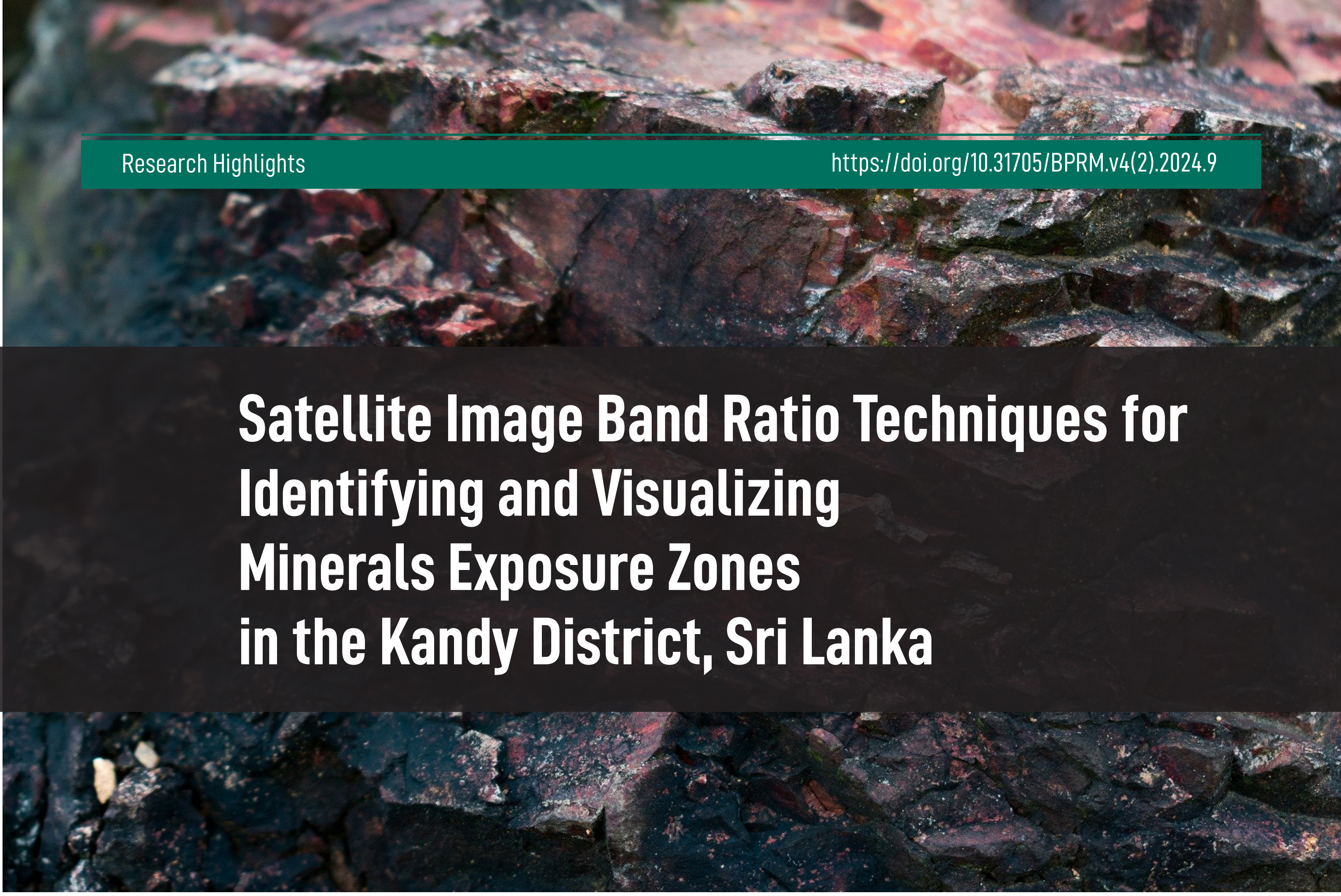

Research Highlights https://doi.org/10.31705/BPRM.v4(2).2024.9

Satellite Image Band Ratio Techniques for Identifying and Visualizing Minerals Exposure Zones in the Kandy District, Sri Lanka

I. Introduction

Recent scientific studies are anticipating the development of novel, expeditious, and dependable methodologies for mineral exploration. This emerging need arises from the extensive depletion of major valuable mineral deposits in easily accessible regions. Furthermore, contemporary exploration strategies are increasingly focused on locating deeper mineral deposits in geologically complex and challenging terrains, where accessibility is significantly constrained [1], [2].Geophysical methodologies comprise a range of techniques utilized to acquire insights into the subsurface properties of the Earth. These methods facilitate the acquisition of data from considerable depths, with verification achieved through borehole core sampling [1]. Additionally, remote sensing data can offer valuable insights such as surface material composition and rock types, particularly in areas where vegetation cover is not comprehensive during the reconnaissance surveys [3]. Remote sensing data, including both multispectral and hyperspectral imagery used for mineral exploration does not serve as a replacement for ground truth data, but rather complements it by providing additional information about the region of interest [1],[2],[4]. The identification of potential mineral deposits is facilitated by the examination of available geological data, which includes observations such as specific mineral occurrences within distinct rock types, the distribution of geological structural features, significant alteration zones, deposits forms with high-temperature zones and hydrothermally altered areas [1], [5]. At a regional scale, diverse lithological features such as the textural properties of igneous and sedimentary rocks, structural configurations, and vegetation patterns can be effectively detected through remote sensing. These observations are instrumental in elucidating the geological and ecological framework of an area, thereby contributing to a comprehensive understanding of its natural environment. Integrating remote sensing with field observations and geospatial technologies provides a comprehensive view of landscapes, enhancing geological accuracy and supporting sustainable development. This approach aids informed land use planning and resource management, promoting efficient and sustainable natural resource utilization.

