The Use of Landsat 8 in Detecting Potential Mineral Zones in West Nusa Tenggara, Indonesia

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Abstract: The remote sensing analysis within the Hu'u District area is known to face a challenge with dense vegetation. The problem affects the accurate reading of spectral reflectance from satellites, influencing the differentiation between potential mineral zones and vegetation. Therefore, this study aims to carry out a remote sensing analysis of densely vegetated areas to differentiate minerals from vegetation and obtain potential mineral zones. The combination band ratios and principal component analysis (PCA) methods are used to acquire potential mineral zones. Furthermore, Landsat 8 images freely available on Google Earth Engine are adopted and the validation is carried out using a drill hole from previous study. The results show that band ratios method cannot distinguish mineral zones from vegetation. However, PCA method can recognize potential mineral zones. This is the result from PCA method with band combination of bands 1, 2, 3, 4, 5, and 6 as the first group and bands 2, 4, 5, and 6 as the second group.

Keywords: Landsat 8, Band Ratio, Principal Component Analysis, Mineral, Densely Vegetated

1. Introduction

Geological mapping is perceived as an indispensable component across different disciplines and applications. In this context, remote sensing datasets have been developed as a cost-effective, efficacious, as well as temporally and labor-efficient methodology, particularly when subjected to traditional approaches of field mapping. Landsat data has also been extensively deployed for tasks such as discriminating among rock units, deciphering lineaments, and showing hydrothermal alterations. Due to economic concerns, mineral mapping using satellite data speeds up exploration, lowers expenses, as well as accurately and quickly identifies broad regions (Aita and Omar, 2021; Bakardjiev and Popov, 2015; Naftali et al., 2015; Shebl and Csamer, 2021).

Optical appraisal of aerial pictures has been leveraged to correctly show these formations, particularly linear structures or lineaments. In the present era, with the advent of Geographic Information System (GIS) expertise, the high-resolution data gained from photos, autonomous parsing of satellite images, and Landsat, is strongly propagated (Wambo et al., 2016). Alteration mineral indices such as the OH-bearing, pyrophyllite, kaolinite, alunite, and calcite were established by detecting argillic, phyllic, and propylitic alternations in epithermal deposit and porphyry copper deposit using Landsat 8 (Ombiro et al., 2021; Parcutela et al., 2022; Shim et al., 2021; Zhang et al., 2016).

Several studies have focused on methodologies to show geological structures by taking advantage of Principal Component Analysis (PCA) and Band Ratio (BR) among other techniques. The use of the conventional PCA approach may substantially enhance the precision of geological mapping, facilitating a more accurate identification and interpretation of geospatial and spectral data (Carranza and Hale, 2010; Chen et al., 2021; Ghasemi et al., 2018).

2. Study Area

The study area is located within the Hu'u district, Dompu Regency on Sumbawa Island, situated in West Nusa Tenggara, Indonesia, and forms a portion of the territory under projects managed by PT Sumbawa Timur Mining (PT STM). Within the district, there exist three principal porphyry Cu-Au prospects, specifically the Humpa Leu East, Sori Hiu, and Onto prospects (Fadlin et al., 2023). The district has been hypothesized to be a paleovolcano, characterized by Upper Miocene Basaltic Andesite lava, with radiometric dating at an age of 5 ± 0.2 Ma years. Regionally, the rock formations are categorized as constituents of the Old Volcanics Rocks Formation (Verdiansyah et al., 2023). The Hu'u intricate features various surface possibilities, manifested as a lithocap of widespread epithermal-style alteration but some are connected to a porphyry situated underneath the ground (Verdiansyah et al., 2021).

The Hu'u project region is situated at the junction of many significant fault zones, according to a seismotectonic assessment. A significant sinistral fault with an NW trend is projected across the region from the southwest face of the Tambora volcano. Furthermore, a significant dextral fault with an NE trend extends along the bay straight west of the Hu'u region (Burrows et al., 2020).

