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COAL MINE FIRE AND TEMPORAL CHANGE IN LANDUSE LANDCOVER PATTERN OF RANIGANJ COAL FIELD AREAS IN WEST BENGAL USING RS AND GIS TECHNIQUE

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ABSTRACT

Mining is one of the bases of economic development in one hand and leads to environmental degradation on the other hand. Coal fire is normal incident in most mining operation. The change in land cover as a result of anthropogenic activities has played a major role in global environmental change and hence has become a hot spot for researchers. The main objective of the paper is to identify and monitoring the coal fires hotspot zones through the use of multi temporal satellite data and show the changes of Landuse Landcover pattern of the study area. The Raniganj Coal Belt area of Paschim Barddhaman district of West Bengal, has been taken as study area in a macro scale. This study adopts the RS and GIS technique as methodology for identify the mine fires depending on the temperature anomaly and also analyse the land use land cover changes of the study area.

KEYWORDS: ***Mine fire, hotspot, land use, land cover, RS and GIS technique***

INTRODUCTION

Mining is one of the primary activities in the world, particularly in the developing countries. It assumes great importance for many reasons. Mining is one of the bases of economic development in one hand and leads to environmental degradation on the other hand. Coal fire is normal incident in most mining operation. Surface and subsurface coal fire is a major problem in many coals producing country like India, Australia, china etc. Mine fire is the normal phenomena of all collieries in the world. Raniganj coalfield, west Bengal is the largest coalfield in India, belonging to the gondwana super group. Initially coal mining was confined to open cast mines only, but gradually it was extended to the underground also. Today coal burns more than 152 meters underground, and is steel slowly spreading in the coal seam. In India, Raniganj some of the subsurface coal fires have already burning over many decades, and now they spreading .coal fire in Raniganj coalfield is either because of fire infection from adjacent fire affected coal seams or anthropogenic activities or spontaneous combustion of coal. Oxidation of coal is an exothermic process and if the heat generated is allowed to accumulate, then the accumulated temperature ignites the coal. This natural process is called spontaneous combustion and is one of the major to its exploitation. Hence, there is need for detection and monitoring of coal fires in coalfields in order to control them effectively. The change in land cover as a result of anthropogenic activities has played a major role in global environmental change and hence has become a hot spot for researchers (Liu et al., 2002). In the present study three different times satellite images of the four blocks in Raniganj coalfields belonging to 1990, 2000 and 2010 is used to identification the coal fire and related land use land cover change. The land use and land cover maps for all the three time periods is created taking into account the various major components that have been affected by the mining activities at Raniganj Coal Field.

Coal mining in the coalfield was started in the last decade of the 19th century. The coalfield having an area of about 450 sq km belongs to Gondwanasuper group of Permian age and comprises Talchir, Barakar, Barren measures and Raniganj formations. It is a sickle shaped coalfield occurring in the form of a basin truncated with a major boundary fault on the northern flank.

Remote sensing technique has proven to be a reliable tool for studying earth surface and atmosphere in many applications. In case of high temperature object conditions, such as forest or mine fire, remote sensing can give a good synoptic view of the area under consideration. Borehole temperature was the main tool to detect subsurface coal fire until the 1960s.The main advantage of this method was that temperature measurement can be done very close coal fires but it was nearly impossible to gather enough data over a large area. In early 60's when airborne and later satellite borne data started to became available, the detection and monitoring of coal fires become easier. (Guha, et al 2008).

OBJECTIVE

This paper aims to:

Identify and monitoring the coal fires through the use of multi – temporal satellite data;

Indentify the hotspot mining zones of the study area; and

Analyses the changes of Land use Land cover pattern of the study area.

LITERATURE REVIEW

Coal mining destroys or significantly alters all the physical features that influence the capabilities of the land. Mining is the only land uses for a long time without reclamation mining operations usually produce large qualities of wastes, overburden and under grade ore materials etc. (Avadhesh Kumar Koshal, Hyderabad, India). Coal as a fossil fuel can catch fire by both natural and manmade causes. spontaneous combustion of coal ,one of the main causative factor for coal fires ,is a natural phenomenon that has occurred repeatedly during the recent geological past , it can occur at any site where deformation, uplift and dissection have exposed coal to the air, several geological processes ,such as faulting ,folding and erosion by river action ,can being the coal to the surface thus lead to coal fires (Roy,et al.2007). Mining operations, which involves mineral extraction from the earth's crust, tends to make a notable impact on the environment, landscape and biological communities of the earth (Bell et al. 2001).The impacts can be seen in the form of deforestation, water and air pollution, changing pattern of rainfall and the local climate,depleting water balance and many others (Mehta 2002; Reddy 1993). Remote sensing of land surface temperature (LST) from the thermal band of Landsat Thematic Mapper (TM) still remains unused in comparison with the extensive studies of its visible and NIR bands for various applications. A proper algorithm for retrieving LST from the only one thermal band of the sensor still remains unavailable due to many atmospheric correction (Qin,et al.2001). Studying changes in land-use pattern using remotely-sensed data is based on the comparison of the time-sequential data. Differences in surface phenomenon over time can be determined and evaluated visually or using digital techniques (Garg *et al.* 1988, SAC 1990). In an area like the Jharia coal field (JCF), where extensive and rapid underground and opencast mining is going on continuously, land-use studies are of paramount importance. This paper discusses the remote sensing-GIS techniques used for identification of various land-use classes on satellite imagery and enhanced products and identification of time sequential changes in land-use patterns (A. parkas and R. P.gupta 25 March 1997*).* coal mine fire is a major problem in Jharia coal field (JCF).The surface and subsurface mine fire areas can be detected with different types of techniques. One of them remote sensing techniques is used to detect coal fires covering a large area using multi-spectral and multi-temporal data. In this paper Landsat-7 Enhance Thematic Mapper Plus (ETM+) and Thematic Mapper (TM) band 6 thermal data is used for detection of surface and subsurface coal fires (Mishra, et al.2010). Land surface temperature (LST) is an important factor controlling most physical and biological processes of the earth. Knowledge of LST is necessary for many environmental studies and management activities of the earth resources .This extensive requirement of LST for environmental studies and management activities of the earth resources has made thermal remote sensing an importance academic topic the last two decades (alavipanah,et al 2007). Surface coal fires which occur either within the coal seam, in piles of stored coal or in spoil dumps on the surface may cause degradation of the land and vegetation, serious environmental pollution, health risk for miners, and local residents etc.(Gangopadhyay et al.2005).

STUDY AREA

The Raniganj Coal Belt area of Paschim Barddhaman district of West Bengal, has been taken as study area in a macro scale. It is known as the birthplace of Indian Coal Mining Industry. It is also second largest supplier of good quality coal in the country at present next to Jharia Coalfield of Jharkhand state. The Raniganj Coal Belt area is located within the Geographical limit of $23^{0}46'$ north to $23^{0}89'$ north latitude and $86^{0}78'$ east to $87^{0}43'$east longitude. Major parts of Jamuria, Pandabeswar and Andal blocks, where mine fire and changing the land use land cover is a prominent problem, has also been considered as areas under special emphasis. This study area is bounded by river Ajay in north and river Damudar in the south.

