Abstract

The Jharia Coal Field (JCF) is located in the state of Jharkhand in the Eastern India. JCF is India's only source of prime coking coal. The coal fields, measure approximately 40 km in length and 12 km in width, covering an area of nearly 480 sq. km. Of this, Bharat Coking Coal Limited (BCCL) operates on a lease hold of 258 sq. km (57 percent of the JCF). Tata Iron and Steel Co. (TISCO) and the Indian Iron and Steel Co. (ISSCO) hold lease for an additional 32 sq. km. Further, within JCF there are numerous forests, industrial & agricultural areas, towns, villages and the settlements.

The JCF contains many thick coal seams, the thickest being about 55m. The average thickness of the coal seams here is 4.5m. It has the highest concentration of thick coal seams in the world. The occurrence of the uncontrolled Coal Seam Fires (CSF) had been reported in the JCF, since 1916. Majority of these fires were reported in the coking coal seams within the eastern half of the coalfields. The assessment of the extent of these fires, their rate and direction of propagation, controlling and preventing them and the abatement alternatives for extinguishing have huge impact on the coal production, both in the short and long term. The problem also has severe impact on the Indian economy, the health and the safety of the local community.

JCF provides about 554.14 Million Tonnes of the total coal output in the country [https://www.coalindia.in/en-us/company/aboutus.aspx]. In JCF, unscientific, improper and unauthorised mining had caused surface and subsurface coalfires that burnt millions of tonnes of valuable coal resources since last century.

Substantial reserves of coking coal are locked up due to active burning. CSF had spread both laterally and vertically through adjoining mines and adjacent coal properties, leading to reduced production. Importing of coking coal at world market prices is financially harmful to the

economy of India. Thus, fire extinguishing, fire abatement and control, fire prevention and fire management are sought through the deployment of adequate technologies. Hence, the issue of CSF resolution would preserve the JCF coking coal and reduce import dependency.

Many approaches had been adopted to study this problem. Since 1960, remote sensing have been deployed quite successfully for identifying and monitoring of coal fires.

In fact, every up gradation in the remote sensing technique has been deployed in the JCF for the CSF study. Present study was undertaken amid this backdrop.

The objectives of the current study are:

- Identification of the available tools, techniques and methods for the assessment of the CSF and the assessment of its extent and predicting its occurrence.
- The study of surface temperature above the underground CSF and its correlation with satellite data.
- Assessing the possible correlation between surface temperature and vegetation cover anomalies above CSF.
- Studying the change in the Land Use and Land cover (LULC) in last 50 years with temporal multispectral data.
- CSF advancement in JCF from 1972 to 2017
- Preparations of LULC map of JCF within 25 different classes.
- The demarcation of CSF in JCF using satellite data and ancillary data and
- Preparation of coal fire buffer map.

The Remote Sensing (RS) and Geographical Information System (GIS) tools have been used for the CSF demarcations in the JCF. The investigations are based on the following data:

(a) Indian Remote Sensing (IRS) Linear Imaging Self Scanner (LISS) –III sensor of Resourcesat-I satellite with spatio- temporal imageries

(b) Survey of India toposheets at 1 : 25 000 scale,

(c) Geological map at 1: 25 000 scale,

(d) Structural map at 1: 25 000 scale and

(e) Fire map at 1: 50 000 scale.

These data were processed in the three phases of pre-processing, processing and post processing. Pre-processing techniques required images' registration with an authentication level of one pixel or less, as the registration defects for the pixels could be interpreted as LULC change. Registration of images brings all data to the identical scale and geometry. Processing of data involved digital image processing (DIP) techniques, contrast manipulation, edge enhancement, colour compositing, density slicing, ratio image generation and Principal Component Analysis (PCA).

The K- Means or Maximum Likelihood (ML) algorithms and unsupervised or supervised classification and image segmentation methods processed each pixel. The analysis of ML Classification on the multispectral data enhanced the qualitative and quantitative aspects of the data. The mean vector and covariance matrices of data were the inputs of the function for the estimate from the training pixels of a particular class. This information has been used by the ML classifier to assign a particular class on pixel by pixel basis for the JCF.

A change detection analysis of Normalized Difference Vegetation Index (NDVI) was carried out to identify the difference between NDVI values through the images of the years of 1972, 1980, 2007, 2008, 2009, 2011, 2012 and 2013 for JCF.

On the findings of the NDVI analysis, supervised and unsupervised classifications have been conducted to measure the changes in the vegetative index.

Vegetation index demarcated the distribution of vegetation and the terrain, on the characteristic reflectance standard depending on the chlorophyll content. The NDVI is a simple numerical indicator that can be used to analyze the remote sensing measurements.

The NDVI technique is used for extracting various features presented in the 4-bands of satellite image. NDVI values vary with the absorption of red light by plant due to chlorophyll and the reflection of the infrared radiation by water in leaf cells. All visible ranges were captured by the satellite camera in the form of bands through which features could be extracted after applying the NDVI method for the different characteristics.

