CHAPTER – 1

INTRODUCTION

1.0 COAL SEAM FIRES: ISSUES INVOLVED

Thousands of the CSF are burning across the globe. The sources of these are almost impossible to reach and extinguish, once they start. The CSF significantly impacts the health and economy of the people living in the vicinity of the coal field. CSF threatens life and property of the towns nearby and generates pollution of the air and contributes to the global warming. The chemical products of the CSF pose a severe threat to the flora and fauna. The problem of spontaneous combustion and uncontrolled CSF is found throughout the world in most of the coal producing countries like United States of America (USA), China, India, UK, Australia, South Africa and Indonesia.

Heat emissions and accumulation have been reported in the air, ground, and water since 1880, from the consumption of fuel energy [1].

In India, JCF has the largest frequency of the CSF. Uncontrolled coal seam fires reportedly began in JCF in 1916[2].

The JCF is located in the state of Jharkhand in the Eastern India. The coal fields, measure approximately 40 km in length and 12 km in width, covering an area of nearly 480 sq. km. Of this, BCCL operates on a lease hold of 258 sq. km (57 percent of the JCF). TISCO and ISSCO hold lease for an additional 32 sq. km. Further, there are numerous towns, villages and settlements.

The JCF is India's only source of prime coking coal. It is currently contributing around a quarter of the country's total coal production.

[https://www.coalindia.in/enus/company/aboutus.aspx].

Primarily, unscientific and illegal mining, termed as slaughter mining, caused surface and subsurface coal fires in these coalfields. These fires burnt millions of tons of valuable coal reserves. The JCF has many thick coal seams, the thickest being about 55 m. The average seam thickness of the coalfields is 4.5m. Within JCF, majority of the fires are reported in the coking coal seams within the eastern half of the coalfield.

In India, a large number of Central Mine Planning and Design Institute Limited (CMPDIL) studies reported that spontaneous heat was the main reason for about 67 percent of the CSF [3]. The remaining about 33% CSF was attributed to some kind of neglect, accident or design defect. Although JCF's coal is not very susceptible to spontaneous combustion, even here the origins of most of the coal seam fires were reported to be attributed spontaneous combustion.

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 and the health and safety of the local community.

1.1 ENVIRONMENTAL IMPACTS OF CSF

There are four main gases that are cause of concern in a coal mine. They are carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), and Hydrogen Sulphide (H_2S). The levels and combinations of these gases along with the level of oxygen, determine the proneness to danger for the workers. Mine fires adversely affect the levels of mine gases and their relative prevalence, thus endangering the safety and health of the mine workers within mine premises.

1.1.1. Dispersion of pollutants from the CSF in the Air

The effects of CSF on ambient air quality are severe. The fissures/ weak rocks provide path for discharging various pollutant gases into the environment. These pollutant gases are mainly carbon monoxide (CO), Carbon Dioxide (CO_2), Sulphur Oxides (SO_x), Nitrogen Oxides, Hydro Carbons (HC), Hydrogen Sulphides (H_2S) and other photo sensitive oxidants like smog etc. Particulate matters (PM) less than 10µm of emission primarily include Sulphuric Acid (H_2SO_4) and Ammonium Bi Sulphate (NH_4HCO_3). These acidic aerosols, likely exist as a consequence of CSF and are dangerous from health point of view. Carbon monoxide can be emitted from mine fires in large quantities because of incomplete combustion of coal seams. Its percentage may sometimes go beyond threshold limit value (TLV), creating a lethal environment for living organisms. The organic compounds are volatile, semi volatile and condensed. These include aliphatic, oxygenated, and low molecular weight aromatic compounds like Alkanes, Alkenes, Aldehydes, Carboxylic acids, and substituted benzene. These compounds are classified into Polycyclic Organic Matter (POM) and Poly Nuclear Aromatic Hydrocarbon (PNA or PAH) [4].

1.1.2. Dispersion of pollutants from the CSF in the water

The effect of CSF on water quality in fire areas of JCF has also been significant. The interactions of percolating water and gases change the pH, Hardness, TDS, Dissolved oxygen, chemical oxygen demand, tar/phenolic compounds, salinity, sulphates and chlorides and trace elements of the area. Salts trickle down by the cracks that make water more saline and toxic for the micro organisms and other species that consume the water.