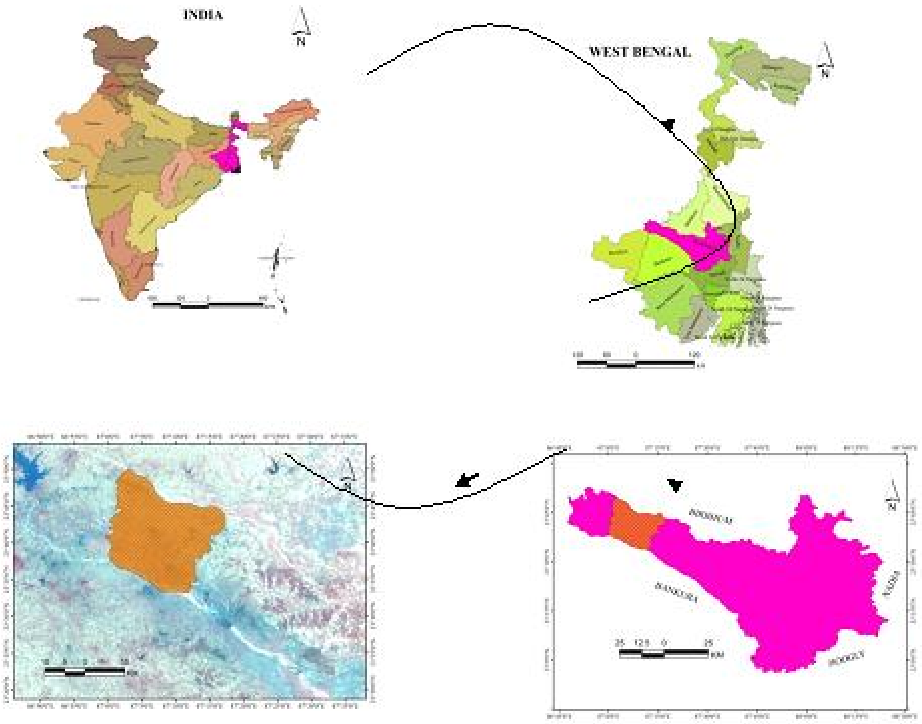


Figure- 1: Location Map of the Study Area

GEOLOGY

Most of the coal in Raniganj coal belt has been deposited in the Gondwana period. Different depositional strata, coal thickness, quality of coal have been occurred by different geological formation.The Raniganj coal belt belongs to the Damudar Valley coal fields, in the Gondwana system. It comprises sedimentary rock formations excepting the recent and sub-recent alluvial and lateritic deposits. These sediments belong to the Lower Gondwana. This sedimentary succession is complicated by the presence of crystalline metamorphic and intrusive rocks. They are present with two phases of igneous activity resulting in the intrusion of the numerous mica perodotite and dolerite dykes and sills, which intersect the Lower Gondwana sediments.

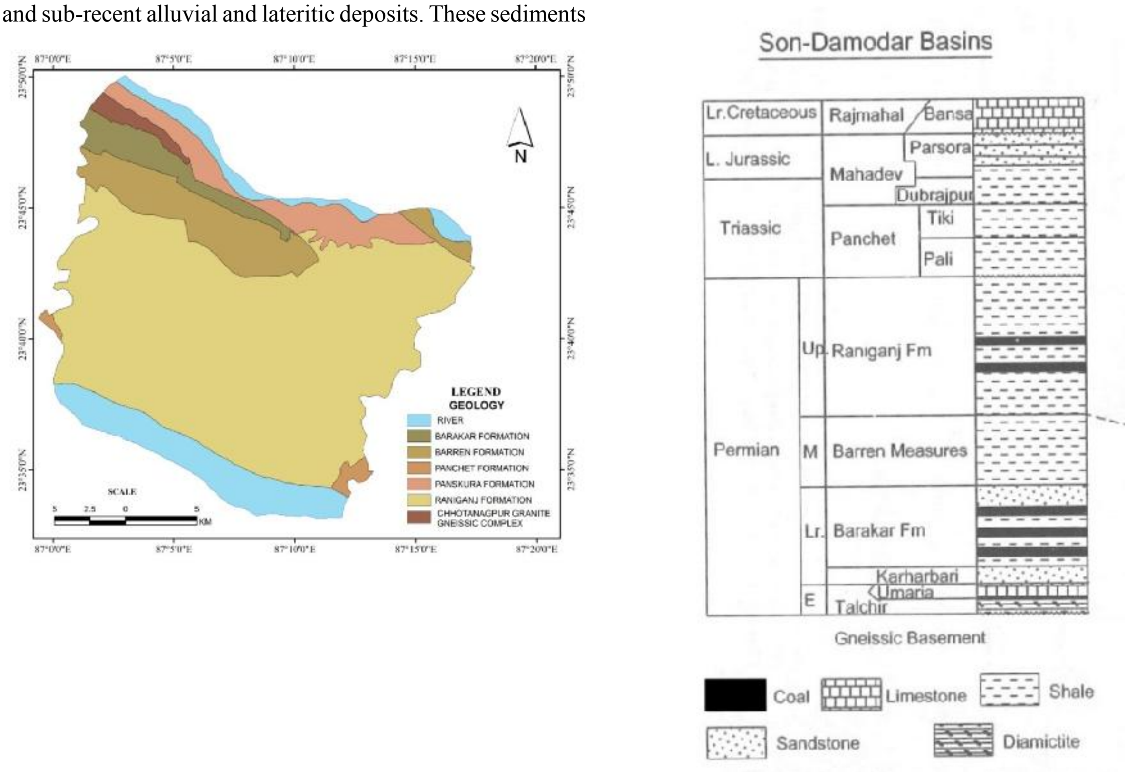


Figure-2: Geological Map of the Study Area with Litho – stratigraphic Column of Gondwana Succession

In Raniganj coal belt, Permocarboniferous rock formation of Talcher, Barakar Barren measures, Raniganj and Panchet series are exposed at many places. Within the Gondwana sequence, the Barakar and Raniganj formation contain all the coal seams in this coal belt. There are altogether eight regional coal seams in Barakar formation whereas, The Raniganj formation contain ten regional coal seams. Barakar seams range from 1 – 30 meters In thickness, while the Raniganj seams vary in thickness between 0.70 meters to 30.35 meters.

CLIMATE

Climatically the area is sub-humid and tropical which have three seasons that is summer, rainy and winter in succession. The annual rain-fall is 1206 mm. and main annual temperature is around 25.4^0 C. The maximum temperature often goes over 40^0C in summer (May-June) and minimum temperature below down 10^0C. During May and June, the area is subjected to cyclonic storms locally called Kalbaisakhi.