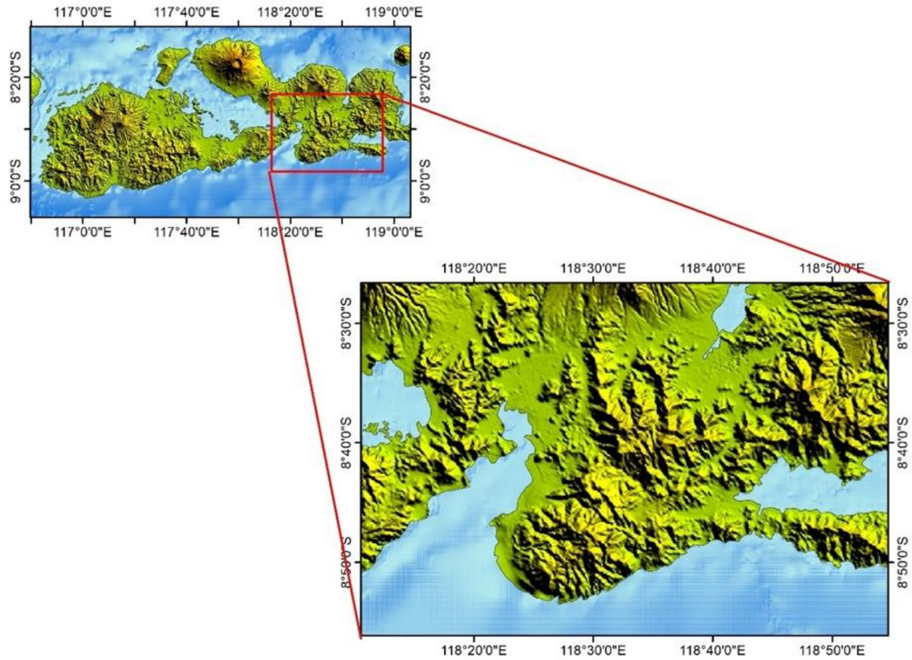


Figure 1. Hu'u District, West Nusa Tenggara, Indonesia as the study area

3. Method

3.1 Images Data

Landsat 8 data used is freely obtained from Google Earth Engine as a compilation of images from April 2013 to 2023. This data is pre-configured in a Top of Atmosphere (TOA) format after radiometric and geometric corrections. Furthermore, cloud cover filter is the preprocessing conducted to obtain the least cloudy images. The purpose of the pre-processing is to derive a collection of satellite images, spanning several years, with minimal cloud interference.

3.2 Pre-Processing

The data, procured from the Google Earth Engine, originates from Landsat 8, Collection 2, Tier 1. This data is pre-configured in a TOA format after radiometric and geometric corrections. In addition, the pre-processing is to derive a collection of satellite images, spanning several years, with minimal cloud interference. Obtaining raw Landsat satellite images in the region of interest is crucial in providing the conditions in the targeted area.

3.3 Band Ratio

Band combinations tested in this study are 4/2, 6/7, 6/5, and 7/5 to obtain iron oxide, hydroxyl-bearing rocks, ferrous minerals, and clay, respectively.

3.4 Band Ratio Composites

The 3 combinations of band ratio composites experienced in the project are Sabin's ratio, Kaufmann's ratio, and composite of 4/2, 6/7, and 5. Sabin's ratio is expected to define a hydrothermal alteration map, while Kaufmanns' ratio is anticipated to distinguish altered rocks and lithological elements from the vegetation.

The composites of 4/2, 6/7, and 5 are used to differentiate altered rocks and outcrops from trees and plants.

3.5 PCA

There are two combinations of bands for PCA. The group of bands 1, 2, 3, 4, 5, and 6, as well as those from bands 2, 4, 5 and 6. Eigenvalue and eigenvector are required to calculate visualization in RGB format.

4. Results

4.1 Raw Landsat Satellite Images

The true color composite requires the visual combinations of bands 2, 3, and 4 from Landsat 8 satellite. The image area should have a low cover of clouds to disturb the reflectance of signal from a satellite. The cloud covering is inversely proportional to the accuracy of the results. From Figure 2, the region of interest can be known as a densely vegetated area, disturbing the reflectance of signal from a satellite. Meanwhile, the signal reads the vegetation instead of mineral and an advanced analysis is essential to obtain the reflection of mineral under tight vegetation. Figure 2 is a compilation of Landsat 8 images from April 2013 to 2023 freely available and obtained from Google Earth Engine showing true color composite.

