SPATIAL-TEMPORAL ASSESSMENT OF THE ENVIRONMENTAL IMPACTS OF MINING IN APAMPRAMA FOREST RESERVE GHANA

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ABSTRACT

Mining activities are major contributors to land cover and land use changes. Since opencast mining is a continuous process, monitoring land cover changes becomes crucial for sustainable land management. This is particularly relevant in areas like the Apamprama Forest Reserve, where mining activities have visibly degraded the surrounding environment. Streams contaminated with pollutants, abandoned waste rock piles, and severe soil erosion exemplify inadequate environmental protection efforts. This study aims to assess the spatiotemporal land use and land cover changes resulting from mining activities in the Apamprama Forest Reserve. The study employs Sentinel-2 imagery for land degradation analysis, using built-in algorithms for atmospheric correction, radiometric calibration, and cloud masking. Additionally, air quality is analyzed using the Sentinel's OFFL L3 product, and land surface temperature data is gathered from the MODIS MOD11A1 V6.1 product, forming a time series from 2018 to 2023.

INTRODUCTION

Mining has a significant impact on landscapes (Bebbington et al., 2008; Mudd, 2010), making it unique among industries. According to Sonter et al. (2014), mines have a disproportionate influence on populations and ecosystems near their locations. Modern mines typically include open-cut pits, waste rock dumps, tailings dams, water storage ponds, access roads, milling and processing infrastructure, supporting infrastructure (e.g., worker housing), block cave areas, heap leach pads, or quarries. Such traits are frequently predictive of repercussions in nearby locations. Some repercussions, such as deforestation, can be seen in aerial or satellite photography, while others, such as social conflict, are often not. As a result, various impacts necessitate distinct geographical analysis methodologies. Remote sensing (RS) and geographic information systems (GIS) are commonly used software technologies in Geographical Information Science (Goodchild, 2003). RS uses aerial or satellite photography to investigate Earth’s surface features, while GIS is a computer-based system that manages, analyzes, and manipulates geographical data to create 2D or 3D visualizations, such as maps. Larger mining corporations utilize these techniques for exploration, environmental impact assessment, and mine management, and they have been advocated by industry associations (see Legg, 1990). Software developers have developed GIS solutions to satisfy the operational demands of mining experts, such as ESRI (2018) and Kim et al. (2012). Academics and civil society organizations use GIS and

RS to study mining impacts for various purposes. Environmental and socioeconomic risk assessments, cumulative and strategic impact assessments, industry wide land use trends analysis, and global comparative analyses of impacts across commodities, locations, and mine configurations are among the services offered. Studies that are free of real or perceived conflicts of interest can either refute or support the mining Industry's assertions. According to Miranda et al. (2003) and Moffat and Zhang (2014), adjudicating mining-related conflicts might be beneficial, especially given the fragile public trust in mining businesses. This research can supplement the mining industry's research needs by filling data gaps on previously unmonitored or under-studied impacts in spatial terms. In recent years, there has been an increase in research using GIS and RS to examine the spatial implications of mining. However, few analysts outside the mining industry have used these tools to study the impacts. GIS and RS are effective tools for analyzing mining impacts, although they are often underutilized. The removal of soils and vegetation from Apamprama Forest Reserve land surfaces has resulted in the degradation of natural ecosystems, which is one of the effects of mining. In addition, according to Byizigiro, Biryabarema, and Rwanyiziri (2020), these effects include haphazard excavations done without a plan for land reclamation, vegetation loss, altered landforms, accelerated soil erosion, disruption of ecosystem fluxes, and the loss of valuable farmland that makes the sites unsafe for use for other purposes. By destroying vegetative cover, forming gullies, rills, and scars that hasten erosion and landslides, mining operations have had a detrimental impact on the terrain. Eroded materials are partially to blame for the drainage system's interruption. The detrimental effects of mining may be long-lasting, if not eternal. This calls for the management of mining sites in accordance with current mining legislation in an exemplary manner both during and after mining. Mining operations may impact communities, making it difficult for them to gain access to land or alter its current use (AGA 2009). For example, arable fields designated for cultivation are encroached upon by open cast mining. The area is less fertile due to increased soil erosion caused by the removal of numerous trees and woods. Because of land clearing, soil erosion, and landscape damage brought on by mineral extraction, farming operations and agricultural productivity are significantly reduced and unsatisfactory.