TOPOGRAPHY

The area is characterized by very gently undulating plain surface with an average height of ground level daring between 70 to 160 meters from mean sea level. The relative relief of the area ranges from 2 meters from more than 80 meters, which indicates that in Raniganj coal belt, relative relief is low over most of the area. It is between 5 to 10 meters. The area is gently sloping down towards east and south east.

SOIL

Soil condition is very poor in mining region due to climate, geology and natural phenomena. The Raniganj coal belt belongs to sub-tropical climate. The whole area consists of barren, rocky and rolling country with literate soil due to huge leaching. Gritty soil blended with rock fragments has been formed from the weathering of pegmatite, quartz veins and conglomeratic sandstones. The soil is of reddish color, medium to course in texture, acidic in reaction, low in nitrogen, calcium, phosphate and other plant nutrients. Water holding capacity of this soil increases with depth as well as with the increase of clay particles. Although the soil is generally not fit for cultivation, paddy can be grown in the areas which become waterlogged during the monsoons. The soil generally supports plantation with necessary additives and care.(Ref: PUBLIC HEARING DOCOMENT on EIA & EMP, ECL, 2010).

DATA USED

These objectives are fulfilling by the some data and many processes and techniques, so these data are required for this study.

Satellite Data:

Here, Landsat TM, and ETM+ are used to fulfill this work and the using data was collected from USGS web site.

- Landsat 5 TM imagery from band 1 to 5 &7 on 1990 & 2010. Resolution 30 meter.
- Landsat 7 ETM+ imagery from band 1 to 5 & 7 on 2000. Resolution 30 meter.
- Google Earth image.

DATA USE	YEAR	SOURCE
LANDSAT 5	1990 & 2010	GLOVIS
LANDSAT 7	2000	GLOVIS
Google Earth image	2015	Google Earth

Table-1: Details of the satellite data used in this study

Collateral Data

- Survey of India Topographical sheets on 1:50000 of my study area. Sheets No: 73M/1,73M/2, 73M/6.
- Geological Map (GSI, Kolkata)

Instrument Used

- Garmin GPS 72:gps was used to collect the geographical co-ordinates of the observed field location during the ground truth study for collecting coal mines, coal field land use land cover information.

Software's Used

- Arc GIS 9.3.
- ERDAS IMAGINE 9.0
- ENVI 4.7, 5.1
- Google Earth
- Others: MS-Office-2007(MS-word, MS-Excel) for documentation and calculation.

Sensors	Spectral bands	Spatial resolution	Spectral region	Time of acquisition
Landsat 5- TM	Band 1: 0.45-0.52µm	30M	Blue	11.04.1990 & 13.02.2010
	Band 2: 0.53-0.60µm	30M	Green	
	Band 3: 0.63-0.69µm	30M	Red	
	Band 4: 0.75-0.90µm	30M	NIR	
	Band 5: 1.55-1.75µm	30M	SWIR	
	Band 6: 1.04-12.5µm	120M	TIR	
	Band 7: 2.09-2.35µm	30M	SWIR	
Landsat7 – ETM+	Band 1: 0.45-0.52µm	30M	Blue	29.03.2000
	Band 2: 0.53-0.60µm	30M	Green	
	Band 3: 0.63-0.69µm	30M	Red	
	Band 4: 0.75-0.90µm	30M	NIR	
	Band 5: 1.55-1.75µm	30M	SWIR	
	Band 6: 1.04-12.5µm	60M	TIR	
	Band 7: 2.09-2.35µm	30M	SWIR	
	Band 8: 0.52-0.90µm	15M	Panchromatic	

Table-2: Characteristics of the Landsat-5 TM & Landsat-7 ETM+

METHODOLOGY

Remote sensing is the time consuming and low cost modern technique for identify various geo-hazard like volcanic activity, forest fire, drought area measurement, ocean temperature and also identify the mine fires depending on differential thermal signature on satellite imagery. This study area adopts the following methodology for identify the mine fires depending on the temperature anomaly and land use land cover changes of the study area.

