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Land Use Mapping and Time Series Analysis of Coal Mining Area in Makum Coalfield, Assam, India

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Abstract

Makum coalfield is one the most important coalfield in northeast India and has a very good deposit of sub-bituminous tertiary coal. Rapid underground and opencast mining going on in this area leads to various land use changes in the mine operating areas. Therefore, land use studies are of utmost significant in the present case. This paper demonstrate the various uses of Landsat data for highlighting the various land use classes and identifying the time sequential changes in Makum coalfield, Assam. It was found that the various digitally enhanced product like standard FCC, hybrid FCC 763(RGB), hybrid FCC 764(RGB), edge enhancement and image rationing, are very useful in classifying a variety of land-use classes in Makum coalfield. The outcome of the remote sensing and GIS technique were verified by ground truthing. The various land use classes identified from satellite imagery and field survey are vegetation, opencast mining, transport network, river, and water bodies. The various enhancement techniques used for land-use studies include edge enhancement of NIR and SWIR band images, false color compositing (FCC bands 7, 6 and 3; FCC bands 7, 6 and 4; and FCC bands 5,4 and 3), color manipulation and image rationing (NDVI image). Temporal surface changes that have occurred in the Makum coalfield since 1998, 2007 and 2017 was also been investigated. Spatial analysis of different years' imagery shows an increasing trend of coal mine areas of Makum coalfields. During 1998 the area under mining was estimated to be about 243.49 ha. In the year 2007 it increased to 398 ha and in 2017 it was assessed 438 ha. A total of 194.51 ha of coal mine area increased from 1998 to 2017.Therefore, the present study give an overview of time sequential changes in the coal mining area with the help of satellite imageries and also discuss few RS-GIS techniques that were used for identification of various land use classes on the satellite imagery. It can also be inferred from the study that extensive coal mining had drastically change the facade of Makum coalfield and its surroundings.

Introduction

Coal is one of the most plentifully accessible fossil fuels around the sphere. It plays a key role in various industries such as power, steel, cement, alumina, refineries as well as for domestic purposes. Excavating of coal and associated events provide enormous energy resource. Nevertheless, coal mining unfavorably affects the environment of the area by burrowing and instigating deforestation. As a consequence of ignorance of environmental impacts, lack of rigorous impact assessment and inefficient technologies, the Indian coal mining sector is not on a sustainable path. Improving environmental performance is therefore an essential step towards attaining sustainable mining practices (Saini *et al*., 2016). Unsustainable and over exploitation of coal mines in northeastern states has raised several environmental issues. Proper study related to coal mines is essential for sustainable development and management of coalfields in northeastern states. Analysis of remote sensing imageries plays a significant role in mapping the coal mining areas of the region, to assess the impact associated to mining. Archive of remote sensing data has tremendously encouraged the global community to assess even the inaccessible areas for different time periods. This has high potentiality to study the various aspects related to coal mining.

Among the various states of this region, the maximum amount of coal is produced in Assam and Meghalaya. The coals occurring in this part of the country are unique in character by virtue of its low ash content, high sulphur and strong coking characteristics in some of the coalfields. The three forms of sulfur in Northeastern (NER) Indian coal are -sulfate sulfur, pyritic sulfur, and organic sulfur (Baruah *et al*., 1998). Pyrite (FeS2) is the key portion of the inorganic sulfur existing in coal. The coals of Northeastern India are rich in sulfur (Chabukdhara & Singh, 2016). Coal dumps cause environmental degradation due to the release of potentially hazardous elements through the process of leaching of pyrite (Equeenuddin, 2015). Makum coalfield area had under gone an extensive and rapid underground and opencast mining continuously. It is therefore important that a systematic study is to be carried out in this particular coalfield. Current study therefore was carried out in Makum coalfield, an effort was taken to portrait, the recent scenario of the coal mining areas.

Study Area

In Northeastern region (NER) of India, the Makum coalfield is the major coalfield among all the coalfields. It is situated in the Tinsukia district of Assam and comprises five functioning collieries specifically Ledo, Baragolai, Tirap, Tikak, and Tipong. It lies between the latitude 27015’-27025’N and longitude 95040’-95055E in the outmost flank of the Patkai Pahar. The Makum coalfield has been chosen as the study area (Figure 1), as it has a protracted and varied mining history, which includes both opencast and underground mining bridging over a century. Unplanned mining of coal in the Makum coalfield, has led to severe environmental degradation in and around the area.