1.1.3. Effect of pollutants from the CSF on the ground surface

The subsidence due to CSF is rampant in JCF. Due to baking, the land or soil is affected by heat causing degeneration of vegetation and degradation of top soil. Top soil becomes biologically sterile and prone for erosion during rainfall and through actions of the wind. The leaching of nutrients is also caused through the cracks of subsidence. Soil conductivity has been reported to have increased from 25 to 151mhos/cm, due to enhanced salt content in the soil. [5]

1.1.4. Impact of CSF on Society and the global environment

For the people living near CSF, the destruction of overall ecosystem occurs due to increase in temperature, poor visibility, air pollution and overall environmental degradation. Loss of land, damage to surface properties, i.e., houses, roads, etc., reduction in availability of groundwater and its poor quality and various associated health effects were also found. Analyses of CSFs in China, United States of America, Australia, South Africa and India showed that CSF contributes to climate change affecting green house gases (GHGs) [6]. The CSF greenhouse gas emissions can be estimated by assuming that gas released from spontaneous combustion / fires is directly proportional to the amount of coal burnt per year. It can be expressed through equation 1 below:

$$\text{Green House Gases Flux (F)} = \left(\sum_{i=1}^{i=n} Qs * EF * CF\right) \qquad \text{………. Eq. 1}$$

Where :
F – Gas emission flux (i.e. mass/year)

Qs - Quantity of coal consumed due to burning in tonnes / year

EF- gas emission factor (kg/ kg)

i - Number of GHG,

CF – global warming potential of GHG gases.

The potential GHG emissions may be estimated from coal composition, combustion characteristics and amount of coal burnt. [7]

1.2. Significance

The demarcation of coal fire areas and probable coal fire risk areas are essential to adequately understand the magnitude of the problem of CSF in JCF. The multispectral reflective information of bands deployed for the demarcations of future coal seam fire risk areas can provide accurate prediction of fire risk areas. SWIR band data was deployed for the calculation of the surface temperature vis-à-vis the derived emissivity. The combinations of multispectral and ground thermal data were used for the environmental related thermal anomaly applications. Hence, these tools in combination could generate adequately realistic understanding of the extent of the CSF in JCF.

1.3. Scope of study

The coal mining activities carried out in the study areas, over the past 45 years, was qualitatively and quantitatively assessed using the temporal satellite data. The CSF' prone areas were demarcated by the modelling of the pixels in the NDVI segmented image and LULC spatial distributions. The various planning related to CSF resource management, Crop harvesting, Fire Management, Map production, GIS for strategic planning and modeling and the Fire Escape plan might also be prepared.

The conventional methods used field surveys for the demarcation and prediction of CSFs, subsidence areas; LULC classifications.

Field surveys were time consuming, expensive and could not cover unapproachable areas due to high temperature and difficult terrain and topographic conditions. In contrast, the integrated RS method could cover all the spatial features and provide a synoptic overview. The areas inaccessible in ground survey could also be feasibly studied through remote sensing. RS and GIS tools are time and resource efficient as a large area can be covered within less time. The CSF data available in directly digital raster format gives greater flexibility of feature identification, enhancement, delineation and representations than paper maps, tabulations or other conventional tools. Satellites provide accurate and precise information about the study areas. Remote sensing data is obtained through recurring coverage of an area at regular time intervals. It provides a useful technique for exploring coalfields on a large scale to detect CSF. The amount of emitted heat is estimated by the carbon dynamics in multi- dimensional remote sensing.

Further, the GIS tools are capable to integrate different types of CSF data in a single analysis.

1.4. OBJECTIVES OF THE STUDY

The objectives of the present work are as stated below:

- Identification of the tools, techniques and methods for the assessment of the extent and the occurrence of the CSF.
- Study of the surface temperature above the underground CSF and its correlation with the satellite data.
- Correlation of the surface temperature and vegetation cover anomalies above CSF
- Studying the change in the LULC with temporal multispectral data.
- CSF advancement in JCF from 1972 to 2017

- Preparation of LULC map of JCF with 25 classes
- The demarcation of CSF in JCF using satellite data and ancillary data.
- Preparation of coal fire buffer maps.

