The Effect of Coal Mining Activities on Soil Surface Temperatures inForested Areas

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Abstract. Coal mines often leave an ecological footprint that can damage the environment. One impact that is often overlooked but has long-term consequences is changes in ground surface temperature, especially in forest areas adjacent to mining sites. This research focuses on an in-depth analysis of the land surface temperature in forested areas around coal mines. Forest areas were chosen as the focus of the study because forests have a crucial role in maintaining climate and ecosystem balance. The analysis method ~~which~~ used in this research is the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) with data sourced from LANDSAT- 8 satellite imagery. The results of the measurements in forest areas adjacent to coal mines showed that ground surface temperatures reached a range of 30.0-36.0°C. This figure is higher when compared to ground surface temperatures in natural forested areas that are not affected by mining activities, which range between 27.5-31.0°C. This significant temperature difference shows the direct influence of mining activities on the thermal conditions of the soil in the forested area around the coal mining area. Increasing ground surface temperatures in forested areas near coal mines can reduce soil moisture and affect vegetation growth.

Keywords: Coal Mines; Environmental Damage; NDVI; Climate Balance.

1. Introduction

Forests play a crucial role as carbon sinks, contributing to climate change mitigation. Additionally, forests help regulate temperatures by providing shade and reducing the impacts of extreme weather events. Factors such as temperature, rainfall, and disturbances affect the size and dynamics of forest carbon space(1,2). The stability of soil organic matter, which is essential for soil carbon dynamics, is influenced by rock geochemistry, climate, and soil properties (3). Therefore, management interventions may be necessary to ensure the health of forests (4).

Deforestation, soil degradation, and changes in water patterns are the consequences of coal mining activities. Deforestation is often caused by uncontrolled mining and rapid agricultural expansion, leading to the loss of forested areas (5). Soil degradation

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can occur due to mining activities, resulting in changes in soil microbial communities and nutrient levels (1). Furthermore, coal mining can lead to groundwater pollution, with microorganisms playing a role in the formation and evolution of mining water quality (6). Changes in land topography caused by mining subsidence can disrupt the water cycle, causing disturbances at the local and regional levels (7).

Coal mining activities have significant environmental impacts, including changes in Land Surface Temperature (LST) and reductions in forested areas (8). Emissions from coal combustion affect surface air quality (9). Moreover, the surface temperature of the soil in coal mining areas can increase over time due to the expansion of mining activities and changes in land cover (10). Coal mining activities have a significant impact on the surrounding areas, particularly on Land Surface Temperature (LST) and the Normalized Difference Vegetation Index (NDVI)(11,12). Disruptions from mining activities alter soil properties and the hydrological balance of the region (13). For example, the surface temperature of the soil in coal mining areas increased from 18°C to 22.2°C over a 13-year period (14).

Research has shown that coal mining activities lead to significant changes in the distribution of surface temperatures (15). Furthermore, coal mining can result in the loss of terrestrial carbon stocks, shifting the function of forests from net carbon sinks to net carbon sources (16). Therefore, understanding the relationship between coal mining and surface temperature is crucial for sustainable coal extraction and use (17).

Understanding how coal mining affects surface temperatures in forested areas is of paramount importance, given the significant impacts of both components on ecosystems and climate balance. However, our understanding of Land Surface Temperature (LST) and NDVI conditions and their relationship in open-pit coal mining areas is still limited. Researchers are focusing on studying the conditions of forested Land Surface Temperature (LST) (using the NDVI approach) around open-pit coal mines. Although open-pit coal mining areas are widespread in South Kalimantan, researchers have chosen the largest open-pit mining area for this study.

2. Method

This research represents an initial study focused on assessing the influence of coal mining on the surface temperature of the surrounding forested land using remote sensing technology. It is a descriptive quantitative study that utilizes LANDSAT-8 satellite imagery data. Sample points were systematically placed in a grid pattern with a 500-meter interval inside and around the mining site.