Continuously changing landscape of Makum coalfields has gained its important in studying the area.

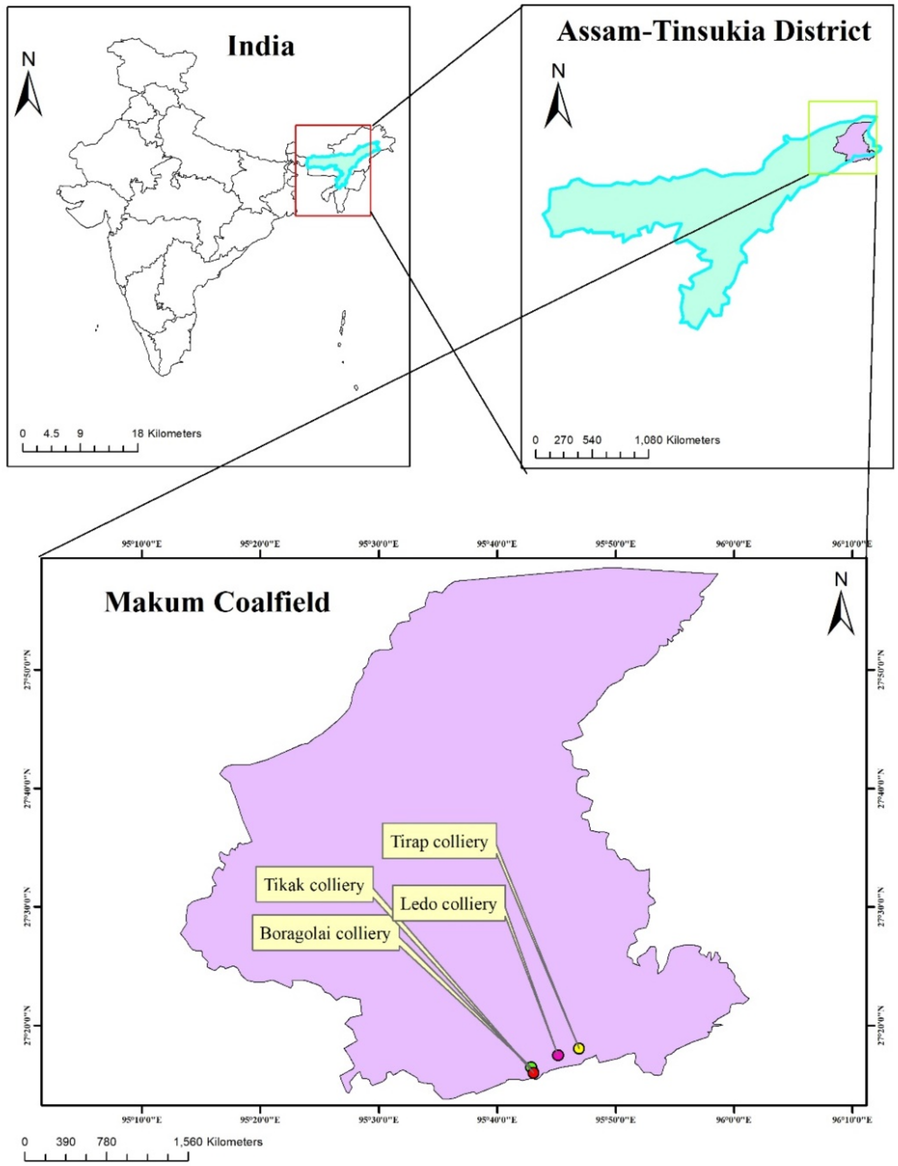


Figure1: Map of the study area

Topography and Drainage: The coalfield is situated laterally in the outmost northern flank of the Patkai-Naga Hill range. The geography is categorized by alluvial plains of the Buri Dihing and Tirap rivers in the north, growing abruptly to heights of 300 to 500 meters to the south. The general elevation above MSL near the plains of Buri Dihing River is 140 m rising to elevation of 500 m on the Patkai-Naga Hill range. The Patkai range is categorized by extremely separated landscape caused by numerous rivers, streams and water channels. The western part of the Patkai range is traversed by northerly flowing Nam dang, Ledopani, Lekhapani and Tipong rivers from West to East and their feeder channels. The rivers cut through the Patkai range creating deep valleys with green forests around and thick undergrowth. The Namdang and Ledopani rivers flow into the westerly flowing Buri Dihing River. The Lekhapani and Tipong rivers release into the westerly flowing Tirap River which in turn meets the Buri Dihing River. The eastern part of the Patkai range in this coalfield is go across by the Tirap River and the Namchik River through its tributary Kathang Hka. The northerly flowing Namchik River combines with Namphuk River and finally flow into the Buri Dihing River. The north of the Patkai range is made by the Buri Dihing River and its tributaries Namchik, Namphuk and Tirap (NEC, GoI. 1987).

Geology and Structure: Makum coalfield is enclosed with rocks belonging to the Tikak Parbat Formation and in the NE and Eastern part the area is enclosed with Tipam Group. Namdang syncline is seen plunging towards east north east. The coal seams of Makum coalfields and its associated strata belonging to the Tikak Parbat formation in the northern region seems to be truncated against the Margherita thrust (GSI, 2016). The coal seams are limited mostly within the basal part of Tikak Parbat Formation and also a few thin coal seams within the Baragolai Formation of Barail Group. A total resource of 452.79 million tonnes has been assessed for the Makum coalfield (GSI, 2016). The general stratigraphy of Makum Coalfields is as given in table1(GSI, 2016).

Table 1. General stratigraphy of Makum Coalfields

Age	Group	Formation	Lithology
Recent and Pleistocene			Alluvium comprising siltstones, clays, gravel beds etc.