Study Area

One of the four forest reserves in the Ashanti Region's Amansie Central and Amansie West Districts is Apamprama Forest Reserve (Fig. 1). The reserve is situated between latitudes 06˚ 17C 14M N and longitudes 01˚ 55′ 16″ W and 01˚ 48′ 21″ W. It has an approximate area of 36.28 km2. The districts make up 8.5% of the region's total land surface area and are located in the southwest of Ashanti (Anon., 2015). Their combined land area is roughly 2074 km^2. The districts are mostly made up of plateaus that are sloping and range in elevation from 150 to 300 meters above sea level. The River Offin drains the forest, and the area has semi equatorial, humid weather with an average annual rainfall of roughly 1700 mm and temperatures ranging from 20 to 32 °C.

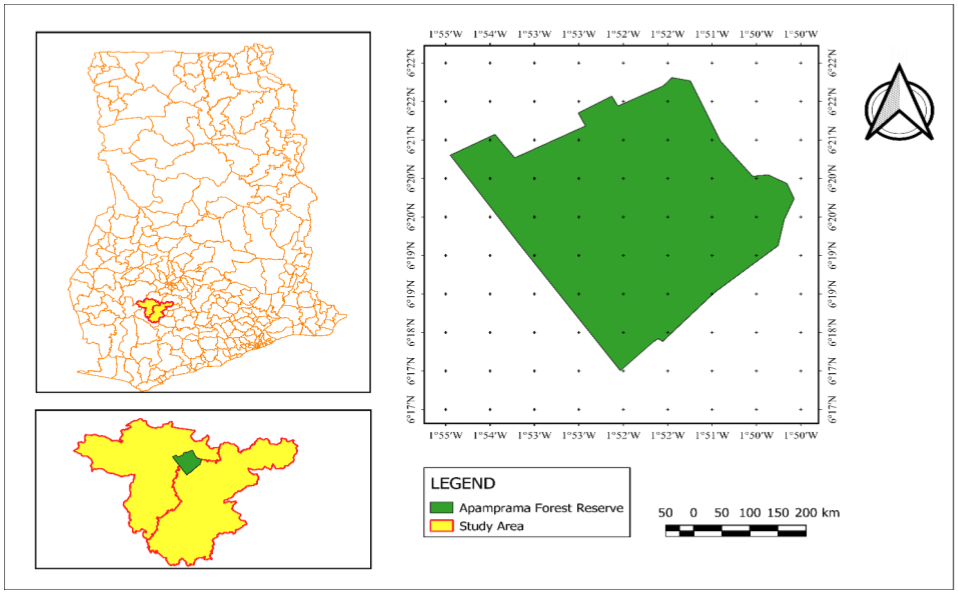

Fig. 1: Map of Apamprama Forest Reserve showing study area.

MATERIALS AND METHODS

1. Land Cover Analysis

The study begins with the preprocessing of Sentinel-2 imagery using Google Earth Engine's (GEE) built-in functions for atmospheric correction, radiometric calibration, and cloud masking. Key indices like the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) are extracted from the imagery.

Principal Component Analysis (PCA) is applied to enhance discrimination between different land cover classes.

2. Data Collection and Model Training

Training data is collected from both forested areas and mining sites to train a Random Forest classification model, known for its ability to handle high-dimensional and non-linear data relationships (Rodriguez- Galiano et al., 2012).

3. Air Quality Analysis (Carbon Monoxide)

The 'CO_column_number_density' band from Sentinel's OFFL L3 product is used to analyze carbon monoxide concentration, generating a yearly time series from 2018 to 2023.

4. Land Surface Temperature Analysis

The MODIS MOD11A1 V6.1 product is used to generate a time series of daytime land surface temperature from 2018 to 2023.