Figure 2. True color composites are presented by bands 2, 3, and 4 to explain the real condition of the study area with the least clouds.

4.2 Band Ratios

Figure 3A, 3B, 3C, and 3D shows the results of band 4/2, 6/7, 6/5, and 7/5, respectively. Mineral potential zone is not reported due to vegetation and the expected result is unachieved by combining some bands. Therefore, this method does not apply to the study area due to increased vegetation.

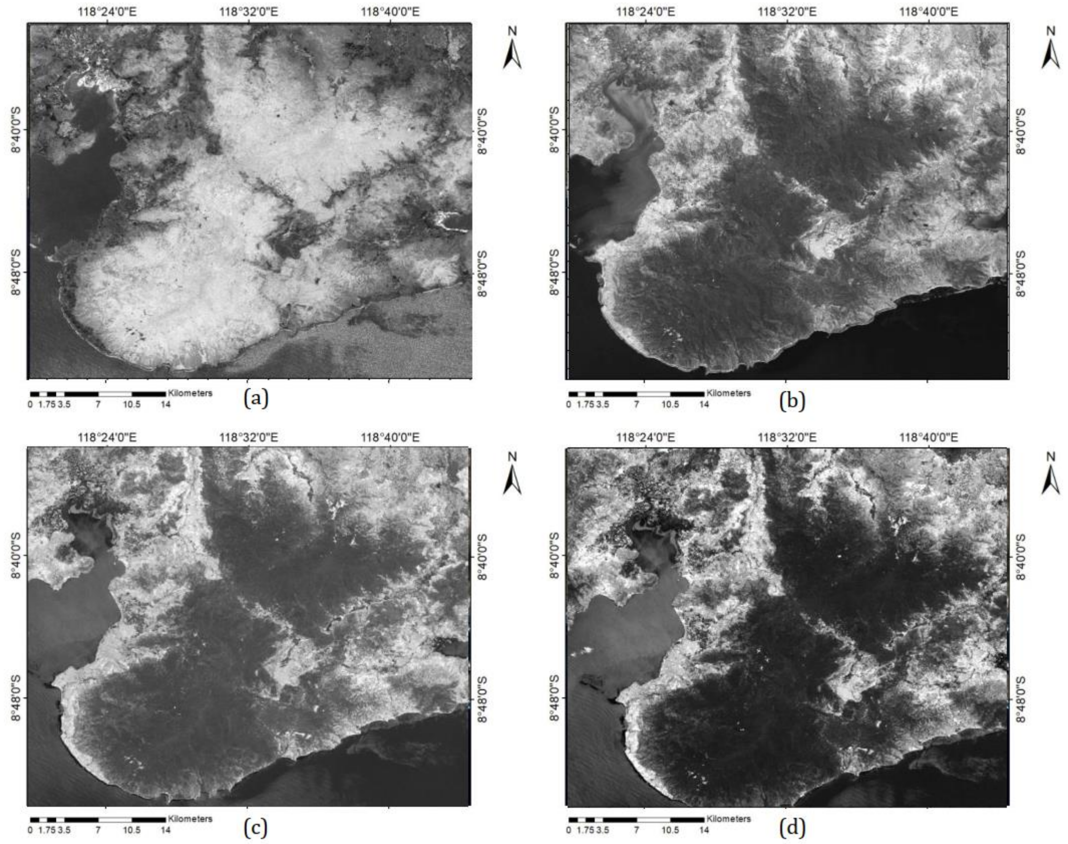


Figure 3. (a) Band ratio 4/2, (b) Band Ratio 6/7, (c) Band Ratio 6/5, (d) Band Ratio 7/5. These combinations were conducted to detect potential zones.

4.3 Band Ratio Composites

Sabin's ratio is expected to define the hydrothermal alteration map by combining bands 4/2, 6/7, and 6/5. Kaufmanns' ratio is anticipated to distinguish altered rocks and lithological units from the flora using a combination of 7/5, 5/4, and 6/7. Meanwhile, composites of 4/2, 6/7, and 5 are optimized to differentiate altered rocks and outcrops from woodlands. Figures 4A, 4B and 4C present the result of Sabin's ratio, Kaufmann's ratio, and a composite of 4/2, 6/7, and 5. These three composites cannot identify potential mineral zones and the vegetation is still the unworked factor. Even though the three bands are tested in one composite of RGB format, the expected result is not attained.

