

Chapter 4

Impact Assessment of Open Cast Mining Activity in ADDA Region, Paschim Bardhaman on Land Surface Temperature



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Abstract Open cast mining affects much on the physical environment adjoining to it. This study has been carried out in Asansol Durgapur Development Authority (ADDA) in West Bengal, analyzing such impact of open cast mines on the environmental issues especially the increasing land surface temperature along some elongated tracts by either excavation or dumping. Monitoring of the spatial extension of open cast mines (1999–2019) and analyzing its relationship, the spatial distribution of the land surface temperature in the ADDA region is the core objective of this work. Land surface temperature was examined by using Landsat 4–5 TM and Landsat 8 OLI and TIRS temporal satellite data by single channel algorithm. The outcome of surface temperature is validated with the field information. Supervised image classification technique with maximum likelihood method which was used to show the changes in land use/land cover along with the temporal expansion of opencast mining areas over time. The temporal changes in the distribution of mining sites undergone a detailed correlation study with the spatial variability of these two environmental quality parameters which came out with a strong correlation among them. The result indicates a significant positive correlation between the open cast mines and the spatial distribution of LST ($R^2 = 0.9578$), respectively. This considers the opencast mining activity as a major contributor to the environmental quality status of the adjacent area.

Keyword Open cast mining · Land surface temperature · Spatial variability · Correlation

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4.1 Introduction

The area under opencast mining has been increasing at a high rate since the last few decades in Asansol Durgapur Development Authority (ADDA), a major mining belt of eastern India, mainly dominated by companies like Eastern coalfields limited (ECL), Bharat Coking Coal Limited (BCCL), and the Indian Iron & Steel Company (IISCO) in both the forms: Opencast as well as underground mining. It is mainly due to changing land use from agro-forestry to mining and its ancillaries such as warehouses, subsidence-prone areas, dumping areas, ash ponds, etc. As a consequence of prolonged mining, the area mostly turned into non-usable with infertile eroded soil.

This study mainly aimed at monitoring the continuous expansion of open cast mines and its correlation with the changing spatial distribution of surface temperature in this area. The analysis was executed on temporal geospatial secondary datasets of 1999, 2011, and 2019. For monitoring the expansion of opencast areas, land use/land cover spatial data is generated from the temporal satellite images of these three phases with proper field checks in 2019. The change detection highlights a prominent cluster wise conversion of vegetative to non-vegetative surface cover, which can be considered as a background behind the increase of surface temperature (Choudhury et al., 2018). The burning of coal and digging up the surface releases increase the land surface temperature as well as air temperature in the surrounding area. Several works were executed on such environmental issues related to mining activities. Choudhury et al. (2018) and Dutta et al. (2018) worked on the land-use dynamics as well as the trend of LST in mining regions. Such environmental depletion leads to the depletion of biodiversity of such areas. These effects are prominent in the eastern coal belt of India (Guha et al., 2012; Gangopadhyay et al., 2005; Kamila & Pal, 2015; Manna & Maiti, 2014). Remote sensing data can provide us with the output for a large coverage area at a time with equally distributed averaging cells; researchers like Karfa and Tah (2019) and Kamila and Pal (2015) used this technology extensively for land-use change monitoring and associated LST change analysis in their study. Mainly thermal band data were used for deriving LST pixels (Choudhury et al., 2018; Fawzi & Jatmiko, 2015).

After all the previous discussions, it is clear that the rising land surface temperature and air temperature caused by changing land use is a serious health issue for living bodies as well as a threat to the ecosystem. While going toward sustainability, it is important to nullify or decrease the level of threat, for which taking a proper plan is an immediate necessity. Now, to configure a proper plan, it is a primary need to understand the scenario of the problem area first; is there any threat or not, if yes, then how much.

As the objective of this research concentrates on the coal mining scenario, the coalfields of Paschim Bardhaman area of West Bengal is selected. This area has an age-long history of coal reserve and is under continuous mining of coal since 1774. In recent time, it covers a total of 6182.37 ha area and is extending in a very fast rate. With this extension, it is very likely to increase the LST.