1.5. METHODOLOGY

In the present work, the RS & GIS tools have been used for the CSF demarcations in the JCF.

For applying the tools of the RS & GIS, following data detailed in Table: 1 were used as inputs:

Table: 1 List of data used in the study

Sl. No.	Platform of Data	Sensors	Bands	Date of Acquisition
1	Landsat- 1	MSS (Path:150	Band 1,2,3 & 4	1972:348:04:13:04.0690000
2	Landsat -1	MSS (Path:150	Band 1,2,3 & 4	1980:018:03:57:03.6000000
3	IRS- Resource sat	LISS III	Band 1,2,3 & 4	16:14:36, 20/10/2007
4	IRS- Resource sat	LISS III	Band 1,2,3 & 4	14:32:15, 20/10/2008
5	IRS- Resource sat	LISS III	Band 1,2,3 & 4	12:14:23, 20/10/2009
6	IRS- Resource sat	LISS III	Band 1,2,3 & 4	16:05:26, 09/12/2011
7	IRS- Resource sat	LISS III	Band 1,2,3 & 4	09:52:54, 09/03/2012
8	IRS- Resource sat	LISS III	Band 1,2,3 & 4	10:59:15, 09/02/2013
9	ASTER	SRTM	Band1	12:17:16, 03/04/2012
10	Google Earth	Multi Spectral	Band 1,2,3 & &4	09:10:27, 02/03/2017
Additional Data				
(a) Toposheets at 1 : 25 000 scale				
(b) Geological map at 1: 25 000 scale,				
(c) Structural map at 1: 25 000 scale and				
(d) Fire map at 1: 50 000 scale.				

These data were processed in the three phases of pre-processing, processing and post processing.

Here, pre-processing comprised of:

(i) *Geo rectification,* where multi images were brought to same scale,

(ii) *Mosaicing,* involved stitching of the different images,

(iii) *Density slicing*, the range of brightness's of pixel values were observed for colour coding and improvising interpretations

(iv) *Colour display,* displays the colour coding and IHS transformations.

The processing techniques involved registration of the images with an authentication level of one pixel or less, as any registration defects for the pixels could be interpreted as LULC change. The registration of the images brings all the data to the same scale and geometry. The data processing involved digital imaging (DIP) techniques, contrast manipulation, edge insertion, colour compositing, density slip, ratio image production, and the Principal Component Analysis (PCA) [8].