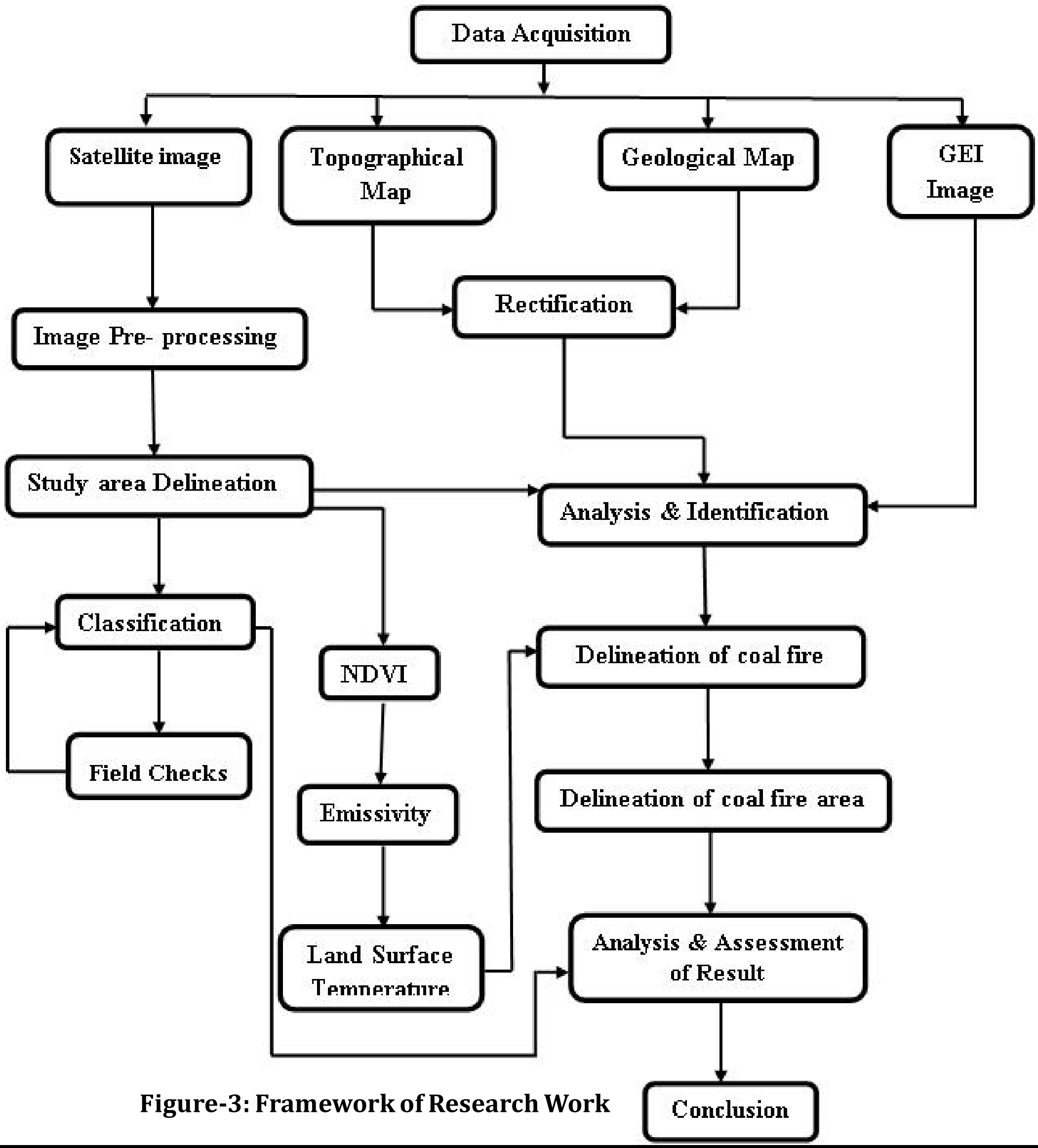


Figure-3: Framework of Research Work

COAL FIRE ZONE IDENTIFICATION USING REMOTE SENSING TECHNIQUES

Use thermal region of electromagnetic spectrum (EMS), for detecting various high temperature hazardous events, such as coal fire, forest fire, oil well fire and volcanic eruption etc. Remote sensing technique in thermal band offers a cost effective and time saving method. It is possible to detect surface and sub-surface coal fire zones by computing land surface temperature (LST) from thermal band signature of the satellite images.

Coal fire can cause higher temperature of land surface than the surrounding area. In the case of a sub-surface coal fire, the surface temperature also depends on rock, topography, soil types, geology, local atmosphere, crack zone etc on the surface and depth of fire.

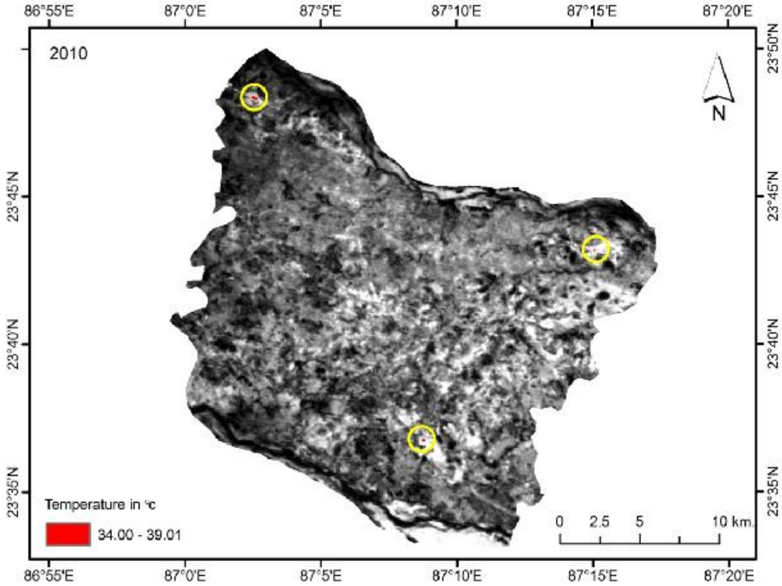


Figure-4: Coal Fire Map of the Study Area (2010)

The coal fire map produced for the years 2010 (Fig- 4) gives an overview of the fire affected areas of the study area. This map was prepared by overlaying and analyzing land surface temperature map, Geo eye image and residual temperature anomalies over regional land surface temperature. Field verifications and research publications, most of the major coal-fire affected areas and high thermal anomalous region of the study area. According this map reveled that coal fires were mostly developed in north-western, north-eastern and southern Part of the Study Area.

Estimation of Mining Growth Using Overlay Analysis

Coal mining areas anywhere in the world face some common problems like changing land use patters due to increase in mining activities, surface and subsurface fire due to natural and mining induced factor and other adverse environmental impacts. The growth of mines in the study area was analyzed for the different time period of 1990 to 2000 and 2000 to 2010.

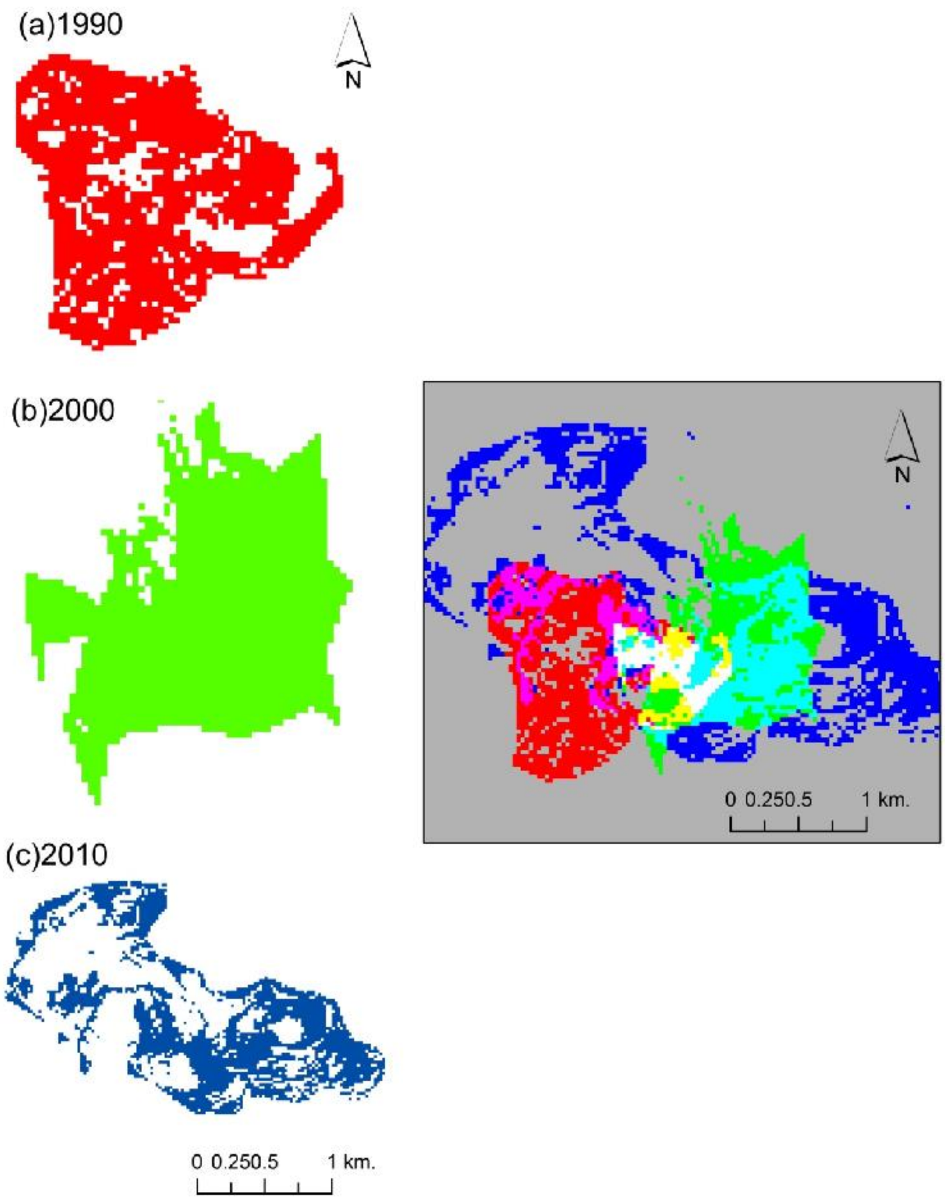


Figure -5: Mining Growth of the Study Area (A) 1990 (B) 2000 (C) 2010

INDEX

Sl. No	Color	Description
1		Mines present on or before1990
2		Areas mined between 1990 and 2000
3		Areas mined between 2000 and 2010
4		Active mine present in 1990 to 2000
5		Areas mined later between 2000 to2010
6		Mine suspended in 2000 and re-excavated before 2010
7		Areas mined since early times (in or before 1990)