To collect data, internet resources were employed to download LANDSAT-8 data for free from https://earthexplorer.usgs.gov/. The data analysis approach involved spatial analysis techniques, specifically NDVI (Normalized Difference Vegetation Index) and LST (Land Surface Temperature), with variables including air temperature, surface soil temperature, humidity, and wood potential. The NDVI and LST analysis methods proved effective in providing valuable insights into the ecological impact of mining activities in the surrounding area. The software tools used for this analysis were QGIS and Google Earth Engine. Figure 1 presents the research location and spatial observations below.

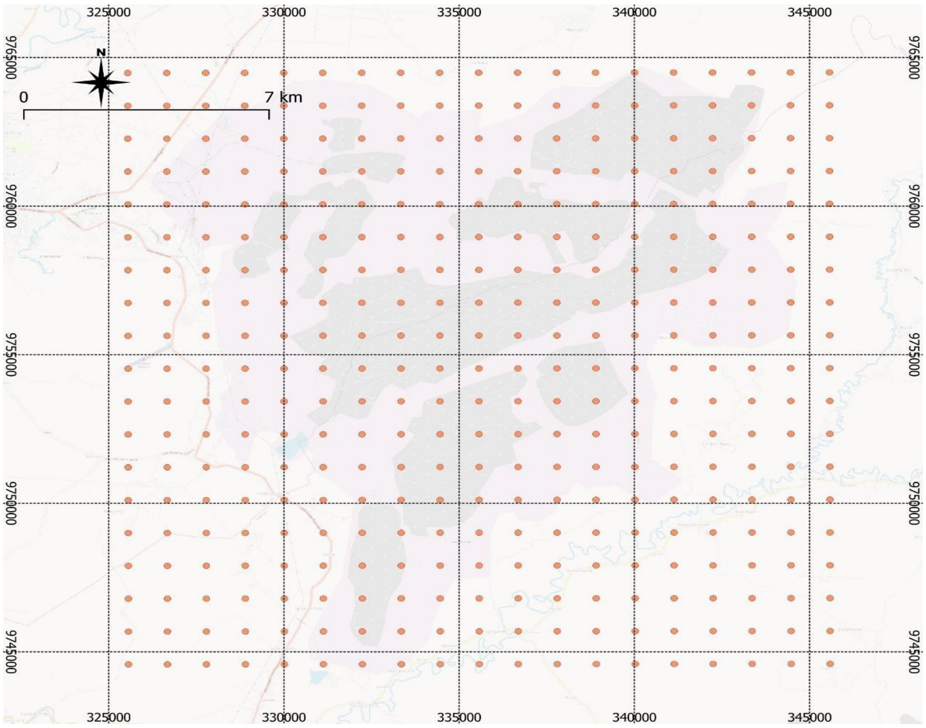

Figure 1. Example points distribution with a box-grid pattern

3. Result and Discussion

Figure 2 visualizes the temperature distribution in the area, ranging from 25.77 to 47.94 degrees Celsius, revealing variations in thermal conditions both around and within the mining site. The zone with temperatures at the lower end of the scale, around 25.77 degrees Celsius, could signify areas further from the mining center or areas with thicker vegetation that serve as natural shade and cooling agents. On the other hand, areas with temperatures nearing 47.94 degrees Celsius are likely located in actively mined zones or areas that have undergone significant changes due to mining activities, such as the loss of vegetation and alterations in soil characteristics. Coal mining activities can impact the thermal conditions in their vicinity, with increased temperatures indicating the direct effects of mining activities. Therefore, such temperature changes should be a concern for environmental management and impact mitigation