Pliocene	Dihing		Alternate coarse grained friable, greyish to greenish grey felspathic sandstones and pebble beds, which are ferrugnous at places and greyish to brownish clays
Miocene- Pliocene	Tipam		Bluish grey to greenish, coarse to gritty, flase bedded, ferruginous sandstone, clays, shales and conglomerates
---unconformity--			
Eocene – Oligocene	Barail	Tikak Parbat	Massive bedded sandstone- marked by thick coal seam in basal part.
		Baragolai	Shale, sandy shale and carboneceous shales with interbedded hardsandstones- marked by thin coal seams
		Nagoan	Well bedded compact flaggy sandstones and subordinate shale
Eocene	Disang		Splintery dark grey shale and thin sandstone

Source: GSI, 2016

Material and Methods

Processing of the data was done for the study of Makum Coafield which involved application of various GIS functions and techniques including contrast manipulation, edge enhancement, colour compositing. For identification of the coal mine areas in different time periods Landsat 8 OLI (2017) and Landsat ETM+ (2007 and 1998) imagery have been utilized. The months selected for all the years of assessment were November and December as these two are normally the cloud free months. After performing the digital image classifications for respective years, mine areas have been extracted and compared. The current study is based on the remote sensing GIS techniques which consist of the following two main subjects (i) Enrichment and image processing of the satellite data and (ii) Identification of the various coal mining area and land use classes in an around Makum Coalfield using satellite data.

Traditional methods use to prepare land use classes may be very costly and time consuming. Surveying can also be very hectic in some inaccessible areas. Changing land use pattern for a particular area also need to be frequently updated. Remote sensing data provides a multi spectral and multi temporal synoptic coverage for any area of interest. The integration of both the objectives i) Identification of various land use classes on satellite imagery and ii)Temporal analysis of coal mining area of Makum coalfields, seems to be very effective, time saving and cost effective to study such coal mining areas.

Results and discussions-

The enhanced satellite imageries and temporal analysis of the study area shows the following results as stated below

Land-use mapping: Delineation of the land use categories in the study area are vegetation, mining area, water body and river. The different land-use classes are recognized in the Makum coalfield, on the basis of satellite image data and field surveys.