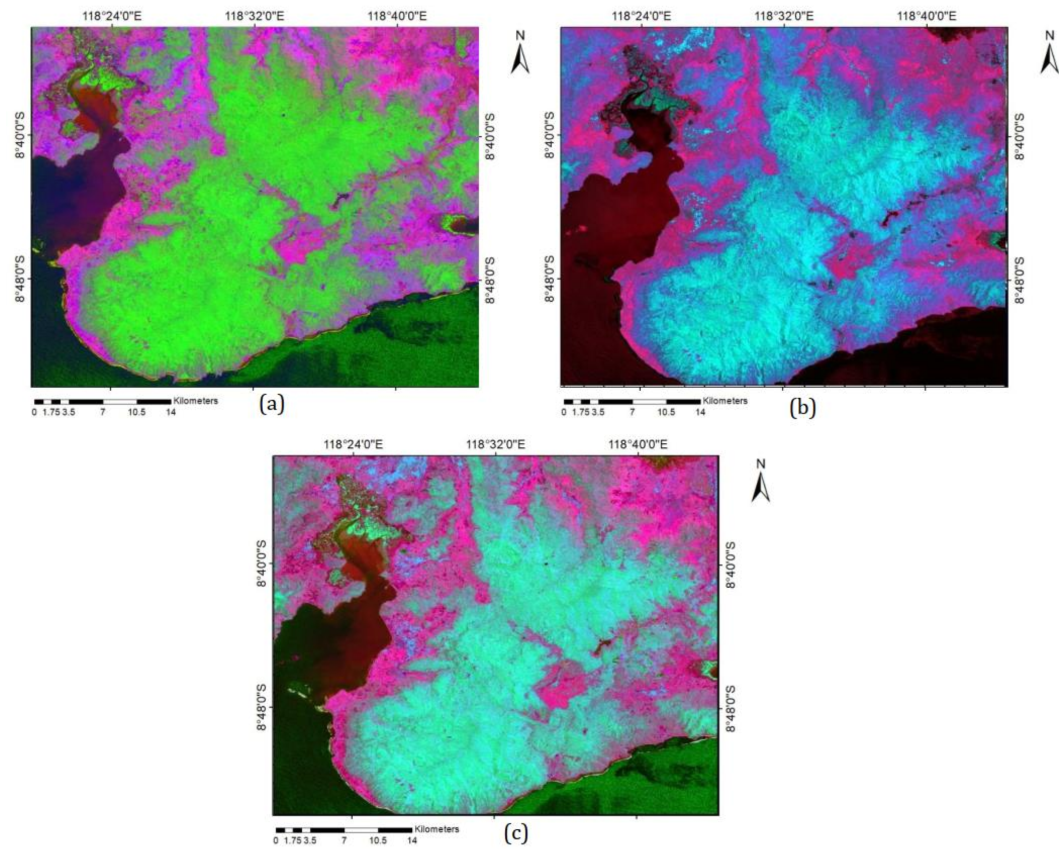


Figure 4. A) Sabin's Ratio (band 4/2, 6/7, and 6/5), B) Kaufmann's Ratio (band 7/5, 5/4, 6/7), C) Composite of 4/2, 6/7, 5

4.4 PCA

The first combination group consists of bands 1, 2, 3, 4, 5, and 6 to recognize hydrothermally altered rocks and other minerals from trees. In addition, the second group of bands 2, 4, 5, and 6 are processed to obtain iron oxides from plants.

Table 1. Eigen Values and Eigen Vectors for Bands 1, 2, 3, 4, 5 and 6

	PC1	PC2	PC3	PC4	PC5	PC6
Band 1	0.020360	0.192974	-0.334840	-0.494944	0.402861	0.665554
Band 2	0.035911	0.238785	-0.402445	-0.452621	0.201009	-0.731068
Band 3	0.103666	0.253710	-0.484258	-0.032229	-0.816609	0.149964
Band 4	0.155918	0.433000	-0.377308	0.723144	0.350531	0.005456
Band 5	0.754882	-0.595431	-0.265794	0.023034	0.066237	-0.007135
Band 6	0.627209	0.547126	0.527643	-0.160181	-0.056473	0.002697
Eigen Values	0.026078	0.004487	0.001089	0.000040	0.000011	0.000001
Percentage of Eigen Values	82.251%	14.151%	3.436%	0.126%	0.035%	0.002%