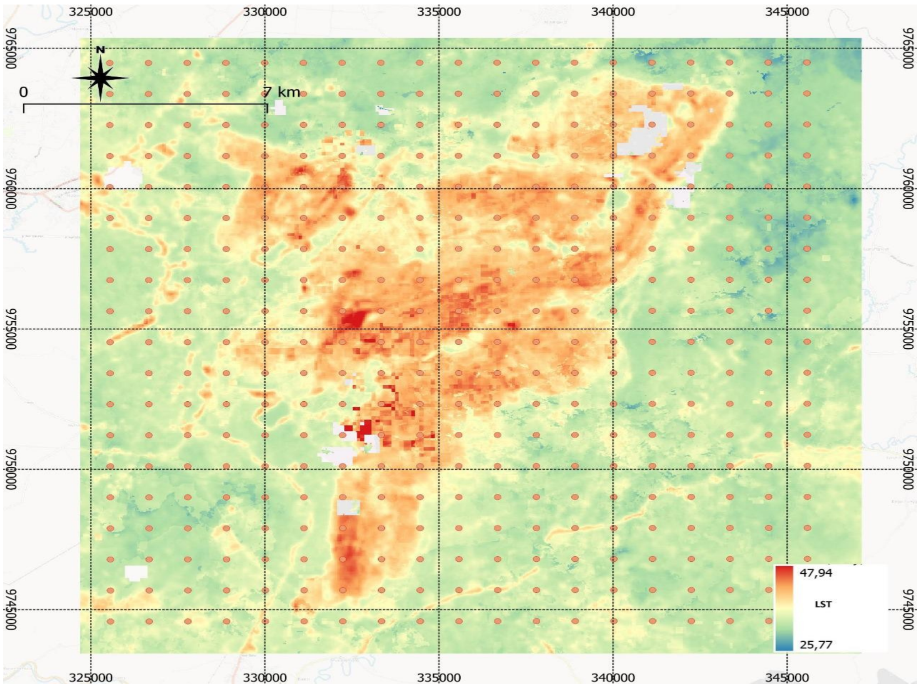

Figure 2. Land Surface Temperature (LST) Values Around and Within the Coal Mining Area

The temperature zones can provide insights into areas that are either farther away from or closer to the mining center. In the context of coal mining, the utilization of Land Surface Temperature (LST) data derived from thermal infrared images can assist in distinguishing minedland from other land use categories, such as built-up areas and fallow land (18). Mined land typically exhibits higher surface temperatures, even during the night ~~time~~, due to geothermal heatand pyrite oxidation, which contribute to elevated warmth (19). By analyzing land surface temperatures and normalizing various vegetation indices, spatial correlations can be observed, offering valuable information regarding the distribution of land surface temperatures among different land cover types within the mining area (20).

Figure 3 displays the distribution of the vegetation index in the observed region. NDVI, depicted in the range of -0.01 to 0.5 in this image, serves as an indicator for measuring greennessor vegetation density. NDVI values that approach -0.01 typically signify areas with minimal or no vegetation, sometimes even water bodies. This often indicates active mining areas or land thathas been disturbed by human activities. In the context of coal mining, low NDVI values can be indicative of actively mined locations or areas that have undergone reclamation but have yet to exhibit sufficient vegetation growth. Conversely, NDVI values approximating 0.5 suggest areas with denser vegetation, which may encompass forests, grasslands, or other vegetated regions untouched by mining activities. Higher NDVI values signal denser vegetation and hold potential for enhancing environmental quality, particularly when situated near active mining sites.