The historical and present status of mines as shown (Fig-:05) has been represented by different colors. The year wise status of mines as shown in index, field area has shown where abandoned mines refer to the mining areas which were present during previous years but these have been closed during later period. The re-excavated mines indicate the mining areas which were abandoned but again excavated during 2010 and the active mines refer to the mining areas which are present in 2010.

These Images of the active mining areas were raster zed as binary images and coded as red for 1990, green for 2000 and blue for 2010. They were then combine together to get final mining change area as indicated in the table "Index". This fusion product indicates different colors as different meanings. Areas mined since early times (in or before 1990) area represented white, while mine suspended in 2000 and re-excavated before 2010 as magenta. Active mines present during 1990-2010 refers, the mining areas were present in the time period of 1990 to 2010.These active mines area represented in yellow color. Active mines grown during 2000-2010, these can be represent that the mines are active in 2010 and these type of mines area are grown up the time period of after 1990 to 2010 these are indicate in cyan color.

Indentify the Hotspot Zone in Mines Area

Coal mine fires are normally not hot enough to be picked up in the short-wave infrared wavelengths, and there show only enhanced brightness temperature in the thermal infrared channel. In order to quantify these, the temperature difference of the hotspot relative to the surrounding mean background pixel temperature was computed by a moving window kernel (high cut filter). Coal mines hotspots were picked up from the residual values computed by subtracting low frequency regional temperature from the original LST image.

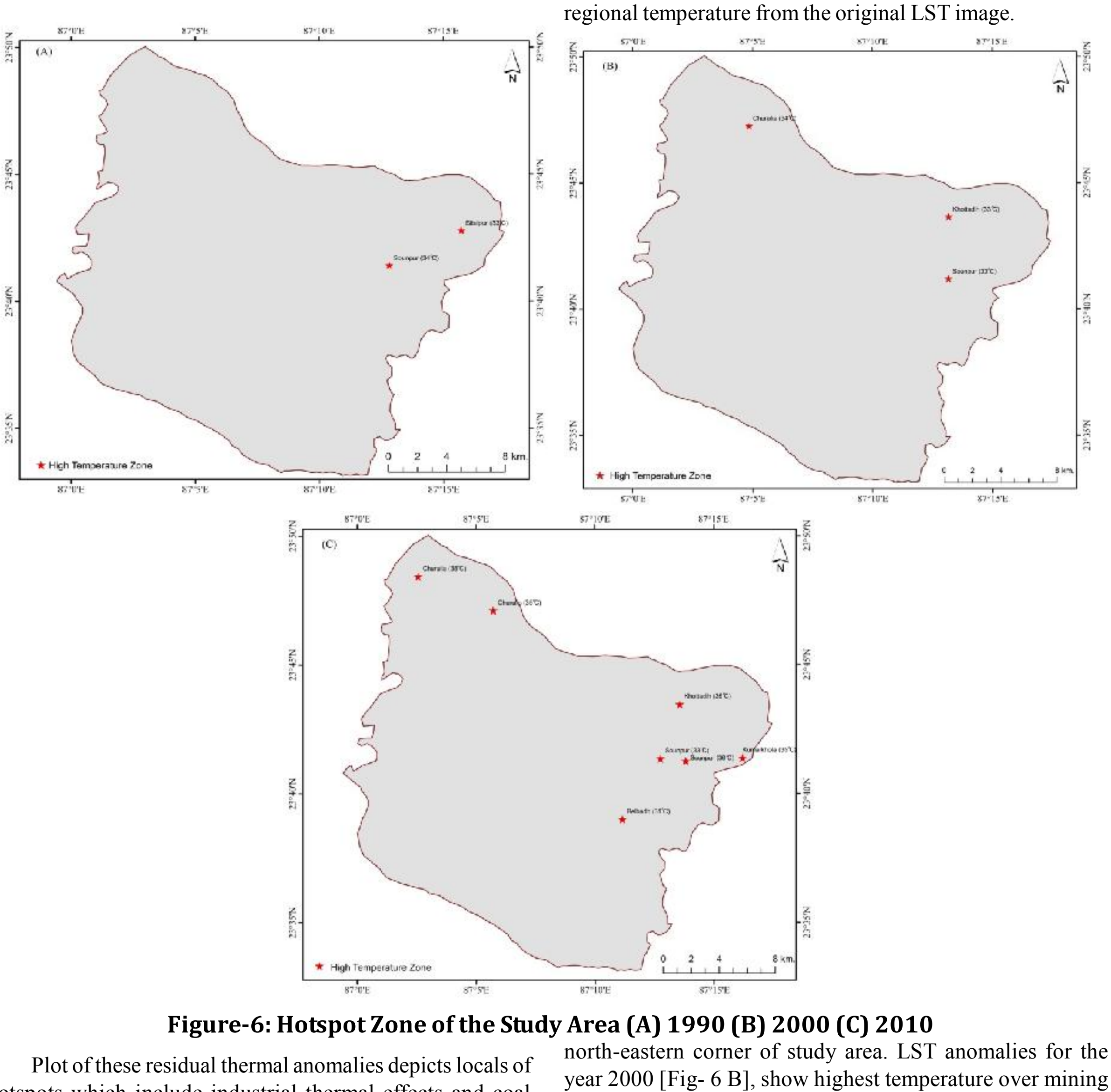


Figure-6: Hotspot Zone of the Study Area (A) 1990 (B) 2000 (C) 2010

Plot of these residual thermal anomalies depicts locals of hotspots which include industrial thermal effects and coal fire zones etc (Fig- 6). High temperature anomalies due to effects of activities such as, industrial heat discharge and cluster of chimneys of brick kilns of the study area were excluded.

Temperature anomalies 1990 [Fig- 6 A] depicts high temperature zones over active mining area. High temperature was observed over Sitalpur (33°C) and Sounpur (34°C) in north-eastern corner of study area. LST anomalies for the year 2000 [Fig- 6 B], show highest temperature over mining areas in the northern part Churulia (34°C) and north-eastern part Khottadih (33 °C), Sounpur (33°C). In the year 2010, larger parts of the study areas have witnessed hotspot zones than previous years [Fig- 6 C]. Eastern part of Churulia (35°C), north-eastern (Khottadih (35°C), eastern part Sounpur (33°C & 36°C), Kumarkhola (35°C), Belbadh (31°C) and north-western part (38°C) were identified as hotspot zones.