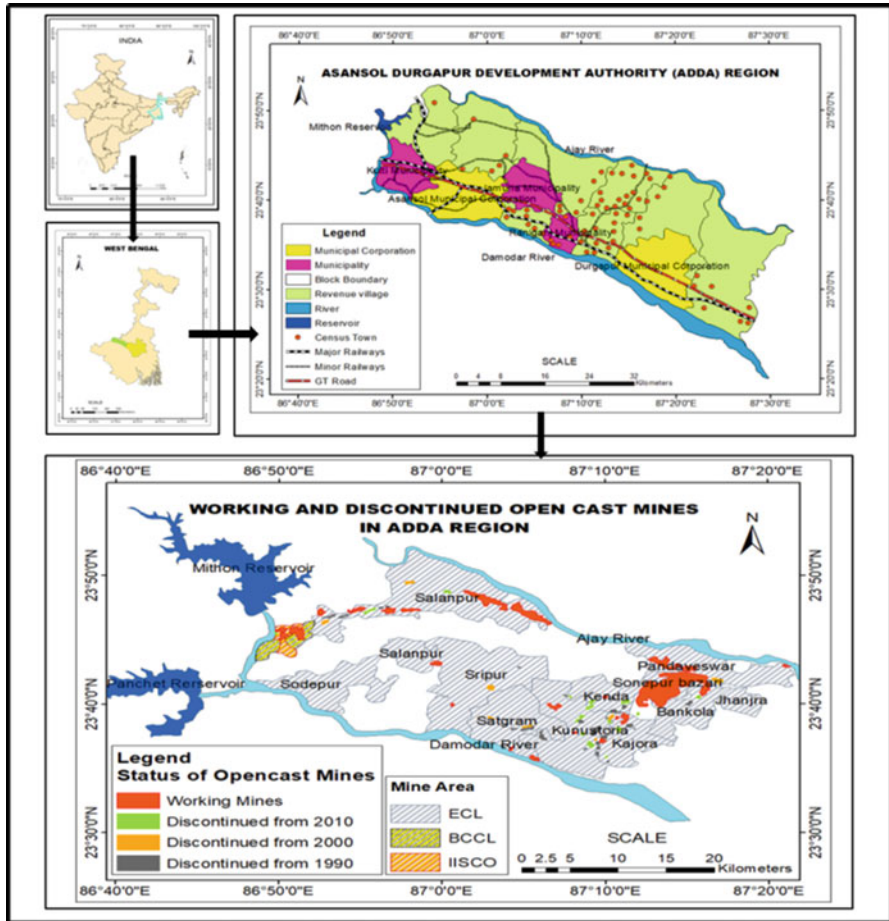


Fig. 4.1 Study area (ADDA region). Source: Choudhury et.al (2018), Eastern Coalfield Limited (ECL) Providing data and author map composition

Accounting those observations, coalfield areas of Paschim Bardhaman, along with the ADDA region, are selected as the study area of this research (Fig. 4.1).

4.2 Materials and Methods

Temporal satellite images (Landsat TM 4–5 for January 1999 and February 2011 and Landsat 8–OLI for January 2019) were used to generate the temporal land use/land cover thematic layers. Supervised classification method was applied with maximum likelihood algorithm for these three temporal images and field validation of the classification was made on 2019 image with an accuracy of 82%. These temporal land use/land cover datasets facilitate in monitoring the changes in land use and