Identification and Image enhancement of satellite imageries: Image processing is a significant phase in remote sensing and GIS for feature extraction from satellite data. Numerous types of digital operations carried out on the satellite data and enhanced products generated for identifying land-use classes are discussed concisely.

i. Edge enhancement: Specific spectral bands have been edge enhanced. Principally edge enhanced NIR (Figure 2) and SWIR (Figure 3) images are beneficial for studying the drainage system in the area (Prakash & Gupta, 1998). Few more features like roadways, water bodies, mining area become very distinctive on edge enhanced images. Roadways appear dark grey on NIR and SWIR band images. Road ways are visible on all band images, but are more prominent on the NIR image. Water body seems to be dark in NIR and SWIR imageries. In general the natural ponds occur in irregular shapes nearby to barren areas. On the other hand the artificial water bodies have uniform shapes. The medium size black irregular patches are the coal mining area. The typical sinuous shape of the river and its tributaries are clearly visible. In SWIR band, dense forest appears bright due to reflectance by the leaf constituents. Smoothness is fine to medium on the remote sensing images.

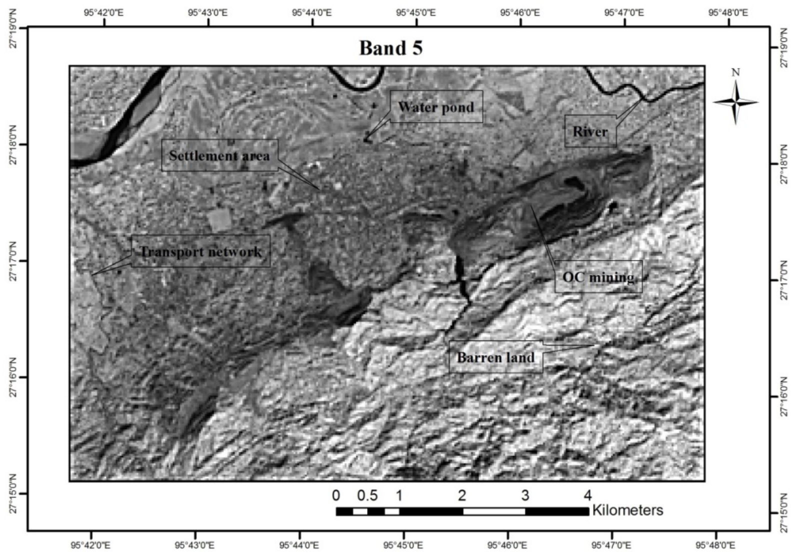


Figure 2: Linearly stretched and Edge enhanced band 5 image depicting different land use classes

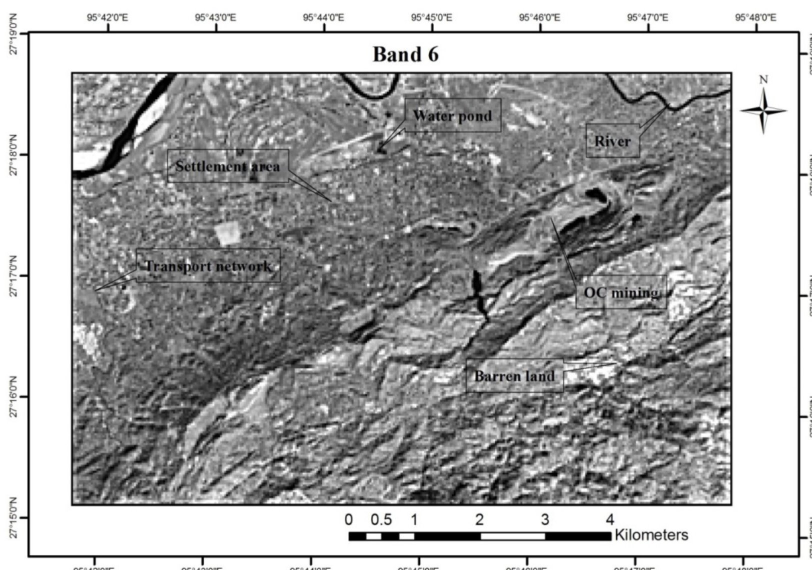


Figure 3: Linearly stretched and Edge enhanced band 6 image depicting different land use classes

