GIS application for tea plantation problems of north-Eastern, India

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Abstract:

While waterlogging is a limiting factor for tea gardens of Brahmaputra plains, soil erosion and landslides are the major problems in the hilly tea plantations of Darjeeling and Barak valley of North-Eastern India. Considering the differences in the nature and extent of soil and water management problems, five major river basins in North Eastern India were selected. Satellite imageries of multiple dates (IRS 1D, LISSIII) between 2004 and 2005 were used. The satellite data were geo-referenced and suitable image enhancement was applied for the delineation and interpretation of different thematic information. Blocking of drainage system, eutrophication of waterways and unplanned extension of tea gardens was the major cause of waterlogging, while denudation of forest areas in upper catchment, loss of grass cover and road construction was responsible for erosion and landslides. Detailed solutions for drainage, erosion and landslides control were suggested.

1. Introduction

The monsoonal climate of North-Eastern India is typified by an alternate wet and dry season, which gives this region a unique opportunity to have too much and too little water. Large tea plantations (about 350, 000 ha) supported by this region have of late become susceptible to continued water logging, droughts, soil erosion etc. in certain areas. Since water follows the catchment for movement, hence drainage problems have to be addressed on the basis of a watershed, which however, has multi-dimensional issues and priorities (Bordoloi, et al, 1996). Thus topographic information is needed at catchment level including the existing natural drainage network. For identifying exact nature of drainage problem and the geographic changes that have taken place over time, very strong and accurate diagnostic tools are required, which are difficult to find with the conventional analytical procedures (Bhagat et al., 2007).
In north-eastern India, basic principles of land use planning were ardently followed in the past, where tea plantations were established, mostly on grant areas situated on high lands, leaving the low lying areas for growing of thatch, bamboo, fuel plants or paddy cultivation. However, with the increasing tendency for expansion of tea cultivation, these areas are being gradually occupied with tea plants (fig 1). As a result, besides facing the high water table problems in these new expansions, it is causing siltation in the natural drainage system in the recent years. Although riparian laws forbid the blocking of the waterways, this is hardly enforced (Bordoloi, 1993). The situation is alarming in case of tertiary

streams, which used to serve as main drainage base of tea estates in the past. Occasional blockades and encroachments of these streams have further deteriorated their carrying capacity. The land locked tea gardens lost their right of accessibility to drainage bases due to long negligence in maintaining the outlet channels that pass through their land holdings. Some of these tea gardens are now adopting pumping system to alleviate the problem. This method of disposal of excess water is again posing problems for the adjoining paddy fields, which are often inundated due to silting/blockage of natural drainage system.
Remote sensing techniques by virtue of its synoptic view, repeatability, wide coverage and cost effectiveness in viewing the inaccessible areas can be a very useful tool to visualize a larger area at a time with its distinctive features and also