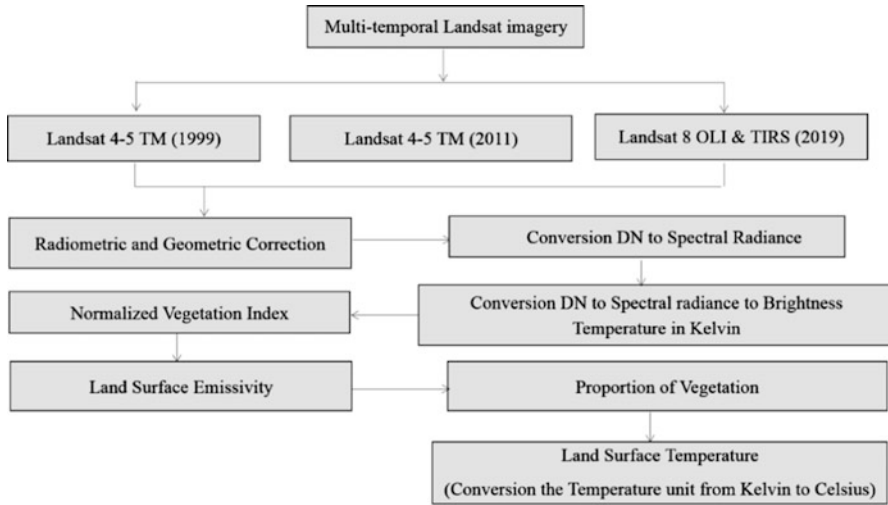


Fig. 4.2 General methodology for land surface temperature

finally the changes in opencast mining activity regions. To assess the effect of such activity, few environmental quality were assessed in which the land surface temperature was one, which was calculated for the study area from the satellite image of the contemporary time scale.

The Land surface temperature (LST) is the radiative temperature which was calculated using top of atmosphere brightness temperature, wavelength of emitted radiance, land surface emissivity by single channel algorithms proposed by Jeevalakshmi et al. (2017) and Anaandababu et al. (2018) (Fig. 4.2).

$$LST = (BT/1) + W * (BT/14380) * \ln (E)$$

where:

BT = top of atmosphere brightness temperature ($^{\circ}\text{C}$)

W = wavelength of emitted radiance [Landsat 4–5 TM = 10.895, Landsat 8 OLI & TIRS = 11.45]

E = land surface emissivity

Here, land surface emissivity (E) in formula-1 was calculated via the following formula for each temporal satellite images.

$$\text{Emissivity} = 0.004 * PV + 0.986$$

where PV = proportion of vegetation (proportion of vegetation or fractional vegetation cover) in formula-2 which was obtained from NDVI values for vegetation and soil according to with value various between 0.00 and 1.00.

$$PV = [(NDVI - NDVI \text{ min}) / (NDVI \text{ max} - NDVI \text{ min})]^2$$

where the Normalized Differential Vegetation Index (NDVI) in formula-3 is a standardized vegetation index which is calculated using near infrared (Band 5) and red (Band 4) bands.

$$NDVI = (NIR - RED) / (NIR + RED)$$

On the other hand, BT in formula-1 can be derived when spectral radiance data were converted to top of atmosphere brightness temperature using the thermal constant values in the Metadata file.

Conversion of Kelvin to Celsius

As the result is in Kelvin, the radiant temperature is revised by adding the absolute zero (-273.15 °C) to get the result in Celsius.

$$BT = K2 / \ln (k1/L\lambda + 1) - 273.15$$

where:

BT = top of atmosphere brightness temperature (°C)

$L\lambda$ = TOA spectral radiance (Watts/($m^2 * sr * \mu m$))

Using the radiance rescaling factor, thermal infrared digital numbers can be converted to TOA spectral radiance.

For the validation of the retrieval methods, the land surface temperatures were also collected in the ground by using an infrared thermometer (LASER—GM320) over seven stations, namely, Mohanpur, Sonapur Bazari, Khottadih, Kalipahari, Gourandi, Gourandi-Begunia, and North Searsole.