ii. Composition of color: The pseudo-color combination was used on the Landsat images in order to highlight the mining areas. This combination stressed the mining areas and differentiated vegetation from barren soil (Charou *et al*., 2010). Various type of FCCs were generated, such as (a) standard FCC (b) Hybrid FCC of OLI bands 7, 6 and 4 (RGB), (c) FCC of OLI bands 7, 6 and 3 (RGB) (Chatterjee *et al*., 1994). The vegetated area in standard FCC (Figure 4) seems to be in shades of red and thinly vegetated areas in faded red. River channels and its tributaries appear to be in dark blue to light blue. Coal mining areas and dumps appear in patches of fainted green to dirty white. Road ways appears in grey uniform linear structure. Settlements and built up areas appear in shades of grey, and showing usual checkered pattern. In FCC, OLI bands 7, 6 and 3 (RGB) (Figure 5) vegetation appears in shades of green and yellow. Opencast mining areas appears brown to brownish-black. Waterbodies seems in deep blue to bluish-black shades. Built up areas and settlements, road ways and river and its tributaries are clearly visible. In FCC OLI bands 7, 6 and 4 (RGB) (Figure 6), vegetation appears in shades of green. Coal mining areas and dumps appears in patches of dark brown to brownish-black. River channels and Water bodies appears dark blue to light blue. Even in this FCC built up areas and settlements, river channels and road ways are clearly visible.

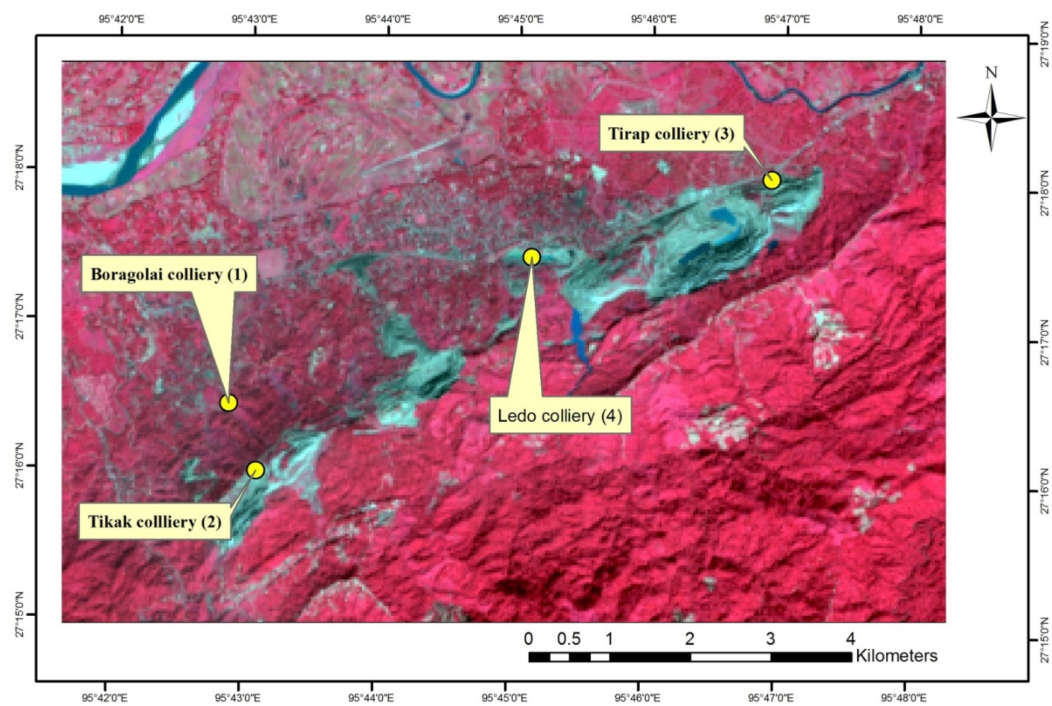


Figure 4: Standard FCC of Landsat OLI bands 5, 4 and 3 (RGB) showing different colliery of the Makum coalfield

