>
<tr>
<td>Tea plantations</td>
<td>28594.3</td>
<td>285.94</td>
<td>4.2</td>
</tr>
<tr>
<td>Total</td>
<td>692200</td>
<td>6922.00</td>
<td>100</td>
</tr>
</tbody>
</table>
Fig. 3.4 FCC image of Barak valley
Fig 3.5 Landuse/landcover map of Barak valley
Fig. 3.6 Distribution of Landuse/Landcover classes
3.4.3 Accuracy assessment

Accuracy analysis was performed on the classified map. The reference values are based on 255 GPS based ground control points. The error matrix was generated to provide accuracy of individual land use/land cover class. The overall classification accuracy achieved was 92.27%. The kappa statistics was 0.90. Producer’s accuracy and Users accuracy were found to 91.3 % and 93.2 %. The producers’ and users’ accuracy is given in Table 3.2.

Table: 3.2 Accuracy evaluation of landuse/landcover map

<table>
<thead>
<tr>
<th>Class</th>
<th>Reference</th>
<th>Classified</th>
<th>Number correct</th>
<th>Producers Accuracy (%)</th>
<th>Users Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tea Plantations</td>
<td>75</td>
<td>72</td>
<td>69</td>
<td>92.0</td>
<td>95.8</td>
</tr>
<tr>
<td>Other Plantation</td>
<td>80</td>
<td>81</td>
<td>72</td>
<td>90.0</td>
<td>88.9</td>
</tr>
<tr>
<td>Agriculture</td>
<td>33</td>
<td>32</td>
<td>30</td>
<td>90.9</td>
<td>93.8</td>
</tr>
<tr>
<td>Forest</td>
<td>37</td>
<td>36</td>
<td>34</td>
<td>91.9</td>
<td>94.4</td>
</tr>
<tr>
<td>Wasteland</td>
<td>30</td>
<td>28</td>
<td>25</td>
<td>83.3</td>
<td>89.3</td>
</tr>
<tr>
<td>Water</td>
<td>45</td>
<td>45</td>
<td>44</td>
<td>97.8</td>
<td>97.8</td>
</tr>
<tr>
<td>Total</td>
<td>300</td>
<td>294</td>
<td>274</td>
<td>91.3</td>
<td>93.2</td>
</tr>
</tbody>
</table>
Plate 1: Field photos of Landuse/landcover categories of Barak valley

A. Forest  B. Tea plantation
C. Other plantation  D. Agriculture
E. Wasteland F. Water
3.4 Discussion

The primary objective of spectral signature analysis was to check the separability or to evaluate the spectral separation between landcover classes. The reflectance curve for all the bands were generated to study the spectral response pattern of each landcover class. In an optical image, vegetation can be easily distinguished from its unique spectral signature. The reflectance of the tea patches and other vegetation classes showed high peak in the NIR band. The low peak shown at the red region of the spectrum are mainly due to the absorption of chlorophyll. Chlorophyll, contained in a leaf, has strong absorption at 0.45 μm and 0.67 μm. The plant structure contributes to the high reflectance at near infrared (0.7-0.9 μm). This result in a small peak at 0.5-0.6 μm (green color band), which makes vegetation surveys and mapping using imageries possible because such a steep gradient at 0.7-0.9 μm is produced only by vegetation. Water gives low reflectance in visible and almost nil reflectance in near-infrared regions.

The landuse/landcover classes were classified into six classes i.e., forest, agriculture, wasteland, water, other plantations/orchards and tea plantations using unsupervised classification. According to the present study, majority of the area were covered by forest which comprises of 3,61,476.95 ha (52.2 %) of the total geographical area. Forest lands have a tree-crown areal density (crown closure percentage) of 10 percent or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the climate or water regime. It can be further classified into dense, moderately dense and open forest type. In the present study dense, moderately dense and open forest type are classified under one class as forest. According to Champion and Seth (1968) the forest vegetation of Barak valley comes under Cachar tropical evergreen forest (1/1B/C3) and Cachar semi evergreen forest (2/2B/C2). Reserved forests of Barak valley are Innerline Reserve forest, Sonai Reserve forest, Barak Reserve forest, Upper Jiri Reserve forest, Lower Reserve forest, Katakhal Reserve forest and Borail Reserve forest. Common tree species found were *Artocarpus chama, Michelia sp., Lagerstroemia flos reginae, Eugenia jambolana, Gmelina arborea, Ficus sp., Dillenia sp., Cedrela toona, Palaquium sp., Cynometra polyandra, Tetrameles nudiflora* and others. The forest of Barak valley has become fragmented due to
encroachment by forest villagers. The unplanned and unchecked removal of mature, old growth forests and their subsequent replacement by poor secondary growth or bamboo forests have severely affected the quality of forests.