4.3 Results and Discussion

Land use/land cover data were generated for 1999, 2011, and 2019 with classes like build-up area, vegetation, mining area, agricultural land, barren land, river, reservoir/lakes/ponds, and river sand (Fig. 4.3). It showed a sharp increase in the mining area (open cast) from 1630.53 to 6182.37 ha (0.93 to 3.51%) during 1999–2019 (Fig. 4.4). This was associated with a significant areal increase of built-up area from 34,293.87 to 52,962.75 ha (19.48 to 30.08%), a steep fall of vegetation coverage from 23,129.01 ha to 15,309.45 ha (13.14% to 8.7%), as well as agricultural land from 100,666.44 ha to 84799.8 ha (57.15% to 48.15%). The field visit was

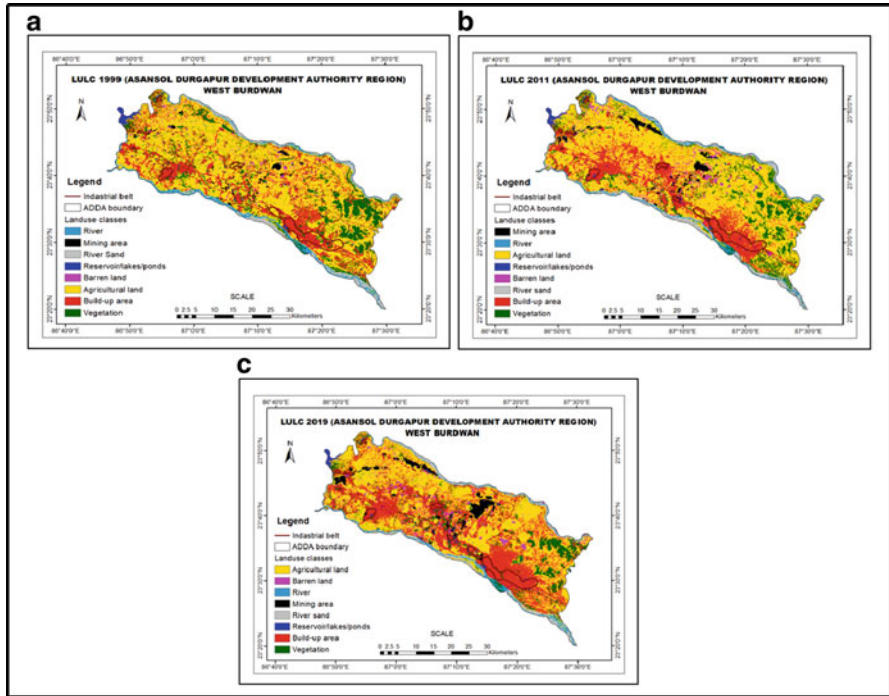


Fig. 4.3 Landsat TM 4 – 5 for January 1999 and February 2011 and Landsat 8 - OLI for January 2019 from USGS (<https://earthexplorer.usgs.gov/>)

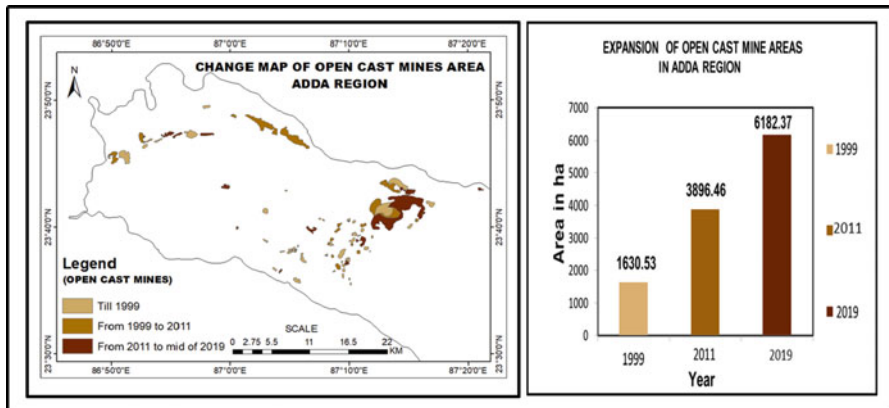


Fig. 4.4 Expansion of open cast mining activity in ADDA region

conducted for land use categories for 2019 with a detailed visit to open cast mining areas. Open cast mining areas on the classified data were also verified with ECL data for an accurate assessment.