CHANGING PATTERN OF LAND USE / LAND COVER

Land is one of the most importance natural resource on which all human activities are based. The earth surface covers another type of natural element like (Vegetation, River, Hill, Mountain etc.) called land cover, when man uses this element require there development & need for living thinks, then called Land use like (Agriculture, Settlement, Industry, Mining etc.) Land use land cover map was prepared on the basis of image interpretation carried out based on the satellite data for the year 1990, 2000 & 2010 with the help of Landsat – TM & Landsat ETM+ satellite images. Following land use/land cover classes' area identified in study area through Remote Sensing and GIS techniques –

Mining area: those areas presently under coal mining activity.

Agriculture land: land under cultivation where various types of agriculture activities are practiced.

Built-up land: areas where human settlements exits at present.

Water body: areas filled with water.

Sparse vegetation: land that cover with vegetation.

Waste land: areas where cover river bank and also fallow land.

Dense vegetation: land that have been protected or unprotected as vegetation or forest land.

Land cover is made by the nature it is change by the man due to need for their life. My study area major economical source is production of coal. For this region increase coal mining area, this effects on forest area, agriculture land, Settlement etc. For change detection analysis multi-temporal satellite data needed, in this study we use Landsat – TM (1990 & 2010) & Landsat-ETM+ (2000) satellite data for time sequential change in these years. Land use & Land cover map for the year 1990, 2000 & 2010 present in Figure -7, Figure-8, & Figure –9 respectively.

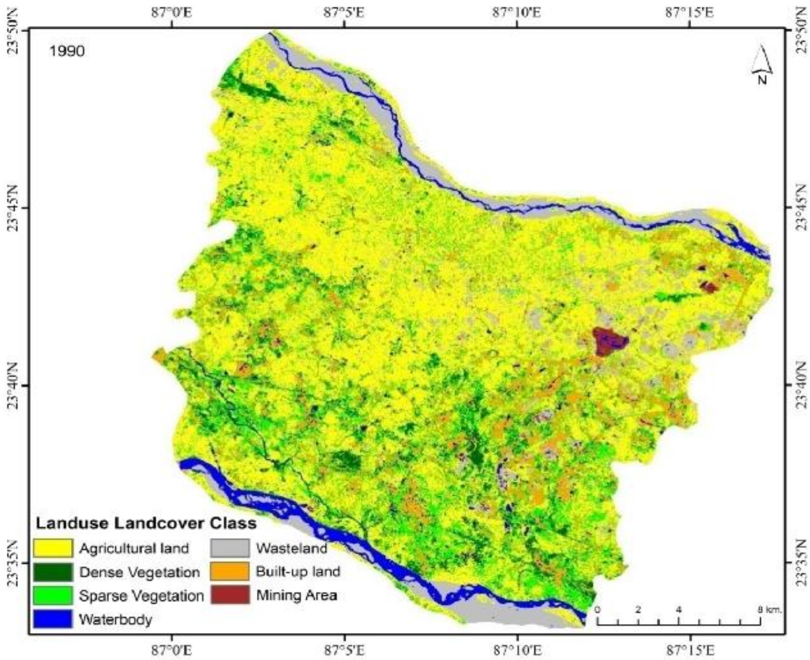


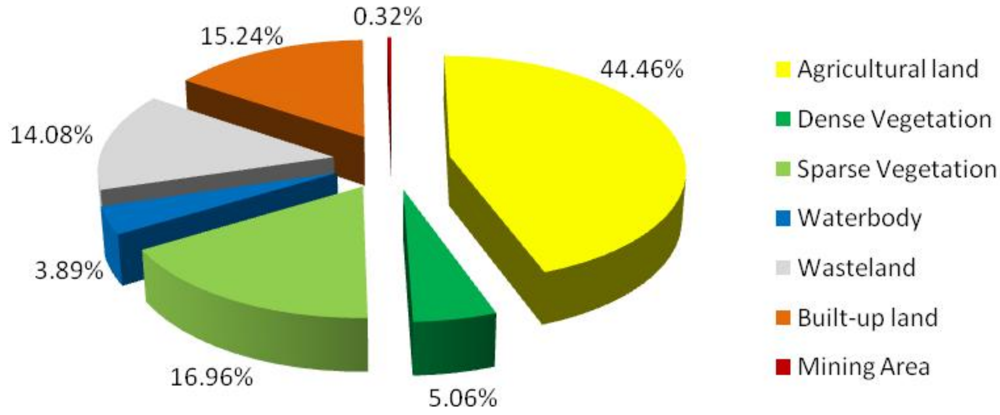
Figure 7: Land Use Land Cover Pattern of the study area (1990)

According to land use/land cover classification for the year 1990, it is revealed that mostly covered by agriculture land & sparse vegetation. Dense vegetation are mainly found in north-eastern and southern part of the study area. Two major river (Damudar & Ajoy) is observed in southern & northern boundary of the study area. Land water body (pond, reserves etc.) is present in a scatter way in whole study area. Waste land found in vicinity of coal mining area and north-eastern part. In the southern, south-eastern & south-western of the study area represent settlement and built-up land. Coal mining area found in north-eastern part of the study area. Total area of land use/land cover and % of each class present in table 3:

Sl.No	LULC Types	Area in hectares	Area in %
1	Agricultural land	24515.19	44.46
2	Dense Vegetation	2788.02	5.06
3	Sparse Vegetation	9350.82	16.96
4	Water body	2146.77	3.89
5	Wasteland	7765.65	14.08
6	Built-up land	8400.87	15.24
7	Mining Area	173.7	0.32
	Total	**55141.02**	**100**

Table 3: Land Use/Land Cover Pattern of the Study Area (1990)