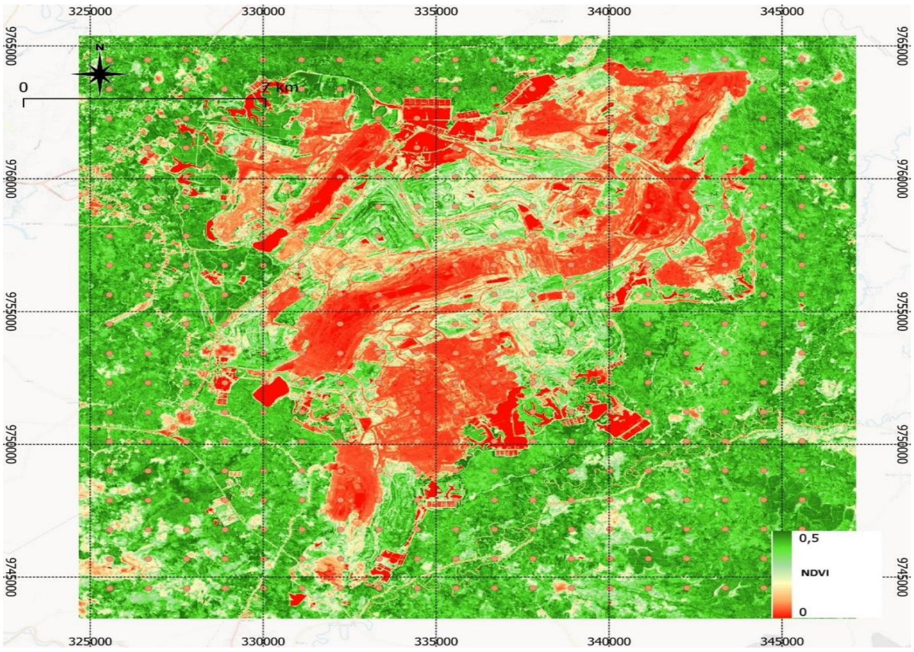

Figure 3. NDVI values around and within coal mining areas

Deforestation in the vicinity of forests results in habitat loss, disrupts ecosystems, and leads to a decline in NDVI values due to the loss of vegetation (21). The construction of mining infrastructure, including roads and other support facilities, can fragment forested areas, thereby causing habitat fragmentation. This fragmentation can disturb species requiring substantial areas for survival and reduce ecological connectivity (22). Mining waste and the use of chemicals during the mining process can contaminate water sources surrounding forests, adversely affecting the health of trees and other species (23).

Figure 4 illustrates the relationship between LST and NDVI both within and around the coal mining area. This graph clearly depicts an inverse correlation between LST and NDVI within and in the vicinity of the coal mining site. From the graph, it becomes evident that as LST increases, NDVI tends to decrease. This observation implies that areas experiencing higher surface temperatures, typically those associated with mining activities, tend to have less vegetation or exhibit less healthy vegetation conditions.

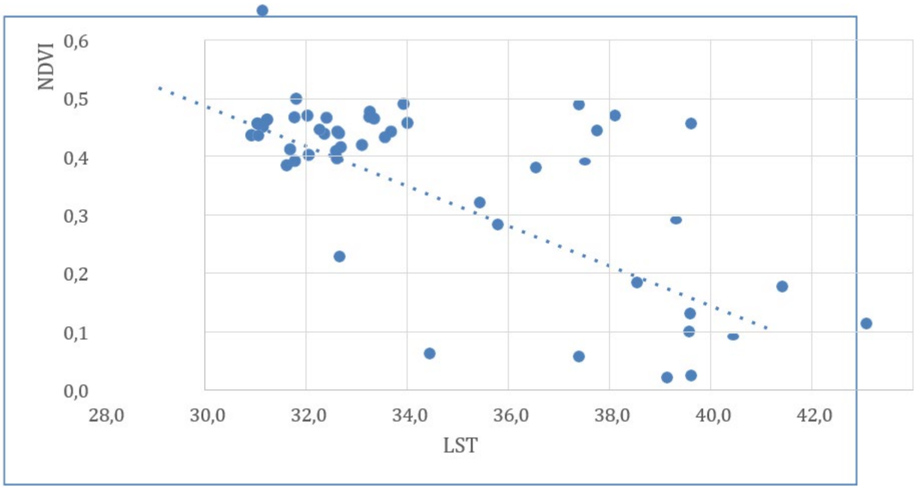

Figure 4. Graph of the relationship between LST and NDVI in and around the coal mining area

Nevertheless, there are pockets of concentrated vegetation displaying NDVI values ranging from 0.3 to 0.5, which generally indicate moderate to dense vegetation. These areas are predominantly situated around the mining site rather than within it. Despite their relatively dense vegetation, the surface temperatures in these pockets vary between 28 and 37 degrees Celsius. This suggests that although the areas surrounding the mine maintain a reasonable level of vegetation, their surface temperatures remain elevated compared to forested areas located far from mining operations.

For example, forest areas in the Lambung Mangkurat University Educational Forest Area(KHDTK ULM), as depicted in Figure 5, tend to have temperatures in the range of 27-30 degrees Celsius. Likewise, as in Figure 6 which compiles the relationship between LST and NDVI in various ecosystem conditions such as Taiga, High Mountains, Forest Steppe, Steppe, Desert Steppe, and Desert, the NDVI value in the range of 0.25-0.5 corresponds to the temperature range of 20-30 degrees Celsius (24).