II. Literature review

Remote sensing works by capturing and analyzing electromagnetic radiation reflected or emitted from the Earth's surface and atmosphere across

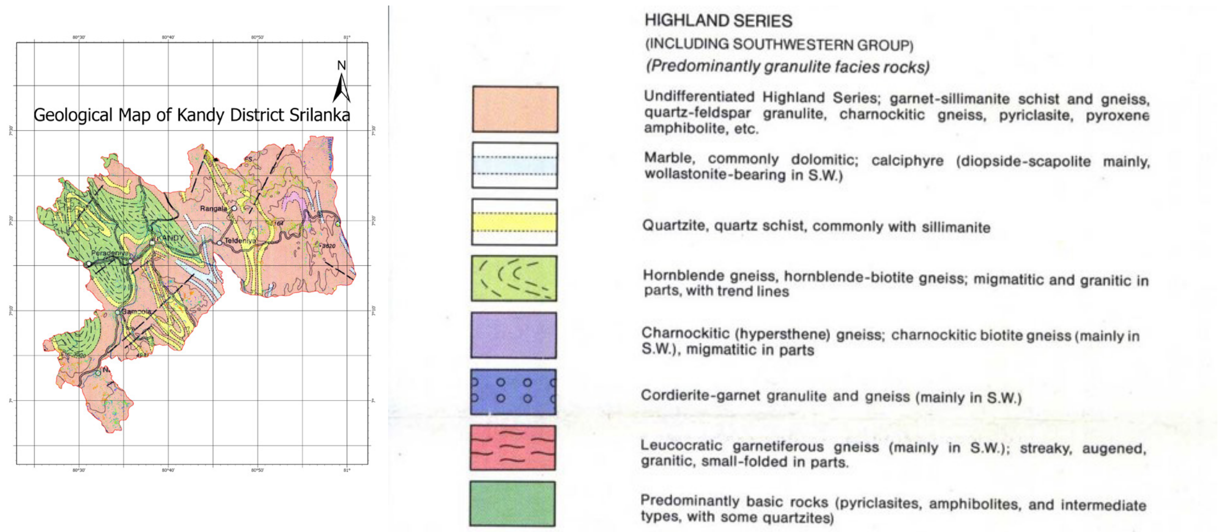

Figure 1: Geological Map of Kandy

a broad spectrum. Various satellite datasets have been utilized for mineral exploration, including ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), Landsat 5, 7, and 8, and Sentinel [1], [3], [4], [5]. The narrower bandwidth of Landsat 8 is expected to enhance the quality of mapping for clay, sand, iron oxide minerals, and other minerals associated with hydrothermal alteration, as they exhibit strong absorption in the near and shortwave infrared (SWIR) regions [5]. The absorption of radiation across different wavelength ranges facilitates the identification of specific mineral types. Primary lithogenic minerals, along with numerous secondary weathering and alteration minerals displays wavelength-dependent absorption characteristics across the visible and infrared regions of the electromagnetic spectrum (400–2500 nm) [1], [3], [5]. Iron minerals are discernible below 1000 nm, while silicates, carbonates, sulfates, and phosphates exhibit distinct spectral features between 8000 and 12000 nm [3], [4].

III. Materials and Methods

A. Study Area

In Sri Lanka, approximately 90% of the land area is characterized by Precambrian metamorphic rocks. These rocks are often overlaid by recently formed clay, laterite, red earth materials, and various soil deposits. The study has focused on the Kandy district of Sri Lanka, and it has revealed significant geological features such as granitic gneiss, charnockitic biotite gneiss, quartzite, marble, and calciphyre based on the geological map (Fig. 1) of the area.

B. Materials

Landsat 8 imagery was utilized for data collection, providing atmospherically corrected surface reflectance from the OLI/TIRS sensors. Images from 2020 to 2023 with less than 5% cloud cover were acquired, and cloud masks ensured data quality. Enhanced composite images were generated to improve mapping accuracy and consistency. While images from Google Earth Engine platform, ASTER, and Sentinel were considered, Landsat 8 was chosen for its superior spatial coverage.