Percentage of Area 1990



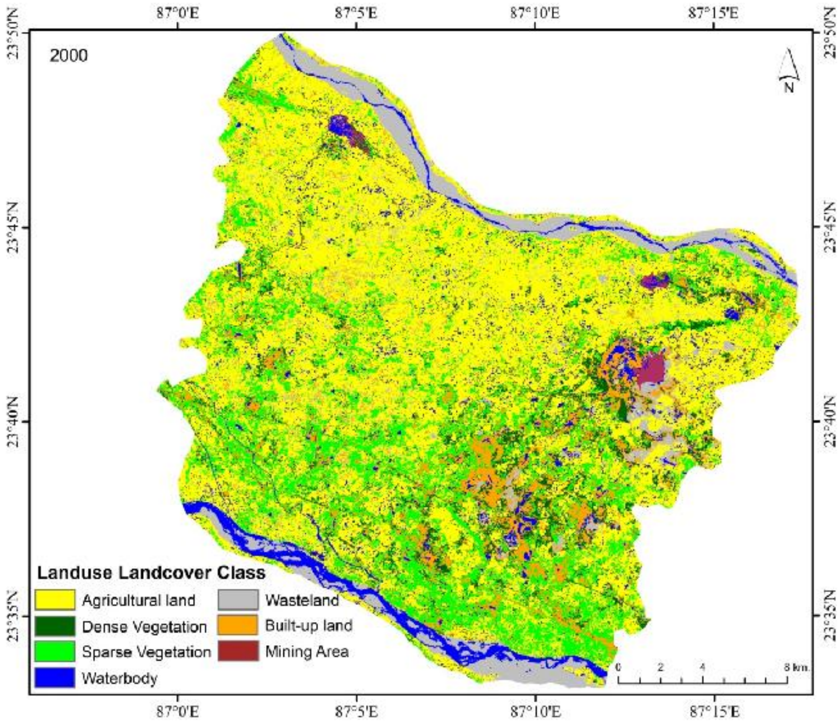
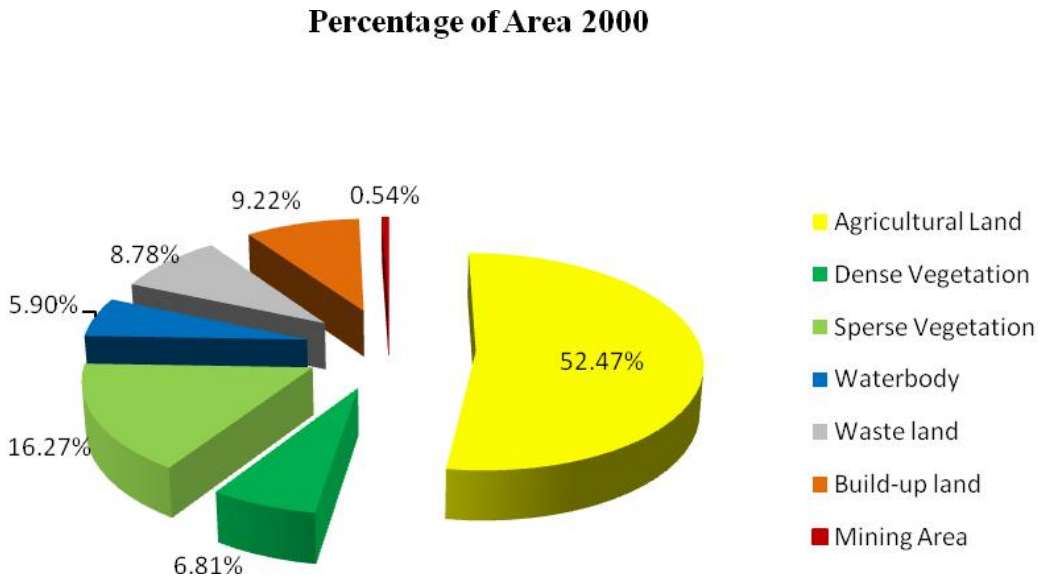


Figure- 8: Land Use Land Cover Pattern of the study area (2000)

According to land use/land cover classification for the year 2000, it is revealed that mostly covered by sparse vegetation, agriculture land. Agriculture land mostly covered northern part of the study area. Dense vegetation is found in eastern part of the map. Two major river (Damudar & Ajoy) is observed in southern & northern boundary of the study area. Land water body (pond, reserve etc.) is present in a scatter way in whole study area. Waste land found in vicinity of coal mining area and north-eastern part. In the southern, south-eastern & north-western part of the study area represent settlement and built-up land. Mining area found in north-western, north-eastern and eastern part of the study area, but mining area was extending then before map (1990). Total area of land use/and cover and % each class present in table 4:

SI.No	LULC Types	Area in hectares	Area in %
1	Agricultural Land	28932.12	52.47
2	Dense Vegetation	3753.36	6.81
3	Sparse Vegetation	8973.36	16.27
4	Water body	3255.12	5.90
5	Waste land	4844.07	8.78
6	Build-up land	5083.65	9.22
7	Mining Area	299.34	0.54
	Total	**55141.02**	**100**

Table- 4: Land Use/Land Cover Pattern of the Study Area (2000)



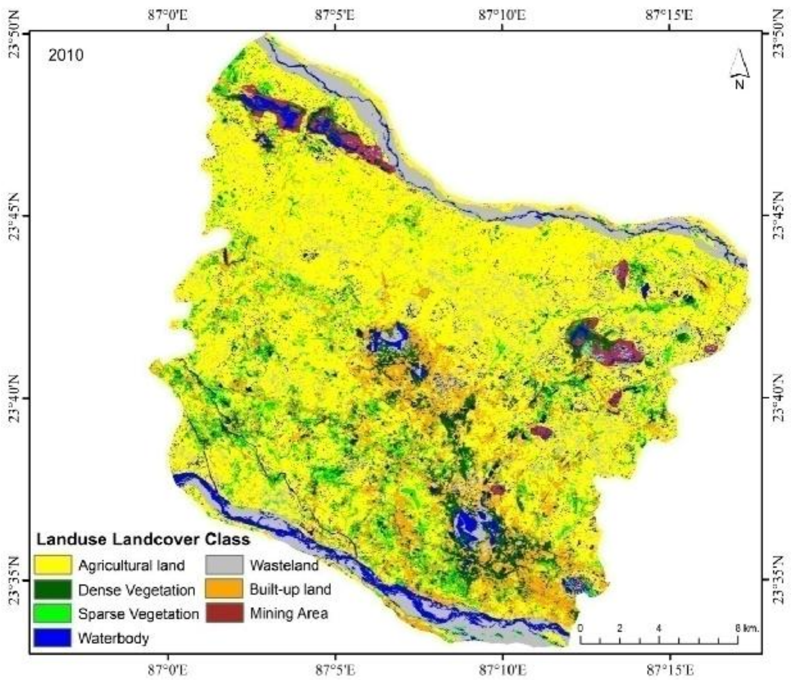
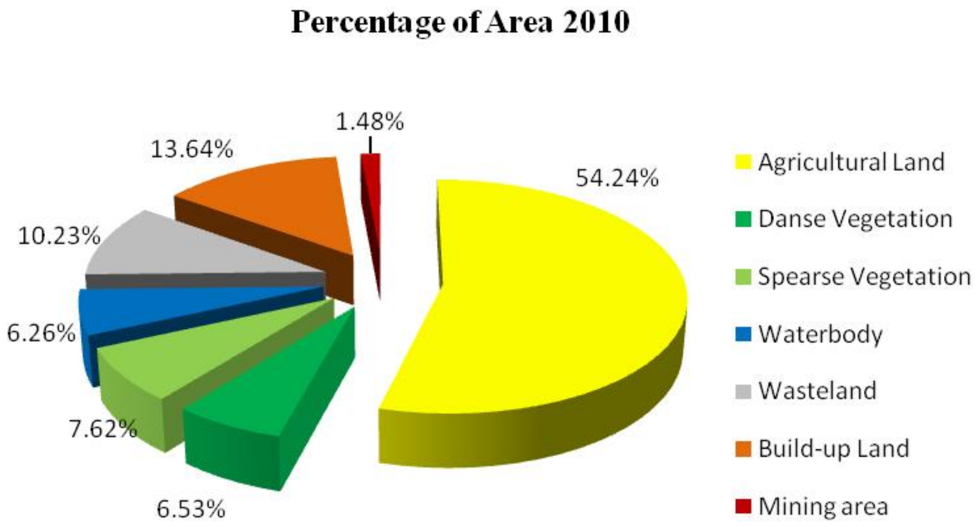