Land Surface Temperature (LST)

As per the change analysis of LST from 1999 to 2019 (Fig. 4.5), it was ranging from 14 to 28 °C in January 1999, with the highest limit distributed over Sonapur Bazari, Mohanpur, and Khottadih mine areas. The temperature of these areas increased to a peak temperature of 32° during February 2011. It further increased to 38° as highest in January 2019.

On the other hand, Narayankuri, New Kenda, and Banshra open cast mines and part of BCCL, IISCO Coalfields were showing the medium LST from 23 to 26 °C with a surrounding LST of 21 °C in 1999. Active mining belts were showing a rise in temperature (up to 34°) in February 2011. It was showing temperature hot spots on Gourandi, Gourandi-Begunia, Jambad, Bonjemehari, and Sonapur Bazari OC with LST values ranging from 32 to 34 °C with surrounding average LST value of 30 °C. This distribution of land surface temperature over this area was showing an increasing trend even in January 2019 as per LST data retrieved from satellite images. The high-temperature pixels were distributed in some non-mining areas also. Those are basically due to the presence of industries and settlements. Hence, the temporal change of land surface temperature is shown to be closely associated with the rapid land use/land cover change (Ziaul & Pal, 2016) (Fig. 4.6).

By using an infrared thermometer (LASER—GM320) land surface temperature was measured in the field to validate the process of deriving LST values from remote sensing data. Figure 4.9 is showing the variation of LST measured and calculated