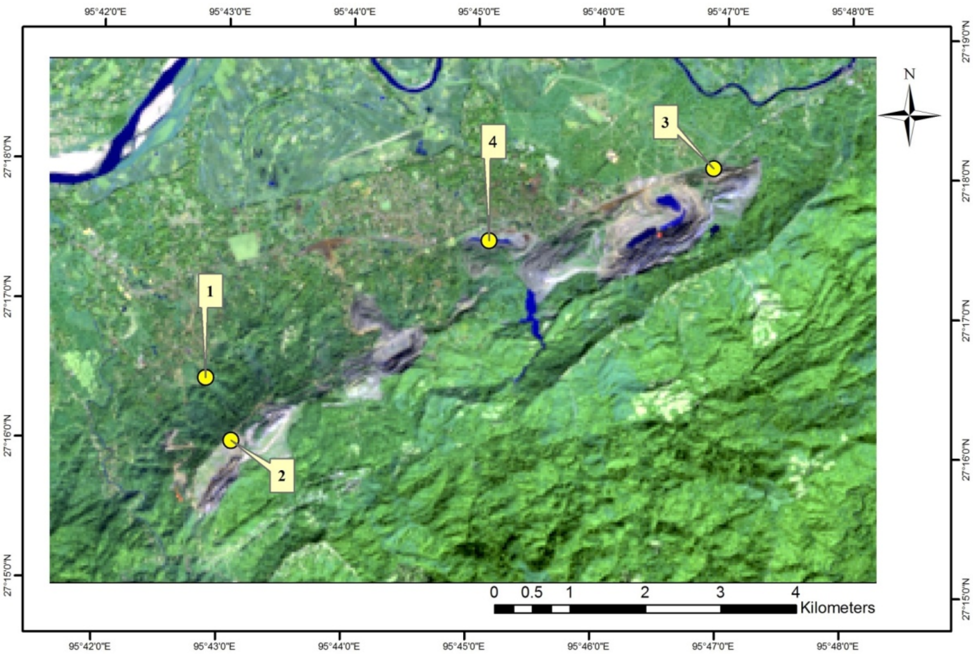


Figure 5: Hybrid FCC of Landsat OLI bands 7, 6 and 3 (RGB) showing different colliery of the Makum coalfield

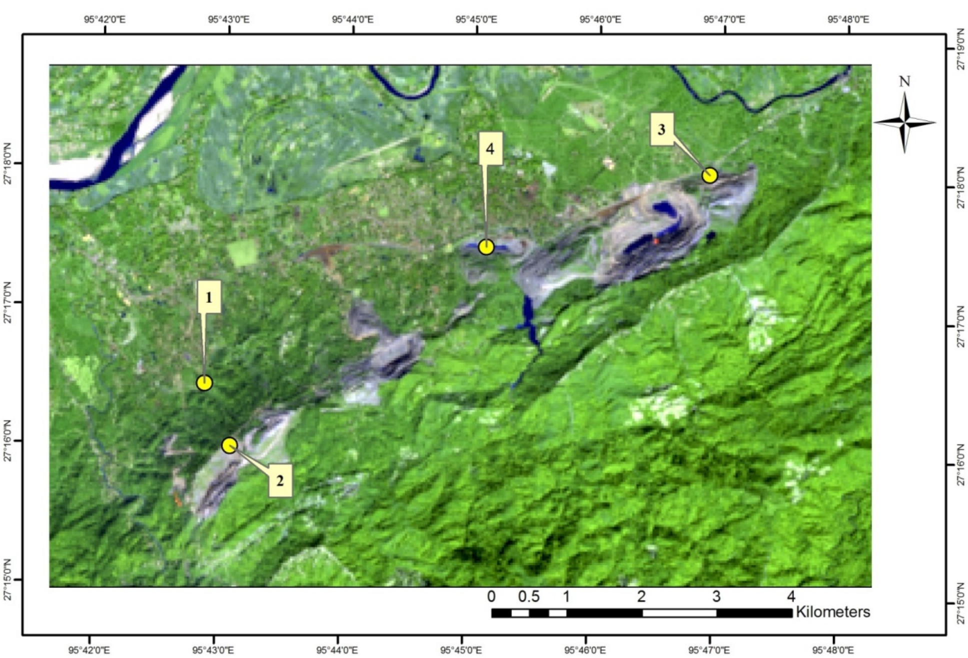


Figure 6: Hybrid FCC of Landsat OLI bands 7, 6 and 4 (RGB) showing different colliery ofthe Makum coalfield