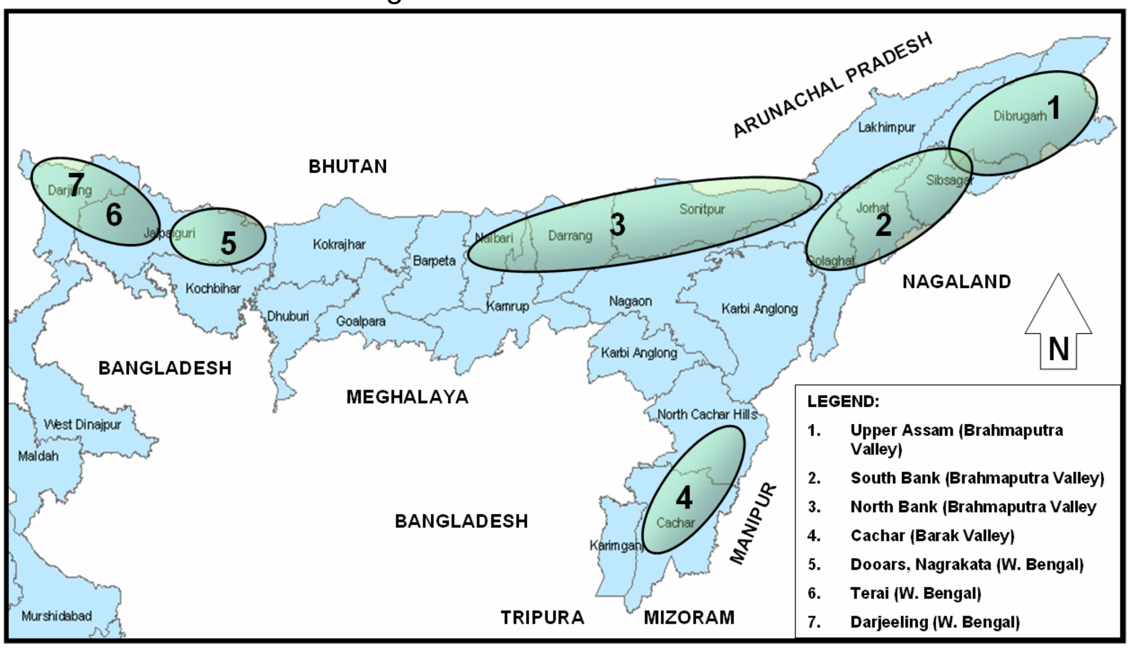


Fig 1. Tea growing areas of north eastern India

the geomorphic changes, if any. Using remote sensing data on a geographic information system (GIS) platform have the additional advantage to store, manipulate, analyze a huge database (spatial and non-spatial) and display/reproduce the data in a more meaningful and usable manner (Bordoloi and Borbora, 1994).
Keeping this in view a study was initiated in the five river basins of North Eastern India with the objective of studying the major cause and extent of water-logging and erosion in tea growing areas.

2. Materials and Methods

2.1 Study area

The area under investigation included a) Tingrai basin of Assam b) Madhura basin of Cachar, Assam c) Nonoi basin of North bank, Assam d) Murti River Basin of Dooars region, West Bengal e) Chhota Rangit watershed of Darjeeling, West Bengal. Two regions viz. Tingrai basin of Assam and Chhota Rangit watershed of Darjeeling, (west Bengal) are described in this paper.

Tingrai basin is located at the border of Tinsukia and Dibrugarh districts of Upper Assam, India. It covers an area of about 457 sq. km between latitudes 27^0 20' and 27^0 30' North and longitude 95^0 15' and 95^0 30' East. More than 35 medium and large tea gardens are situated in this area. Tingrai is a part of vast flat alluvial terrain between Brahamputra river and Patkai hills. Tingrai river is the main drainage channel. Its main tributary is Hugrijan, while Khetorjan, Tipling Nadi, Loharijan and Nagajan are few of the small rivers serving for drainage of water. The area experiences humid monsoonal climate, with hot summers and cool winters. Heavy rainfall (annual average 2850 mm) occurs during monsoon (June to September) months. The alluvial sediments cover large portion of the Tingrai area and conceal the other geological formations. The major reason for selecting this as a study area was, the water logging becoming a serious and speedily aggravating problem in this prime tea growing area.

The Chhota Rangit watershed forms the northwestern part of Darjeeling district of the state of West Bengal and the hills of this region belong to Darjeeling Himalayas. It covers an area of about 196 sq. km between latitudes 27^0 00' and 27^0 08' North and longitudes 88^0 07' and $88^0$15' East. The area is bounded in the north by Jhum and Dharamdin Reserved Forest, on the south by Ghum Simana Reserved Forest, east by Ghum & Darjeeling town, while on the west by Singalila Reserved Forest. The area consists of ten major tea gardens.

2.2 Data source

The main sources of data was LISS IV (5.8 m resolution) mono and LISS III (23.8m resolution) geo-coded standard false colour composite (FCC) digital image of RESOURCESAT 1 (IRS P6), procured from National Remote Sensing Agency (NRSA), Hyderabad, India (fig 2). The statistical data were collected from the tea gardens records and Tea Research Association data files.