The RS & GIS tools with satellite imageries have been used for the surveillance and the identification of the surface features and the subsurface characteristics that heavily influenced the LULC. On any site, the natural and artificial integuments under CSF surveillance of land parcels included forests, grasslands, croplands, soil, topography, surface water, groundwater, human structures and the urban structures.

The design of the landuse classes and the monitoring of their changes with temporal interval required suitable information system. These RS & GIS tools proved important in studying LULC patterns, associations and their dynamics. LULC classes of land cover and the enhanced colour products have been classified in 25 distinct classes of Dense Forest, Open Forest, Degraded forest Artificial (Forest), Coal Quarry, Advance Quarry, Mining Pit, Stock, Dump, Barren, Overburden (OB), Cultivated Land, Fallow Land, Waste land with or without shrub, Siltation, Ash, fire area, Fly ash pond, Urban, Rural, Industrial, Ponds, Water Logged Area, Open Scrub, Barren Land and Sand.

RS and GIS have today been established as reliable tools for examining the earth's surface and atmosphere. In case of high temperature object conditions, such as forest or mine fires, remote sensing could provide a synoptic view of the area under consideration. In the electromagnetic (EM) spectrum, 3–60 μm is considered as thermal infrared. Within this range, 3–5 and 8–12 μm is actually used in thermal remote sensing. The advantage of this method was that the temperature measurements could be conducted, even very close to fires.

In 1960, with the availability of the airborne data, the detection and monitoring of the coalfires became quicker and easier. Studies in the United States, Australia, India and China were done by different researchers using remote sensing as a prime tool for the detection of the mine fires.

The CSF poses threats to the stability of public rail/road lines and the potential collapse of perennial waterways. Before fire abatement plans can be implemented, social and environmental issues need resolution. These issues include: resettlement, the disposition of infrastructure, environmental quality (air, water and land) and the mined land reclamation. This study could be useful in reducing threats to the individual health and safety, infrastructure and waterways and mitigation of the global environmental and associated social issues.

Ground truths' acquisition, with the help of hand held Global Positioning System (GPS) and the pixel sampling with the high resolution images were used to validate the classification results. The models of pixels' matrix values were simulated by data mining and validated in the field with geo-tagging. The accuracy assessment of the map was done by the ground truths' control points. The ground truth positions were imposed over Digital Elevation Model (DEM) of Shuttle Radar Topography Mission (SRTM) of United States Geological Survey (USGS).

The accuracy of the landuse type prediction through the classification maps was found to be 69%. This increased by about 23% on applying maximum likelihood classification method on the data.

The Histogram Equalization values for all the temporal data depends on the vegetation cover of the study area. The NDVI values varied in all the satellite images data after applying vegetation index ratios. The LULC have significantly changed within the last five decades due to mining activity.

CSF temperature was used for the prediction and extent-delineation of the fires. Most of the coal fire zones were in the eastern part of the Jharia coal field i.e. the Lodna– Tisra–Kujama–Jiyalgarha and the Kusunda–Kenduadih zones. However, the most significant coal fire zone was at Gonudih, in the western part of the JCF. In Tisra, Kenduadih and Nadkhurkee areas, the pixel temperatures, on calibration with field data, were found to be above 47°C. The fire zone in the western part of the JCF was limited to the Dumra–Nadkhurkee–Jayramdih area. The collieries, that showed an increase in the fire affected areas were Kusunda (0.62 km^2), Golukdih (0.23 km^2), and Lodna (0.21 km^2). In contrast, the impact of the fire had reduced considerably in the collieries of Nadkhurkee (0.27 km^2), Godhar (0.19 km^2), Benedih (0.14 km^2), Gonudih (0.26 km^2) and South Tisra (0.24km^2). The reported analysis of the spectral image provides the classified land use land cover of the coal seam fires areas.

The optimization of the pixels by the data mining classifications for the decision making was advantageous in coal seam fire mapping with vegetation growth. The data mining scrutinized the facts of coal seam fire for the requisite information. The recode algorithms have been applied to the pixels.

The segmentation of data by the ML improved the interpretations of the original image. The segmented result was validated in the field and it was proposed that ML algorithm provided better inferences.

The pixels in SWIR & IR band of the data provided the peak of high and low values. It indicated the presence of CSF that was verified in the field also.

The image show variations in pixel values because of change in surface radiations and thermal anomaly due to solar and CSF.

The LULC changes were identified under various classes from imagery by the pattern, association and digital numbers of kernel.

The mining operations increased in the past decades that induced and increased the incessant supply of the oxygen to the CSF through cracks and fissures of the weak zones, mapped in the various maps in GIS. The various maps were prepared for integration and mapping of CSF.

The Statistical modelling of pixels with supervised and unsupervised classification methods reduced the redundancy of the classification methods and facilitated the comparisons for the data.

The field measurements at various sites were made with the help of GPS for geo tagging on DEM for point to point elevation mapping on SRTM data.

The 10 km buffer map shows the changes in pixel values that demarcated the fire prone areas that were helpful for the predictions of the CSF for the JCF.