Figure 9: Land Use Land Cover Pattern of the study area (2010)

According to land use/land cover classification for the year 2010, it is revealed that mostly covered by agriculture land. Dense vegetation is found in eastern and southern part of the map. Sparse vegetation is found south, north western part of the study area. Two major river (Damudar & Ajoy) is observed in southern & northern boundary of the study area. Land water body (pond, reserve etc.) is present in a scatter way in whole study area. Waste land found in vicinity of coal mining area and north-eastern part and southern part also. In the southern, south-eastern & north-western part of the study area represent settlement and built-up land. Mining area found in north-western, north-eastern and eastern part of the study area, but mining area was extending then before map (2000). Total area of land use/and cover and % each class present in table 4:

SI.No	LULC Types	Area in hectares	Area in %
1	Agricultural Land	29906.73	54.24
2	Dense Vegetation	3602.07	6.53
3	Sparse Vegetation	4200.84	7.62
4	Water body	3450.96	6.26
5	Wasteland	5643.63	10.23
6	Build-up Land	7519.23	13.64
7	Mining area	817.56	1.48
	Total	**55141.02**	**100**

Table 5: Land Use/Land Cover Pattern of the Study Area (2010)



SI.No	LULC Types	1990		2000		2010	
		Area in hectares	Area in %	Area in hectares	Area in %	Area in hectares	Area in %
1	Agricultural land	24515.19	44.46	28932.12	52.47	29906.73	54.24
2	Dense Vegetation	2788.02	5.06	3753.36	6.81	3602.07	6.53
3	Sparse Vegetation	9350.82	16.96	8973.36	16.27	4200.84	7.62
4	Water body	2146.77	3.89	3255.12	5.90	3450.96	6.26
5	Wasteland	7765.65	14.08	4844.07	8.78	5643.63	10.23
6	Built-up land	8400.87	15.24	5083.65	9.22	7519.23	13.64
7	Mining Area	173.7	0.32	299.34	0.54	817.56	1.48
	Total	**55141.02**	**100**	**55141.02**	**100**	**55141.02**	**100**

Table- 6: Changing Land Use/Land Covers Pattern in This Study Area (1990 To 2010)

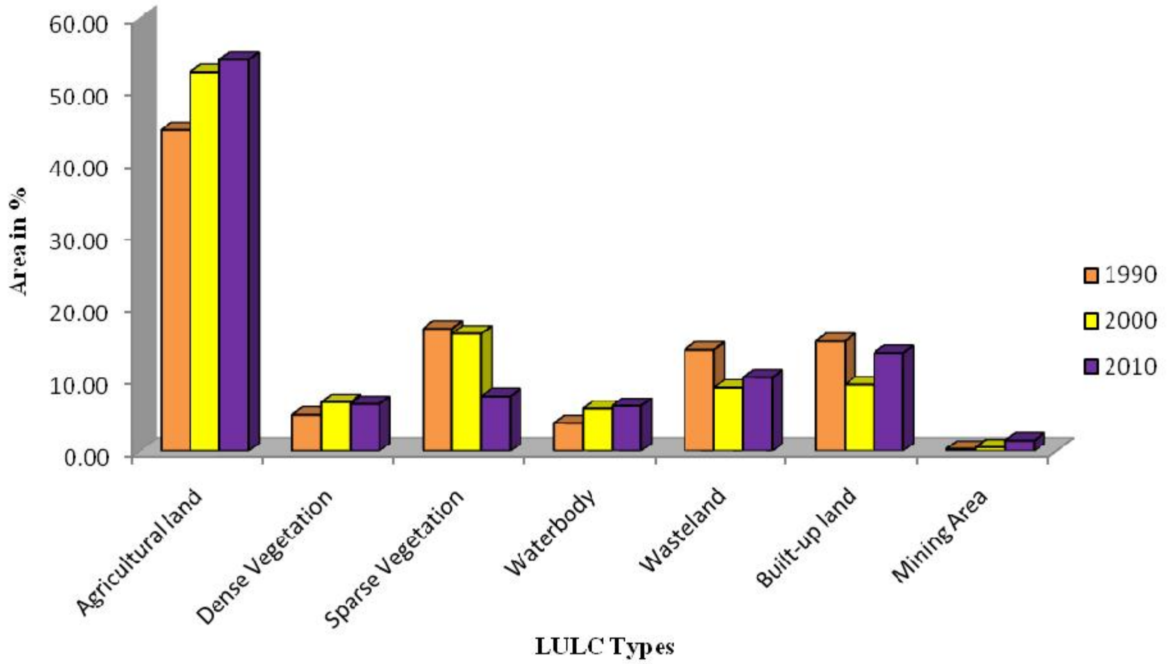


Figure - 10: Showing the Comparative Bar Diagram Of LULC Change of Different Years

The land use/land cover categories in the study area are agricultural land, dense vegetation, sparse vegetation, water body, waste land, built-up land and mining areas. Land use/ land cover details of the area as obtained from landsat-5 TM data of 1990 & 2010 (Fig.6 & 9) and landsat-7ETM+ data of 2000 (Fig.8).

Table-5 Prepared different Land use / Land cover area & changing area between 1990-2010.Different types of land use land cover present, but some classes had increase and some classes had reduced in areas. In this table indicate that major change agriculture, vegetation & mining area. Settlements are develop than 2000 (13.64%) but decreases 1990 (15.24%). Maximum area of the study area cover on Agriculture land, in 1990 (44.46%), 2000 (52.47%) and 2010(54.24%) area cover in total area. Some waste land (10.23%) is increases. vegetation area change due to mining activity, settlement/built-up land and some develop agriculture land. Mining area are increases 1990 (0.32%), 2000 (0.54%) and 2010 (1.48%).Other feature of the study area as Water body also increases (6.26%).

CONCLUSION

This study demonstrated that the recent advancements in remote sensing and GIS technologies provide powerful tool for detection of coal fire and monitoring related to land use land cover changes. It also shows the hotspot zone different mining places of the study area. Dimension of the hotspot are often very small compared to the pixel dimension and contribute little for increased DN values in thermal data band-6. Temperature derived from satellite data may not match corresponds to the surface temperature so temperature anomalies are unusual. These techniques are used for determined heat source of mining area.

The land use land cover map prepared from Landsat-TM & ETM+ data for time sequential change of LULC patterns. Mining area rapidly increase day to day, total increase mining from 1990 to 2010 is 1.48 %. These are some human settlements present close to mining and fire affected areas. This poses serious health problems for the local inhabitants.

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