iii. Ratio images: To define the solidity of green area of land, one must observe the distinctive wavelengths of visible and near-infrared sunlight reflected by the plants. In plant leaves, the chlorophyll pigments, strongly absorbs visible light (from 0.4 to 0.7 µm) for use in photosynthesis. The structure of the leaves, strongly reflects near-infrared light (from 0.7 to 1.1 µm). The more leaves a plant has, the more these wavelengths of light are affected, respectively. Almost all satellite Vegetation Indices work on the difference formula to measure the solidity of plant growth on the Earth. The result of this formula is called the Normalized Difference Vegetation Index (NDVI). The formula is: NDVI = (NIR — Red)/(NIR + Red). The calculations of NDVI for a particular pixel always result in a number that ranges from minus one (-1) to plus one (+1), yet, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves (Xijie, L., 2013). NDVI are good indicators of photosynthetic activity on the vegetation surface. NDVI is the ratio of the differences in reflectivity for the near-infrared band (Pnir) and the red band (Pred) to their sum (Das & Das, 2016). Using the formula NDVI=(TM-5-TM-6)/(TM-5+TM-6), the normalized difference vegetation index (NDVI) was generated. In additional to this NDVI was further color enhanced where different land use classes were recognized. In the color enhanced NDVI imagery (Figure 7) the green color represents healthy vegetation, yellow represents barren lands, coal mining areas and dumps appears faded red in color. Linear sinusoidal red features are rivers and streams.

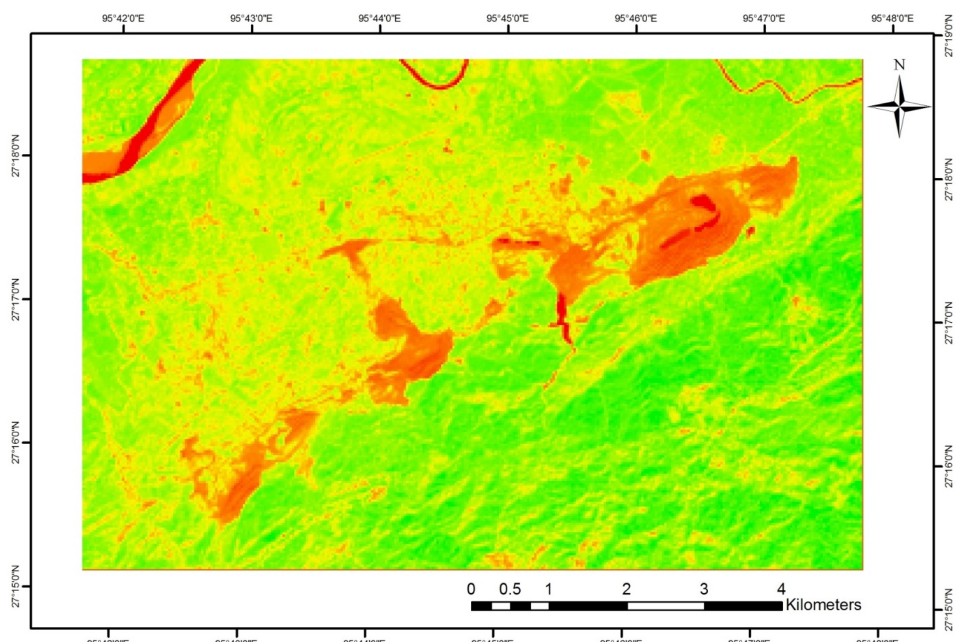
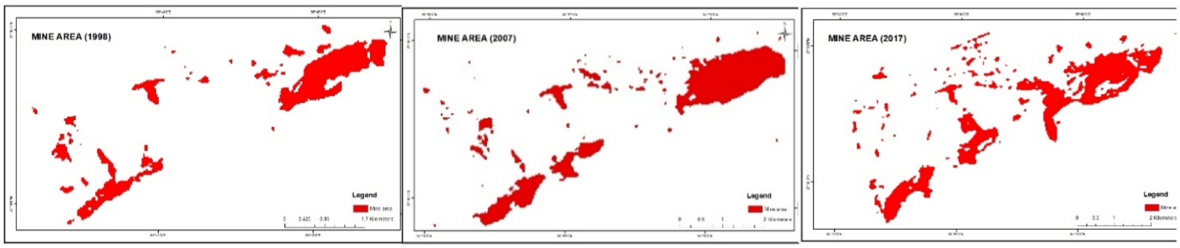


Figure 7: Color enhanced NDVI imagery

iv. The temporal analysis of different year imagery shows an increasing trend of coal mine areas of Makum coalfields (Figures 7 and 8). During 1998 the area under mining was estimated to be about 243.49 ha. In the year 2007 it increased to 398 ha and in 2017 it was assessed 438 ha.