C. Methods

Band ratioing in multispectral analysis entails the mathematical operation of dividing the spectral values of one band by those of another to ascertain the ratio of spectral reflectance, thereby highlighting the distinct spectral characteristics of materials intended for mapping purposes [1][3][5]. The band ratios 4/2, 6/7, and 6/5 are indicative of clay or hydroxyl, ferric iron, and ferrous iron alterations, respectively. The RGB color composite generated from these band ratios is referred to as Sabin's ratio [4][5]. To further enhance the detection of hydrothermally altered zones, Hydrothermal Alteration Index (HAI) can be calculated using equation (1). This equation emphasizes the distinction between hydrothermally altered zones by leveraging the spectral differences between the Short-Wave Infrared (SWIR1, Band 6) and Near-Infrared (NIR, Band 5) bands. The resulting map of hydrothermal alteration highlights potential areas of mineralization, offering valuable insights for geological exploration and mapping.

$$HAI = \frac{(Band\ 6 - Band\ 5)}{(Band\ 6 + Band\ 5 + 0.0001)} - 1$$

IV. Results and Discussion

Figure 2 revealed distinct spectral patterns that correspond to different surface materials and alteration zones. The application of these band ratios provided valuable insight into the distribution of key mineralogical features and potential hydrothermal alterations across the study area. Green areas are indicative of clay or hydroxyl-bearing minerals found in altered regions. Pink areas are associated with ferric iron oxides, indicating zones of oxidation and potential hydrothermal activity [5]. Water bodies were clearly distinguished in blue, showcasing effective spectral separation between land and aquatic features. The observed patterns align well with the existing geological map, validating the accuracy of this remote sensing approach.

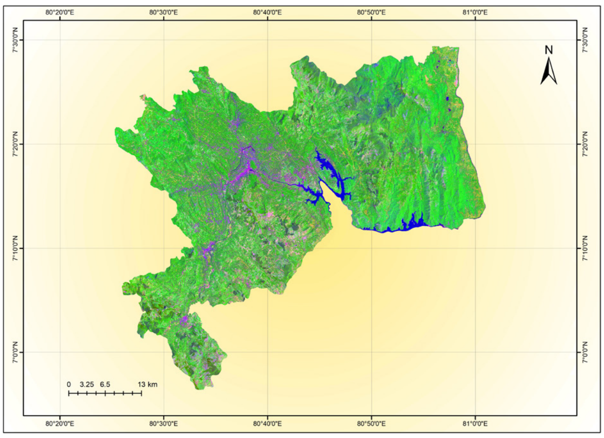

Figure 2: Band ratio composite map (4/2-6/7-6/5)

Figure 3 illustrates the hydrothermally altered zone map, visually depicting areas of potential hydrothermal alteration. The map utilizes a color gradient to represent the intensity of alteration, ranging from low (blue tones) to high (red tones), thereby indicating varying degrees of alteration. The application of Landsat-8 SWIR and NIR bands facilitates the detection of mineral alterations typically associated with hydrothermal processes, which are crucial for identifying prospective zones of mineralization or geothermal activity. Higher HAI values (green to red) are indicative of significant hydrothermal alteration, which could be related to the presence of clay minerals or hydroxyl-bearing minerals. These zones might correspond to regions where fluid-rock interaction has altered rock chemistry, often linked to mineral exploration and geothermal studies. Conversely, lower HAI values (blue regions) suggest minimal or no hydrothermal alteration.

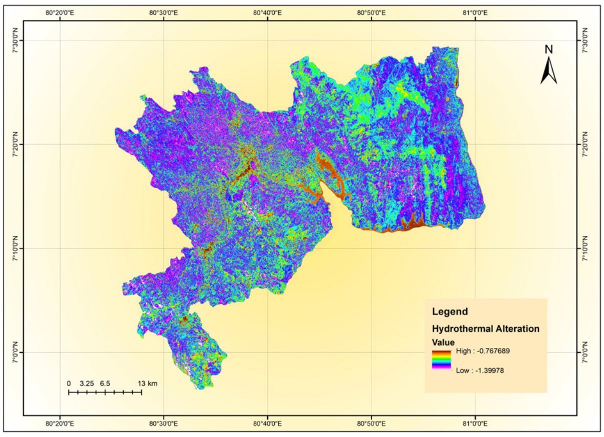

Figure 3. Hydrothermally Altered Zones

V. Conclusion

The study explores the approach of satellite remote sensing techniques for mineral exploration, emphasizing the effectiveness of Landsat 8 imagery and band ratio methods in identifying hydrothermal alterations and mineralized zones. While these methods offer efficient and large-scale insights, challenges such as dependence on atmospheric corrections and resolution limitations highlight the need for validation with ground truth data. Future research should explore additional band ratio techniques, such as the Rock Index, Rock Alteration Index, Iron Oxide Index, Vegetation Index, and Built-Up Area Index, to provide more comprehensive analysis. Combining these techniques with advanced methods like Principal Component Analysis (PCA), spectral unmixing, and high-resolution imagery can enhance the accuracy and detail of mineral mapping. This integrated approach has the potential to significantly advance mineral exploration, particularly in geologically complex and remote regions, by delivering valuable insights into alteration zones and associated mineralization processes.

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