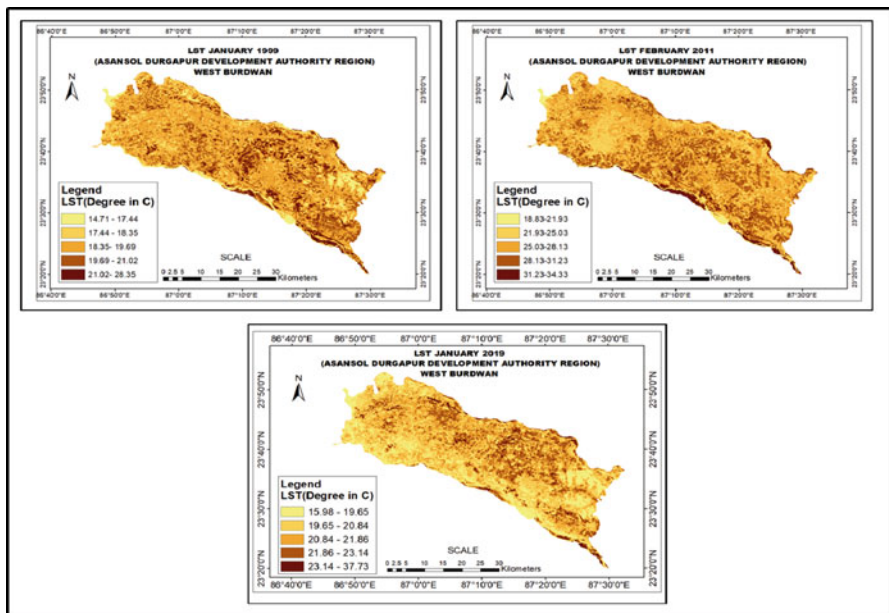


Fig. 4.5 Land surface temperature

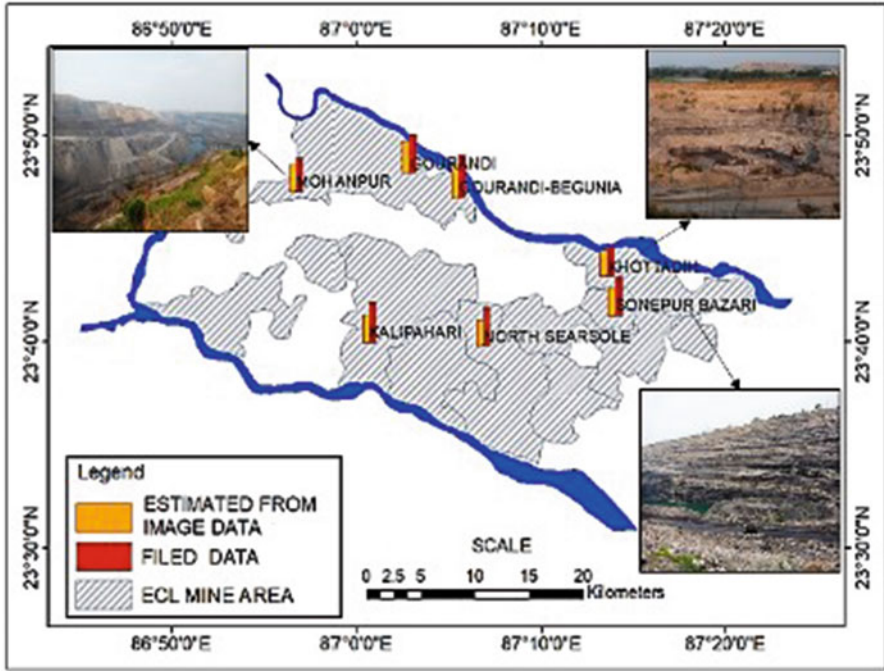


Fig. 4.6 Bar graph comparison between Field LST data and Estimated from image data of ADDA region, February 2019. Source: By Author

values. Field measurements give the highest LST at Gourandi-Begunia OC (43 °C) and the lowest value at Khottadih OC with 32 °C.

In the cross-sectional profiles in Figs. 4.7 and 4.8, the increasing trend can be recorded for a time interval from 1999 to 2019. Though it represents a sharp increase in value for the full graph, the spatial pattern of hotspots is almost static.

Along with the cross profile AB in 1999 LST data (Fig. 4.7), it is found that Mohanpur OC of Salanpur colliery area experienced maximum LST of about 28 °C which was increased to nearly 30 °C in 2019. The average LST of Kenda, Bankola ECL areas were ranging between 26 °C and 24 °C in 1999 but in the 2019 cross-section, it is showing the value of nearly 29 °C. In 1999, which areas that include water bodies and forest areas (Fig. 4.3), there giving an LST value of nearly 14 °C. The LST of the rural and semi-urban areas in the cross profile was identified within the range of 21 °C and 17 °C.

Along the other cross-section CD, Sripur, Satgram, Kunustoria, and Kajora ECL were showing an LST up to 24 °C in 1999, which increased to nearly 29 °C in 2019 (Fig. 4.8). Cross profile EF was showing the LST of Salanpur–ECL area nearly 18 °C in 1999, which is seen to be increased to as high as 35 °C in 2019. On the other hand, Sripur, Kenda, Kunustoria, and Kajora were experiencing LST of nearly 21 °C in January in 1999 which was ranging between 28 to 35 °C in 2019.