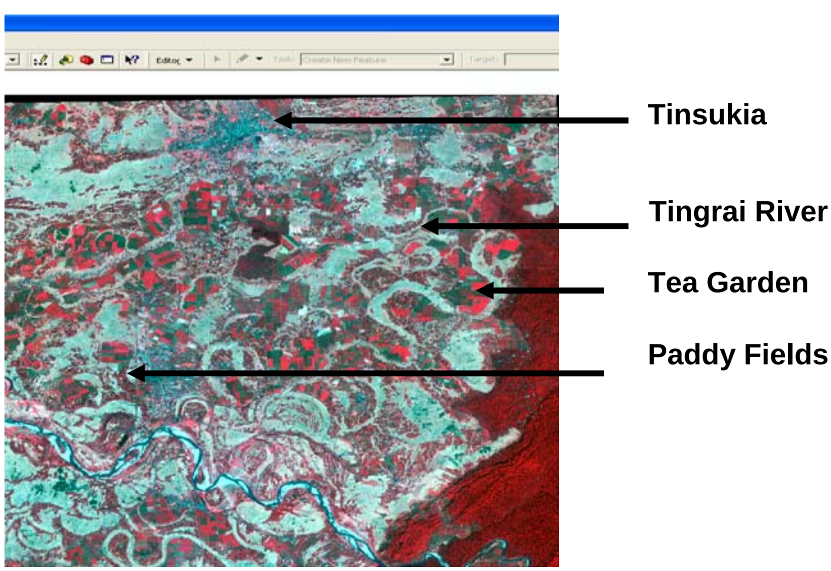


Fig 2. LISS III image of Tingrai basin

2.3 Data processing

By using ESRI's ArcGIS (ver. 9.1), the basic spatial layers, such as administrative boundaries, contours etc. were digitized from topomaps obtained from survey of India (SOI) at 1:50,000 scale. The digital elevation model (DEM) was derived from the interpolation of contour lines and spot heights. The LISS IV mono image was geo-referenced with LISS III FCC geo-coded image. After image enhancement by using 'resolution merging' technique, supervised classification was done by using signatures based on information collected from the base map of both the areas during ground truthing and landuse/land cover map was generated. Further, the geo-morphological map was generated from LISS III and LISS IV mono merged data and also by incorporating field information collected from the field. The drainage maps were generated by an on-screen digitization of the images and also by extracting Survey of India drainage system, which was later superimposed to identify change detection.

2.4 Data analysis

The image was classified using both supervised and unsupervised classification techniques. Sometimes supervised techniques seem inadequate because of complexity and heterogeneity of target feature, narrow cover type spectral separation and limited potential for automated classification.

2.5 Field verification and data collection

A ground survey of the randomly sampled area of Tingrai basin, based on Area Frame sampling Method was carried out to verify and improve classification. The data collection in the field was aided by GPS in order to locate the ground verification points on the image. Attribute information on vegetation, geomorphologic, soil and topographic parameters were also collected. Some spectral confusion encountered for some features - tea and dense shades within shaded areas, sand and gravel with non-irrigated dry land etc. were noticed, which are not unusual for this type of study. The information and knowledge obtained during ground truth studies were helpful in post processing of the classified (supervised) images, which was done to improve and refine the classification. About 10 per cent of the total sample area was randomly selected for accuracy assessment and the overall accuracy was 90 per cent.

2.6. Finalization of maps

Based on pre-field assessment and interpretation, field investigation and available secondary data, final maps were generated. Both visual and digital approaches were conjunctively used for the finalization of maps

3. Results and Discussion

3.1. Land cover and land use pattern

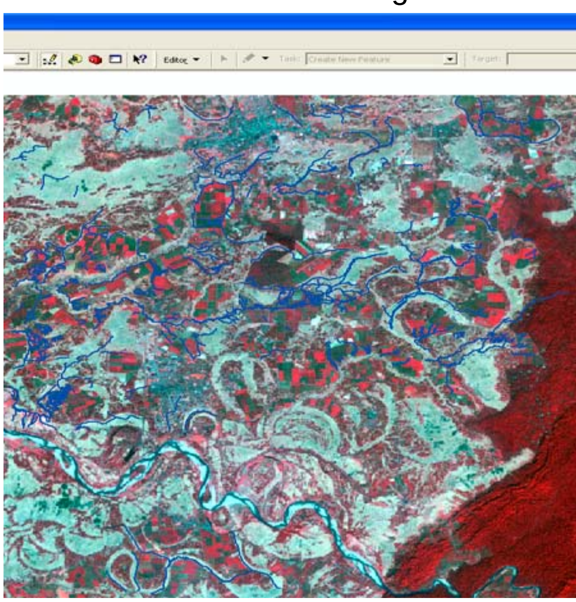
The various land cover classes delineated include tea areas with estate boundaries, built up lands, settled agriculture, open mixed forests, degraded forests, small vegetation, swampy areas, barren areas and water bodies. The spatial coverage showed that 27.78% (127.13 sq km) of the area is covered with tea gardens. Majority of the area (145.38 sq km) are covered with agricultural lands. The image showed that most of them are situated in the newer alluvium created due to shifting of the Burhidihing river. Tea gardens are generally situated at higher elevation than the agricultural lands. But at few places the reverse is true. It was observed that these are the places where the flooding problem is more prominent.

3.3. Geomorphology

The two geomorphic units of the area are younger alluvial plain and older alluvial plain. The younger alluvial plain is mainly found as cultivated fields. Some settlements also fall within the unit. The older alluvial plains are situated comparatively in higher elevation than the younger alluvial plains. All the tea gardens and settlements are situated in the older alluvial plains. Few paddy fields are also observed in the older alluvial plains.