(a) **(b)** **(c)**

Figure 8: Spatial distribution of mine area during (a) 1998, (b) 2007 and (c) 2017

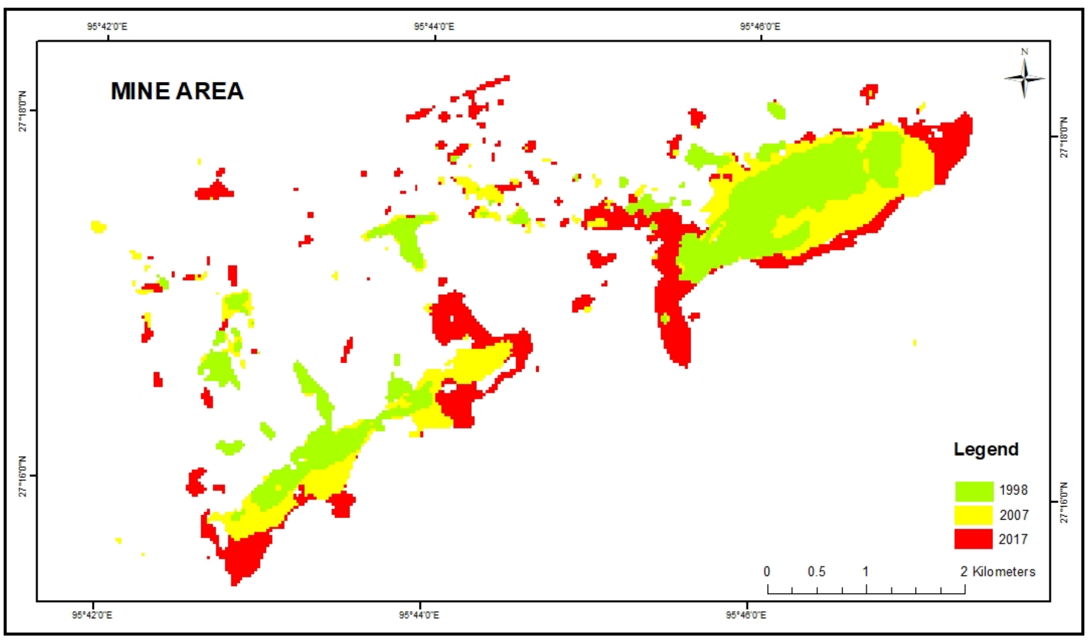


Figure 9: Temporal analysis of coal mining area during 1998 - 2017

The present work demonstrate the various utility of Landsat data for highlighting the various land use classes and identifying the coal mining area within the vicinity of Makum coalfield, Assam. The study was carried out using the various digitally enhanced products like standard FCC, hybrid FCC 763(RGB), hybrid FCC 764(RGB), edge enhanced. Using remote sensing-GIS techniques supported by ground data, a variety of land-use classes were identified in the Makum coalfield. These are vegetation, opencast mining, transport network, river, and water bodies. There are many enhancement techniques for providing info on all land-use types. Useful enhancement techniques for land-use studies include edge enhancement of OLI NIR and SWIR band images, false color compositing (FCC bands 7, 6 and 3; FCC bands 7, 6 and 4; and FCC bands 5,4 and 3), color manipulation and image rationing (NDVI image). Therefore, the study give an overview of time sequential changes in the coal mining area with the help of satellite imageries and also discusses few RS-GIS techniques that were used for identification of various land use classes on the satellite imagery. It can also be inferred from the study that extensive coal mining had drastically change the facade of Makum coalfield and its surroundings.

Authors Contribution: *Baruah Lakhyajit (Ph.D. Scholar) performed the research work, data collection and writing of the manuscript and also the corresponding author; Varun Joshi (Professor) has contributed in final editing of manuscript; Kiranmay Sarma (Associate Professor) has contributed in GIS part and its interpretation including the editing of manuscript.*

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