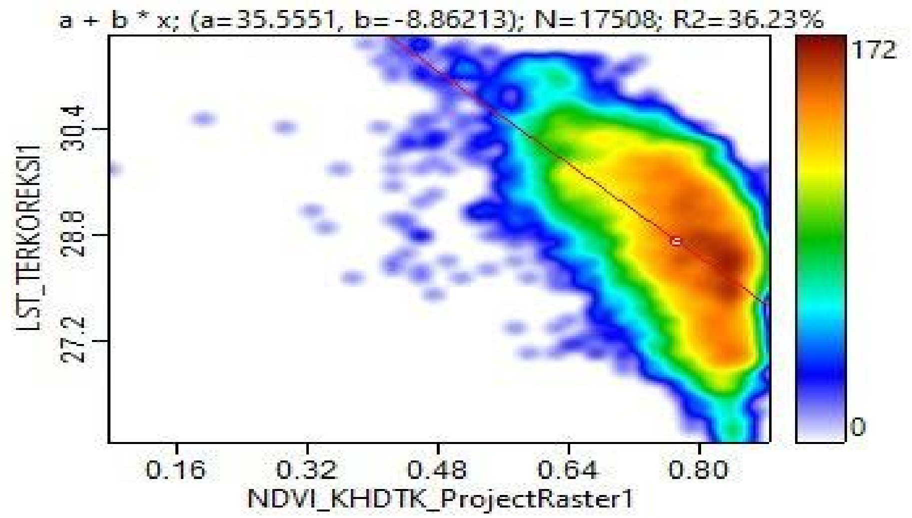

Figure 5. Relationship between NDVI and LST in the KHDTK ULM area

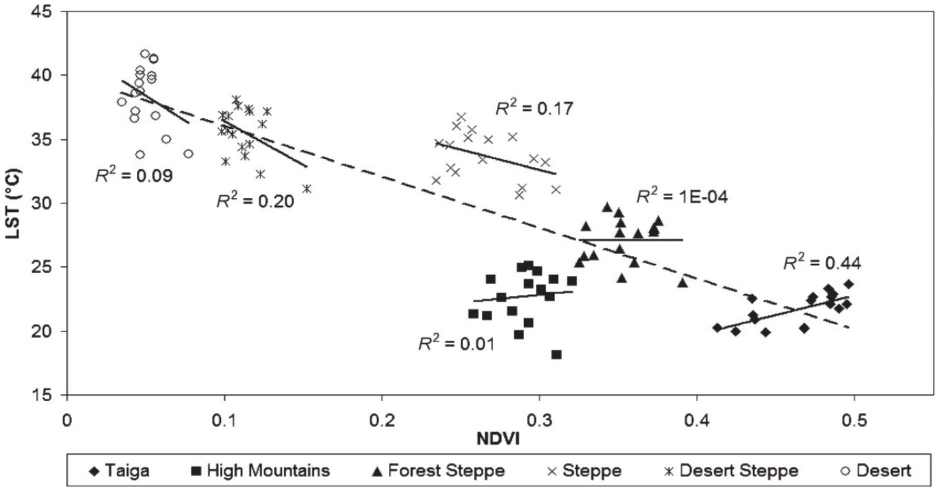

Figure 6. Relationship between NDVI and LST in Various Ecosystem Conditions.

4. Conclusion

The relationship between LST (Land Surface Temperature) and NDVI (Normalized Difference Vegetation Index) is inversely related. When the land surface temperature increases, NDVI tends to decrease, indicating that areas with higher surface temperatures have less vegetation or less healthy vegetation. However, there are forested areas around the mine with NDVI values ranging from 0.3 to 0.5, and their surface temperatures range from 28 to 37 degrees Celsius. This suggests that the vegetation around the mine is likely impacted by mining activities. In contrast, other forested areas, where there is no nearby coal mining activity, and with NDVI values of 0.3-0.5, have temperatures between 20 and 30 degrees Celsius

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