Tea gardens are next most important feature of economy of Barak Valley. In Barak valley tea plantation started in 1856. The region is also interspersed with small hillocks, and the hilly slopes are suitable for tea plantation. The Barak Valley has 107 tea gardens and the net area in 1992 under tea plantation was 33026 ha containing 4.8% of the total geographical area of the region. Tea plantation continues to be an important economic activity providing employment to 10.4 percent according to 1991 census. In 1994, a total of 71,280 persons were employed in tea plantation in Barak valley of which 58,591 were permanent employers and remaining 12, 689 were employed temporarily (Mazumder et al. 1998). Tea gardens are a complex of several landuse categories within a small area. They include tea, water bodies, human settlement area, factory site, plantations, paddy fields etc. along with the major portion under cultivation of tea.

The total area of tea plantations was found to be 28594.3 ha i.e., 4.2 % of the total geographical area. The estimated area comes out to be very close to the estimate of the Indian Tea Board of 2005-2006, which was 33,374 ha comprising of 4.8 % of the total geographical area of the region. Tea patches were difficult to delineate in the study area with a medium resolution image i.e., AWiFS. Spectral reflectance value along with some visual interpretation keys helped in delineating the tea patches.

The agricultural sector plays an extremely dominant role in the economy of the region. 2, 24,063 hectares comprising 32.43 percent of the total reporting area of the region were in agricultural use in 1997-1998. As per 1991 census about 70.3 percent of the total work force of Barak valley was engaged in primary sector (agriculture and allied activities), 6.26 percent in secondary sector and 23.01 percent in the tertiary sector. Thus, agriculture and allied activities are still the predominant source of livelihood of the population. Paddy cultivation is the main agriculture pattern of the Barak Valley followed by mustard seed and sugarcane. Some vegetables like potato, brinjal, cabbage, sweet potato, beans and chillies etc., are also grown on raised lands (tillah) or on the river bank.
slope. Agriculture comprises of 1,85,839 ha i.e., 26.8 % out of the total geographical area.

The delineation of water areas depends on the scale of data presentation and the scale and resolution characteristics of the remote sensor data used for interpretation of land use and land cover. (Water as defined by the Bureau of the Census includes all areas within the land mass of the United States that persistently are water covered, provided that, if linear, they are at least 1/8 mile (200 m) wide and, if extended, cover at least 40 acres (16 hectares). It includes river, lake, reservoirs. The main water bodies in Barak valley are the Barak river and its associated tributaries, Son beel, Chatla lake and other reservoirs. It constitutes 14,605.6 ha i.e. 2.1 % of the total geographical area. The low percentage of water observed in the LULC may be due to dry season as the AWiFS image is of January month when most of the water bodies dry up.

The Northeastern states of the country as a whole and Assam, in particular, are endowed with highly productive soil, suitable climate and enough water besides rich forest wealth. It is ideally suited to produce a whole range of plantation crops, fruits and vegetables, flowers. Barak valley has conducive agro-climatic condition, favorable for growing wide varieties of horticulture crops like Areca nut, Coconut, Pineapples, Oranges, Papaya, Banana and Black pepper. Other plantation includes teak and rubber plantations. It comprises of 1,007.86 ha i.e., 14.6 % of the total geographical area.

Wasteland is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover. In general, it is an area of thin soil, sand, or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the Shrub and Brush category of Rangeland. In the present study wasteland corresponds to 898.15 ha i.e., 0.1 % of the total geographical area. It comprises of under-utilised/ degraded forest (scrub dominated) and under-utilised/ degraded forest (agriculture) in the present study area.