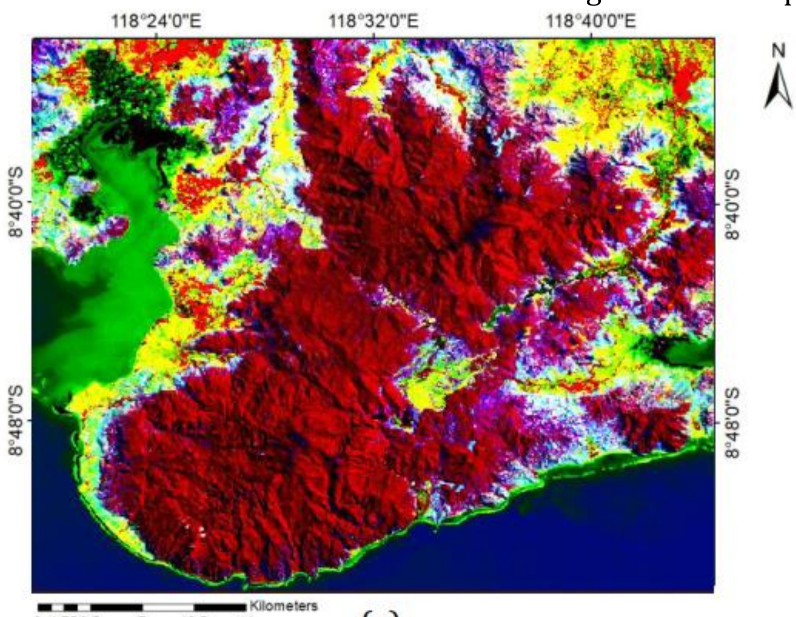
Cumulative Percentage of Eigen Values	82.251%	96.402%	99.837%	99.963%	99.998%	100.000%

Table 1 shows that PC1, PC2, and PC3 account for 99.83% of the variation to create the RGB composite for producing the primary component seen in Figure 5A. According to the illustration, the green and blue colors symbolize flora and rocks subjected to hydrothermal alteration, respectively.

Table 2. Eigen Values and Eigen Vectors for Bands 2, 4, 5, and 6

	PC1	PC2	PC3	PC4
Band 2	-0.033644	0.223736	0.583605	0.779882
Band 4	-0.153175	0.432613	0.643692	-0.612408
Band 5	-0.761896	-0.611333	0.213294	-0.017100
Band 6	-0.628427	0.623747	-0.446734	0.128249
Eigen Values	0.025795	0.004078	0.000661	0.000027
Percentage of Eigen Values	84.40%	13.35%	2.16%	0.09%
Cumulative Percentage of Eigen Values	84.40%	97.75%	99.91%	100.00%

PC4 comprises 0.09% of the variance data and has the greatest loading positive and negative Eigenvector values of 0.779882 and -0.612408 for bands 2 and 4, respectively. In broad terms, minerals related to iron oxides show low absorption and reflectance between 0.64-0.67 μm and 0.45-0.51 μm, respectively. Therefore, regions connected to iron oxides in bands 2 and 4 are bright in the PC4 picture.



(a)