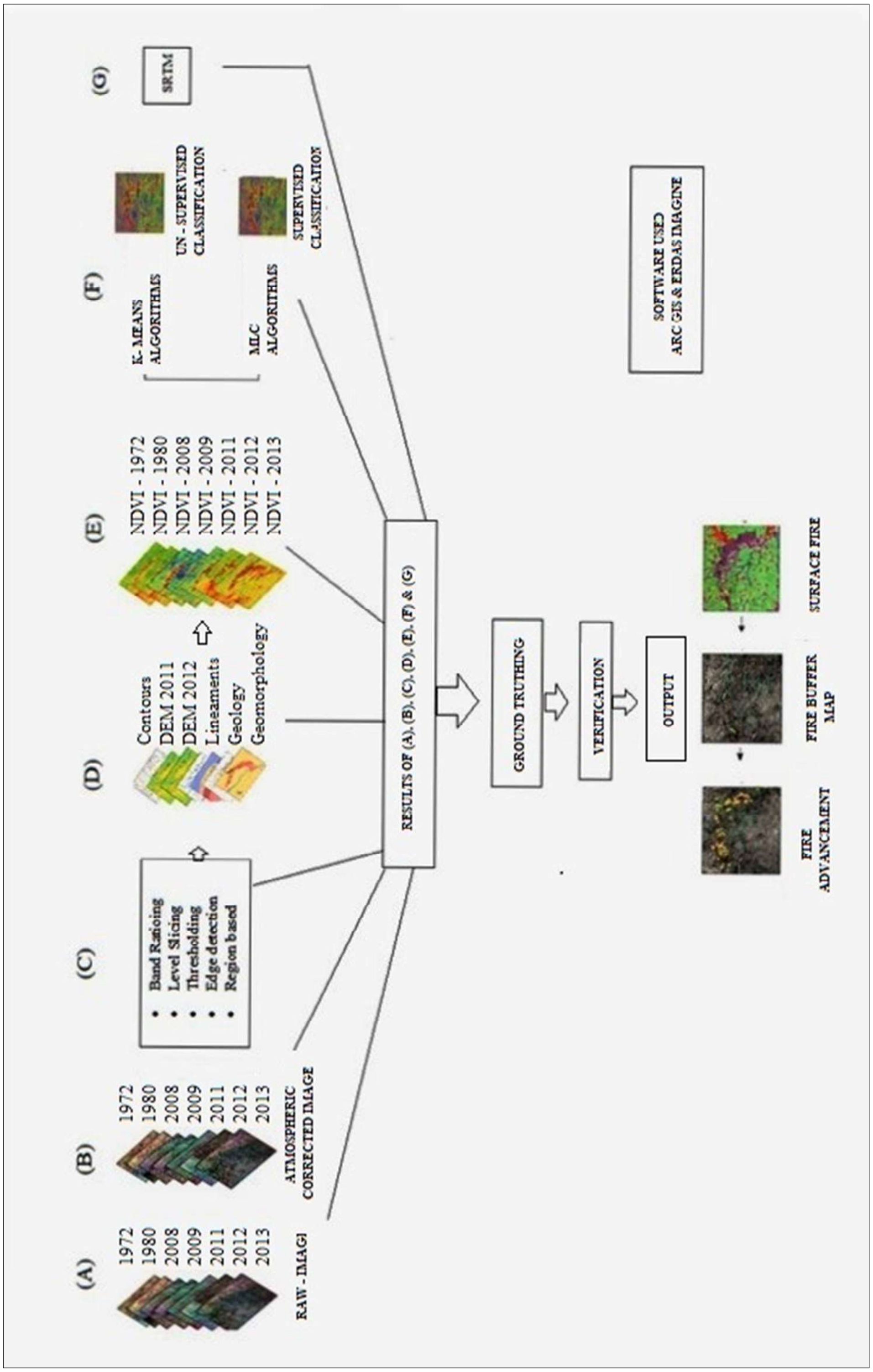

Fig1: Schematic representation of methodology for LULC change detection studies in JCF

Two approaches were employed to carry out the change detection analysis

First, a change detection analysis of NDVI was carried out to identify the difference between NDVI values during the images of the years of 1972, 1980, 2007, 2008, 2009, 2011, 2012 and 2013.

NDVI technology was used to extract the various features of a 4-lane satellite image. The vegetation cap was one of the most important biophysical indicators of soil erosion, which could be estimated by using vegetation indices obtained through satellite imagery. Vegetation indices define the vegetation and soil distribution on the basis of the chlorophyll characteristics of vegetation. NDVI is a simple numeric indicator that can be analyzed from RS measurements on a remote platform and evaluate whether or not a target is detected by living green vegetation. The degree of greenery corresponds to the chlorophyll content. The NDVI values are obtained from absorbing red light through the plant due to chlorophyll and reflection of infrared radiation in water in leaf cells. From the satellite camera, all visible areas are taken as strips through which properties can be distinguished after the NDVI method has been introduced for different properties.

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

Second, to supplement the findings of the NDVI analysis, classification was conducted to measure the changes in vegetation cover. The image classification and image segmentation method for each pixel was processed for the single LULC unit. The high probability ML rating analysis was used to evaluate the qualitative and the quantitative aspects. The average vector and the covariance matrices were the inputs of the function for estimating the training pixels of a given class. The field data of the JCF had been used in the selection of the threshold boundary of LULC and for the validation of the findings. This information was used by the ML classifier to assign a particular class to pixel values in the JCF.

1.6. ORGANIZATION OF THE THESIS

Chapter one provides the introduction of the thesis and develops the context of the CSF, the scope of the study, the objectives of the work, the methodology, the significance of the work and the organization of the thesis.

Chapter two discusses the literature survey on the existence and monitoring of CSFs, factors affecting it, its determination and prediction techniques.

Chapter three presents the work on the field visits, satellite imagery analysis and its validation details.

Chapter four states the results and the discussions of the study including LULC classification, zonations of CSF advancements and buffer maps.

Chapter five has the conclusions of the study and the suggestions for the future work.

The references and appendices follow thereafter.