5. **Time Series Generation**

Yearly time series datasets were generated for both carbon monoxide concentration and land surface temperature. These time series captured the temporal variations of the respective variables from 2018 to 2023

RESULTS

1. Land Cover Changes

Between 2018 and 2023, the forested area in the Apamprama Forest Reserve decreased by 495 hectares, from 2,254 hectares in 2018 to 1,759 hectares in 2023. Concurrently, the degraded area expanded by 495 hectares, from 613 hectares in 2018 to 1,108 hectares in 2023. These changes reflect the environmental toll of continued mining activities.

Fig 2: Map showing degraded area for 2018

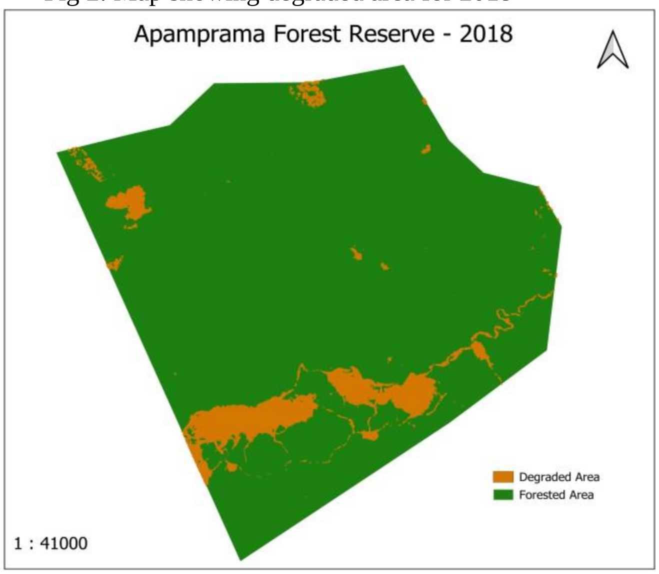

Fig 3: Map showing degraded area for 2023

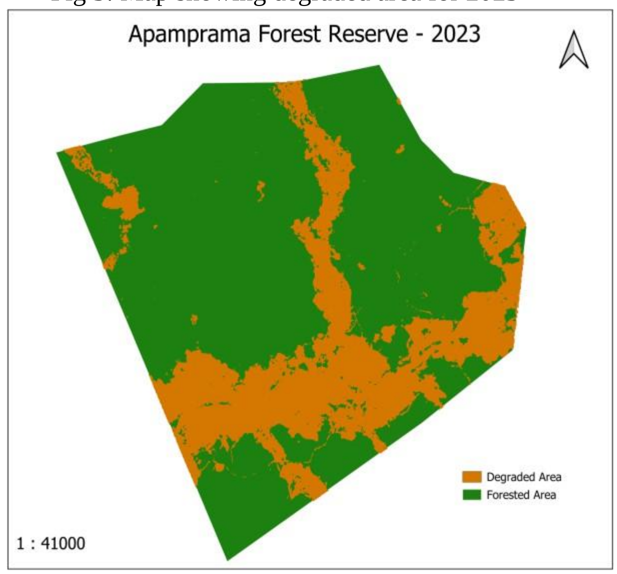

Table 1: Numerical extent of degraded area

Land cover	**2018**	**2023**
Forested Area	2254	1759
Degraded Area	613	1108
Total Area	**2867**	