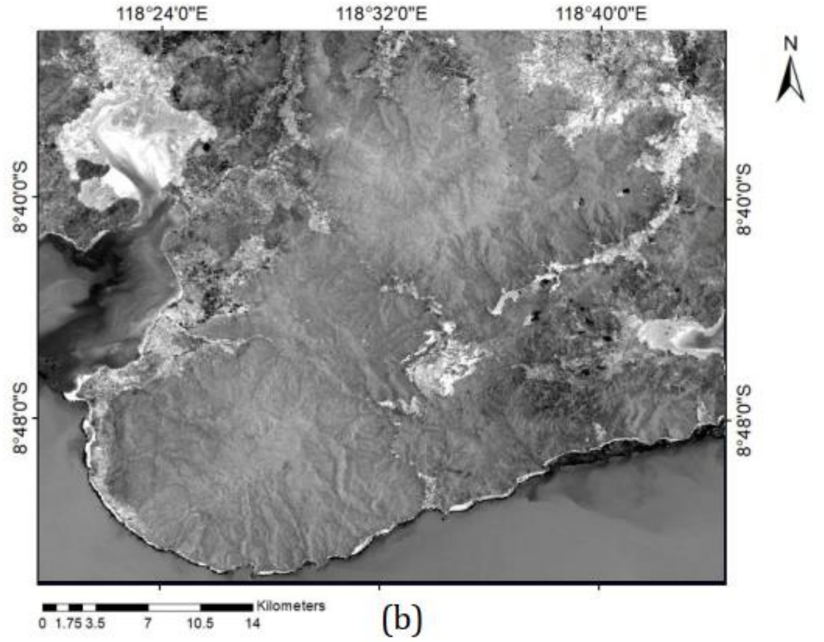


Figure 5. A) The PC1, PC2, and PC3 components in RGB combination. Potential mineral zones are illustrated in dark blue. B) Principal component 4 (PC4). The bright pixels correspond to hydrothermally altered rocks.

Figure 5A explains that potential mineral zones are depicted in dark blue, while vegetation is shown in green. In this context, the bright pixels represent hydrothermally altered rocks in Figure 5B.

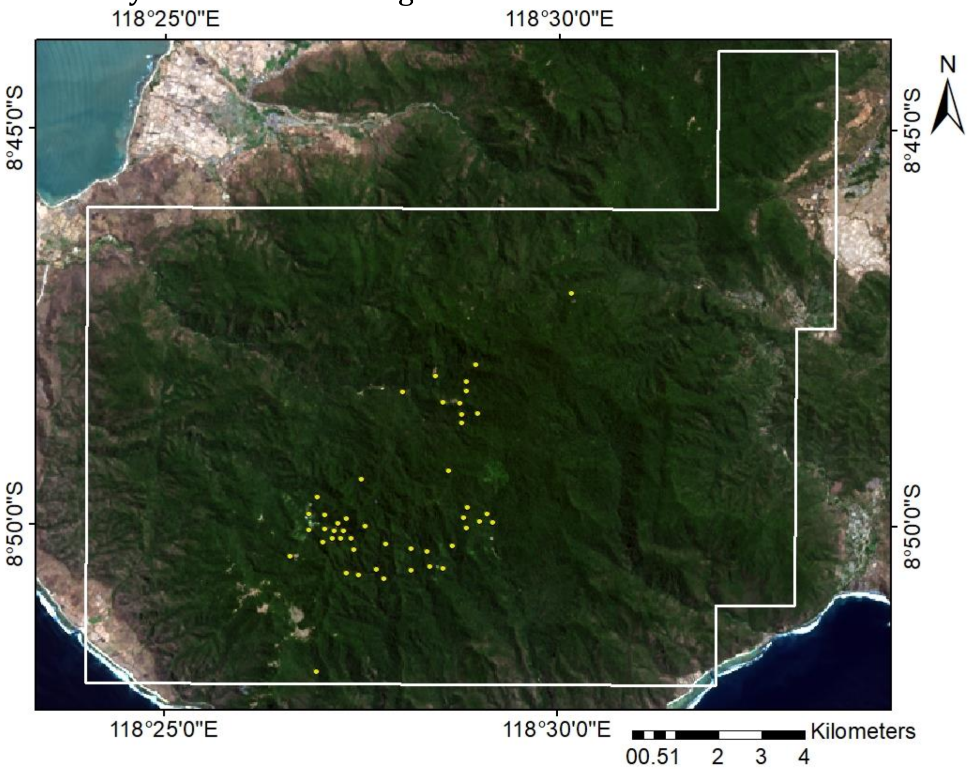


Figure 6. Drill hole locations (modified after (Burrows et al., 2020)). The yellow dots and white lines are drill holes and project boundaries, respectively.

The drill hole data and boundaries of the company's project area used are presented in Figure 6. The white lines and yellow dots represent the project area boundaries and drill hole locations, respectively. From Figure 7, the locations of the drill holes are matched with the blue areas from the analysis representing potential mineral zones. Therefore, the green squares can be potential areas for upcoming exploration projects.