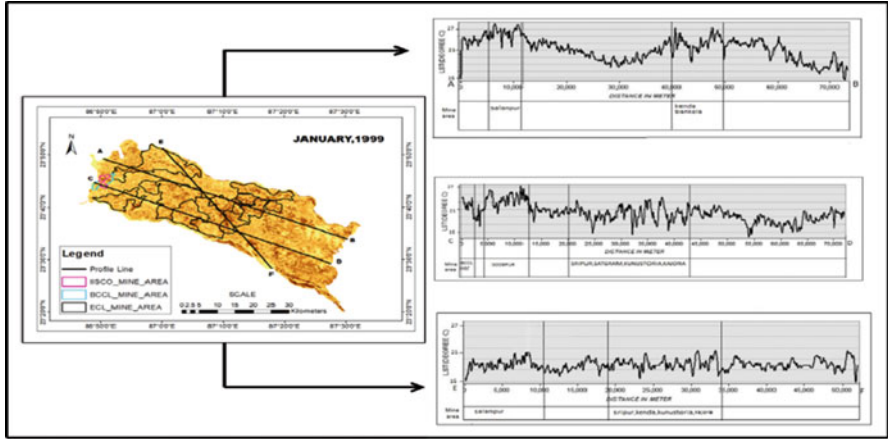


Fig. 4.7 LST profiles (A-B, C-D, and E-F) in January 1999

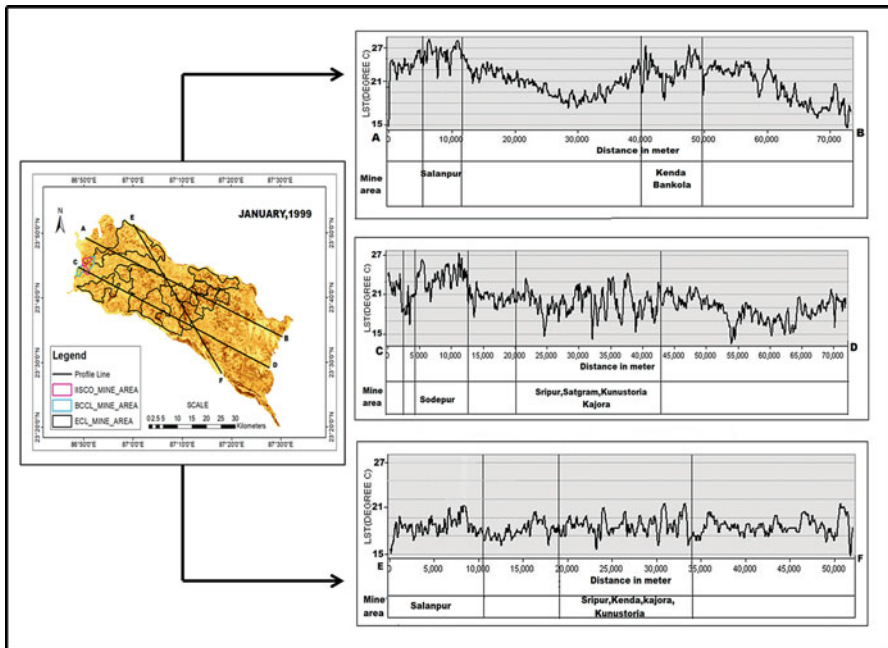


Fig. 4.8 LST profiles (A-B, C-D, and E-F) in January 2019

Hence, the cross profiles reveal an abrupt increase in LST during 1999 and 2019 where the mining area also increased to 2.58% during this period. There are many instances of the unauthorized digging of open cast mines, which can be seen in the field. The most important reason for increasing LST is coal fire and the loading-unloading of the overburden of open cast mines. Instances of coal fire were documented at Ramnagar, Bonjemehari, Jambad, Sangramgarh (Guha et al., 2012), Khottadih, Sonapur Bazari, Churuliya, Kamarkhola, Belbadh, Sitalpur, Khayerbandh, Jamuria, and Dhadka (Karfa & Tah, 2019). They may be due to the spontaneous heating of coal. Sometimes, the heat produced is not dissipated completely due to the poor supply of air in a confined space. It can also be an excessive amount of overburden.

As recorded in 2019, the Gourandi and Gourandi-Begunia OC have the highest LST ranging from 39 to 43 °C, and its surrounding areas having an LST of nearly 37 °C. On the other hand, Mohanpur, Bonjemehari, Dabor, Sonapur Bazari, Khottadih Madhabpur, Jambad, New Kenda, North Searsole OC, and parts of BCCL, IISCO Coalfields have the medium LST ranging from 34 to 38 °C, and its surrounding areas experienced LST of 36 °C. The LST of Madhabpur, Dalurbandh, Itapara, Madhabpur, Banshra, Narayankuri, Nimcha-Amkola, Bhanora west OC was within the range of 31 and 34 °C, and its surrounding LST is 30 °C. Besides, there are many discontinued OC where work is in the disruption. They are generally showing a moderately lower value of LST from 26 to 29 °C. Though these are not active mine areas, the vegetation cover has not been replaced and that increased the LST value.