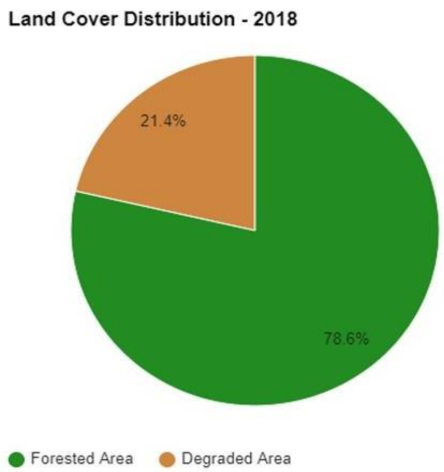

Fig 4: Land cover distribution for 2018

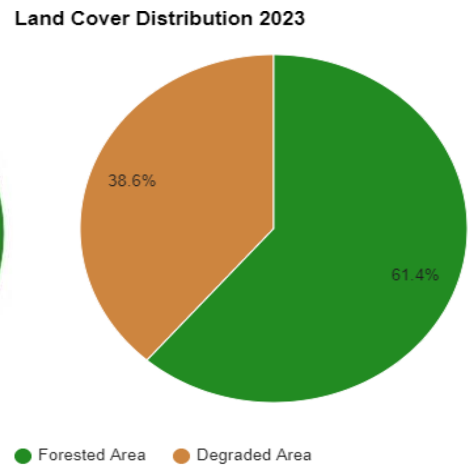

Fig 5: Land cover distribution for 2023

2. Land Surface Temperature

Land surface temperatures showed a consistent increase over the study period, rising from 26.887°C in 2018 to 27.658°C in 2023, with the highest recorded temperature of 27.76°C occurring in 2021. This upward trend suggests potential environmental stress linked to mining activities.

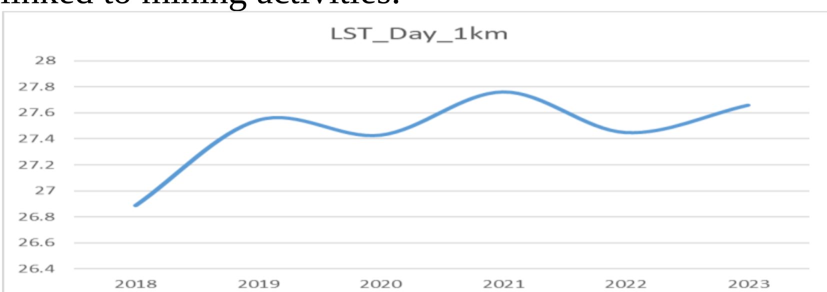

Fig 6: Land surface temperature from 2018-2023

3. Carbon Monoxide Concentration

Carbon monoxide levels also increased substantially, from 3.616 mol/m² in 2018 to 10.246 mol/m² in 2023. The peak concentration of 12.063 mol/m² was recorded in 2020. These findings underscore the rising air quality concerns associated with mining.

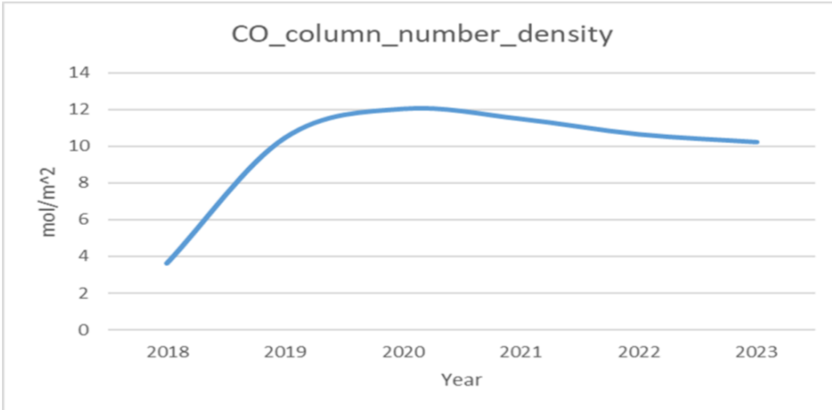

Fig 7: Carbon monoxide Concentration from 2018-2023

CONCLUSION

The Apamprama Forest Reserve has experienced significant environmental degradation over the five-year study period, largely due to ongoing mining activities. The loss of forest cover, increasing land surface temperatures, and rising carbon monoxide levels all point to a pressing need for improved environmental protection measures. Future efforts should focus on enhancing land reclamation practices, reducing pollution, and implementing sustainable land management strategies to mitigate the environmental impacts of mining. Continued monitoring through remote sensing and GIS technologies will be essential in guiding these efforts.

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