3.2. Drainage

From a comparison of the drainage layers extracted from both the SOI map of 1971 and satellite image of 2004 appeared that most of the drainage in the SOI map has become extinct in the satellite image (fig 3, 4). When the field data was correlated with the drainage maps, it showed that this is happening because of the eutrofication and man made bunds, besides several new sub-divisions coming up as built up areas. This is one of the major causes of floods that obstruct the natural flow of water. Further, the dried drainage networks appearing in the image (locally called *hollas*) are also blocked by this problem and natural flow is obstructed. In some gardens these are used as reservoirs and pumping is



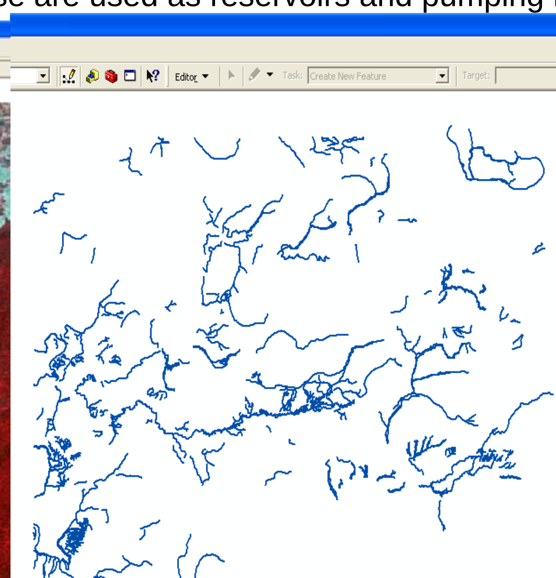


Fig 3. Drainage situation in 1970

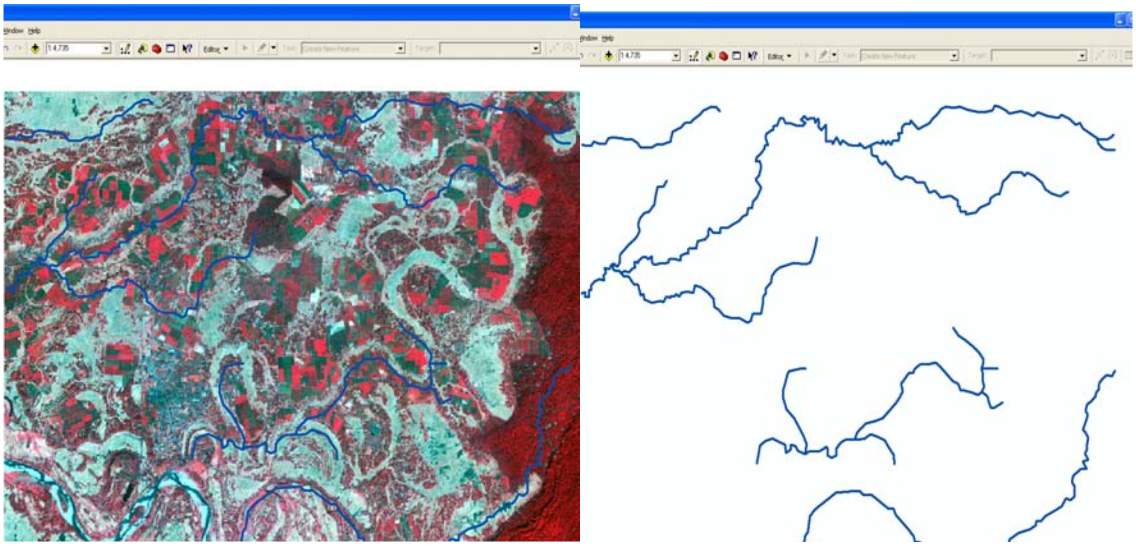


Fig 4. Drainage situation in 2004

done to drain out excess water. In the Tingrai area it was observed that majority of the flood and water logging problems are created largely due to hindrance of free flow of water through natural channels. Also some of the channels have became extinct over the years since no water is flowing, more so because some were diverted by the garden authorities. Following suggestions are recommended to over come the problem.

(i) Impose ban on man made fish bunds to ensure free flow of water.
(ii) A separate project should study the bed level & width of the stream/river so that bridges should not be the obstructing factor in the free flow of water.
(iii) Immediate steps should be taken to clean the unwanted vegetations from channels.

3.4. Soil Erosion

The major soil erosion problems were encountered in the Darjeeling area of West Bengal where tea was planted on steep slopes. Landslide and soil erosion problems were also not uncommon on Cachar (Assam) where tea plantation was done on *Tillas* (small hillocks). The soil erosion problems were mostly confined to young tea areas in Cachar, whereas, these were observed in all areas in Darjeeling. In the soil erosion maps generated, areas with moderate and severe erosion were delineated. More areas with severe erosion were encountered in Darjeeling than in any other basin under study. Erosion protection measures like grassed waterways and contour planting, besides stone embankments were suggested for the steeply sloping areas.

Conclusions

The study indicated that the tea area problems in the North Eastern India can be easily monitored by using a GIS platform. Major problem of water logging of tea areas is caused by blocking of the drainage channels over the years by eutrophication, built up areas and siltation. The solution of this continuing problem is to clear the blocked drainage channels through governmental efforts and planters participation.

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