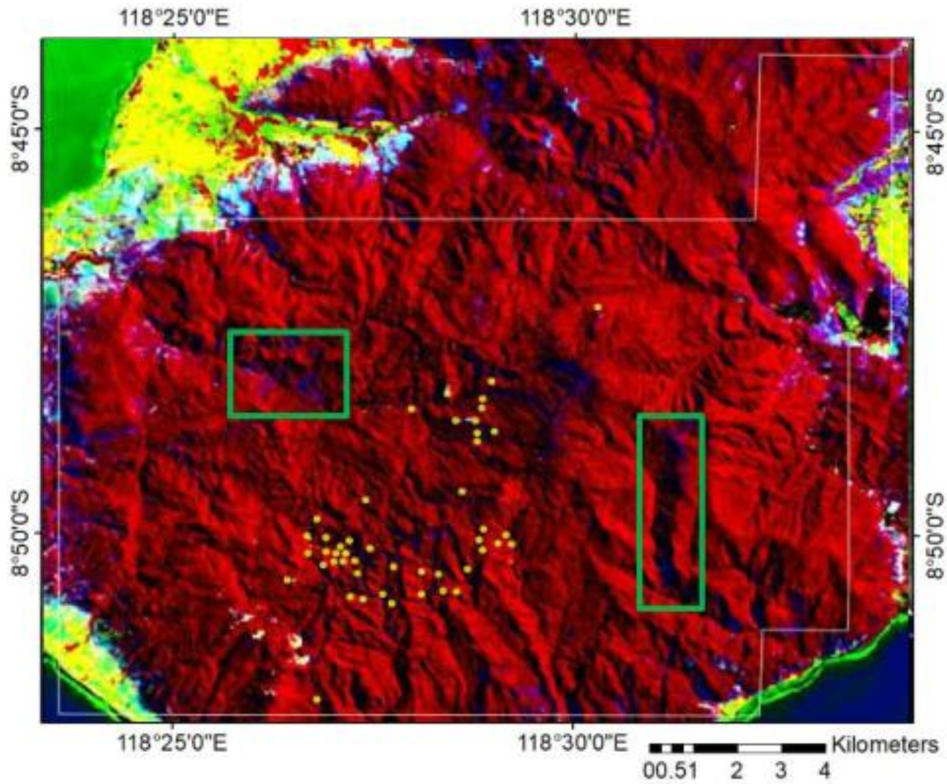


Figure 7. Validated map. Yellow dots are drill holes. Dark blue are potential mineral zone. The green boxes are the suggested next exploration areas.

5. Discussion and Conclusion

The true color composite was reported to require the visual combinations of bands 2, 3, and 4 from Landsat 8 satellite. The image area had a low cover of clouds to disturb the reflectance of the signal from a satellite. The clouds covering was inversely proportional to the accuracy of the results and the region of interest could be known as a densely vegetated area. In this context, the vegetation disturbed the reflectance of the signal from a satellite. Therefore, an advanced analysis is essential to obtain the reflection of minerals under tight vegetation.

Band ratios 4/2, 6/7, 6/5, and 7/5 were tested as visualized in Figure 3 but could not differentiate mineral potential zone. The vegetation disturbed the satellite signal reflectance and the expected result could not be accomplished by combining some bands. Therefore, this method did not apply to this study area due to high vegetation. Sabin's Ratio (band 4/2, 6/7, and 6/5), Kaufmann's Ratio (band 7/5, 5/4, 6/7), and composite of band 4/2, 6/7, 5 were also examined as shown in Figure 4.

Advanced analysis was conducted using PCA andpotential mineral zones were visible. Based on eigenvalue and eigenvector calculations, PC1, PC2, and PC3 possessed data variance of more than 99.83% in RGB format. The dark blue and green tint sections showed possible mineral zones and flora, respectively. Meanwhile, the bright pixels represented hydrothermally altered rocks in Figure 5B. Figure 7 shows that mineral zones from PCA method were located as drill holes and yellow dots were drill holes from the previous study. Dark blue zones were potential mineral areas and the green boxes were the suggested exploration areas.

In conclusion, PCA method could reduce the effect and identify the targeted zones even though the vegetation disturbed the read of the satellite signal in detecting mineral areas. The integration of the method with machine learning might produce clearer differences for potential zones.

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