Though the mining activity is not the sole contributor for increasing LST over the area, an attempt was made to see the correlation between the overall expansion of the OCM area in 1999, 2011, and 2019 and the changing annual average value of LST for those years. The correlation coefficient value (R^2) came as 0.9578 which is representing a strong positive correlation between them (Fig. 4.9).

4.4 Conclusion

This research indicates that the increasing area under open cast mining (1999–2019) has a significant impact on the economic, social, and environmental fabric of adjoining areas of ADDA. Expansion of the opencast mining area took place at the cost of displacement of settlements, demolish of agriculture, and other vegetative covers. Such a change in land cover especially with a decreasing rate of greeneries subsequently took the environment toward a quality fall. A change in the annual seasonal temperature also took a hike. To confirm this, this study got a correlation statistics between the temporal expansion of open cast mining areas and annual mean surface temperature change of the corresponding area. The analysis came with a very strong positive correlation between these factors. Mining area expansion has direct control over the NDVI change and resulting change in the mean surface temperature of this Asansol-Durgapur Development Region. This study also explored the

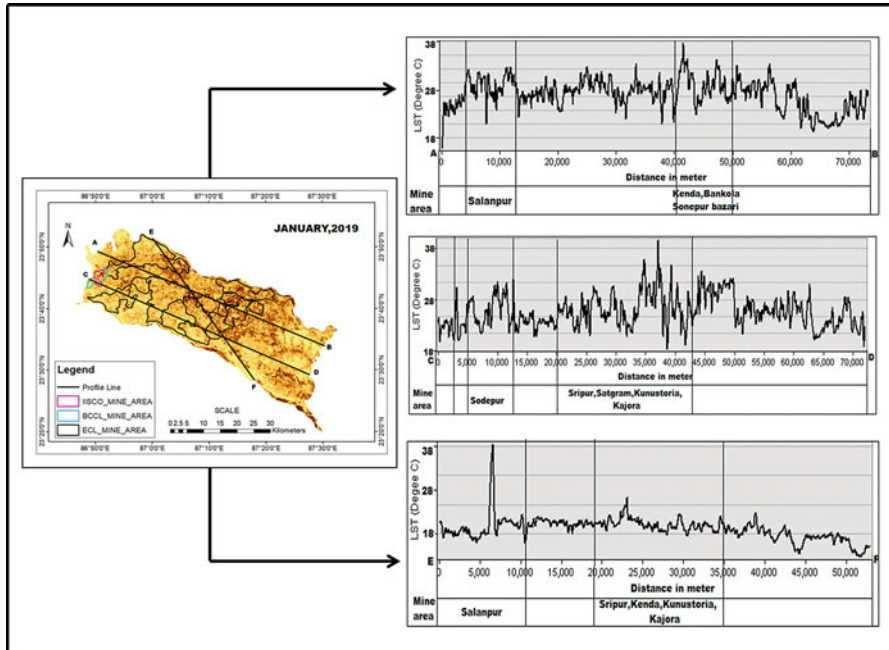


Fig. 4.9 Correlation between areal changes of mines (ha in %) and LST

correlation analysis result between LST and areal change (%) of coal mine areas ($R^2 = 0.95$) showed a positive relationship and a negative relationship between LST and NDVI ($R^2 = 0.89$). As a result the spatial relationship linear correlation between areal changes (%) in Mining, LST, and NDVI where R^2 value near about 1.

Sometimes, the exploration is complete in one region, the deactivated mine remains the same without the proper land reclamation and rebuilding of vegetative cover. Mining operations can't be the sole responsible factor behind the environmental quality deterioration, but rather industrial development along with urban expansion also contribute much. Therefore, these mining activities should be followed by proper environmental protection measures. Reclamation planning is one of the major environmental protection measures to reduce air temperature. After the completion of exploration, abandoned coal mines should be filled up with sand or soil, or water. Regaining of the soil fertility should be planned along with afforestation programs. Advanced mining technology and effective strategies to reduce air temperature around coal mining areas, as well as public awareness and education, should be encouraged.

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