COMBINATION OF REMOTE SENSING AND GIS TECHNIQUES FOR EVALUATING DISTRIBUTION OF CLAY AND HYDROTHERMAL MINERALS IN VEGETATION DEVELOPING REGIONS

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ABSTRACT

The paper proposes a new model for processing Landsat ETM+ bands to detect clay and hydrothermal minerals in regions with developing vegetation. This model combines image ratio and DPCA analysis to highlight regions containing clay and hydrothermal minerals. It also uses GIS analysis tools for mapping and evaluating distribution of minerals for each region. The detail processing steps are implemented. The experiment was conducted on Landsat ETM+ images in Quang Ninh province. The proposed model has validated and showed reliable result by comparing experimented map with geology reference map.

1. INTRODUCTION

Remote sensing techniques have been used extensively for hydrothermal alteration zones identification. It is because certain alteration minerals associated with hydrothermal mineral deposits show diagnostic spectral characteristics that permit their identification on remotely sensed images. Common techniques have been used in this field are: Color combination, image ratio, principle component analysis. Techniques for digital enhancement of Landsat ETM+ data to map hydrothermally altered rocks commonly aim at the identification of clay and iron oxide (limonitic) alteration zones (Crosta and Rabelo, 1993; Fraser and Green, 1987). The use of band ratio images, in particular was very popular, since this technique was simple to apply and proofed to be very effective in enhancing absorption features of Fe-oxides and hydroxides in the visible and near-infrared ranges of the electromagnetic spectrum. Fraser (1991) described the technique for identifying hematite, goethite and vegetation using dimensional ratio. Tangestani and Moore (2000) enhanced Iron oxide and hydroxyl using the Crosta method. Tangestani and Moore (2001) compared three principal component analysis techniques to porphyry copper alteration mapping.

The present study aims at utilizing Landsat ETM+ data for mapping clay mineral and hydrothermal zones in Quang Ninh Province, Viet Nam. The unique approach in this research is the combination of adaptive image ratios, DPCA and the GIS techniques. The adaptive image ratios and DPCA strongly improve the highlight of clay and hydrothermal minerals. The classification and statistical techniques in GIS are for mapping and assessing distribution of these zones.

2. STUDY AREA

Province area is 8239.243 km2, in which about 80% area is covered by forest and mountainous terrain, 20% area in the southeast side of the province is in the Red River Delta. Quang Ninh's climate is typical of northern Vietnam with 4 seasons in year: spring, summer, autumn and winter. This is tropical monsoon region. It has abundant mineral resources, especially coal and minerals including limestone, clay for cement producing, clay for firebrick and clay products brick, kaolin, sand, paving stones, etc.

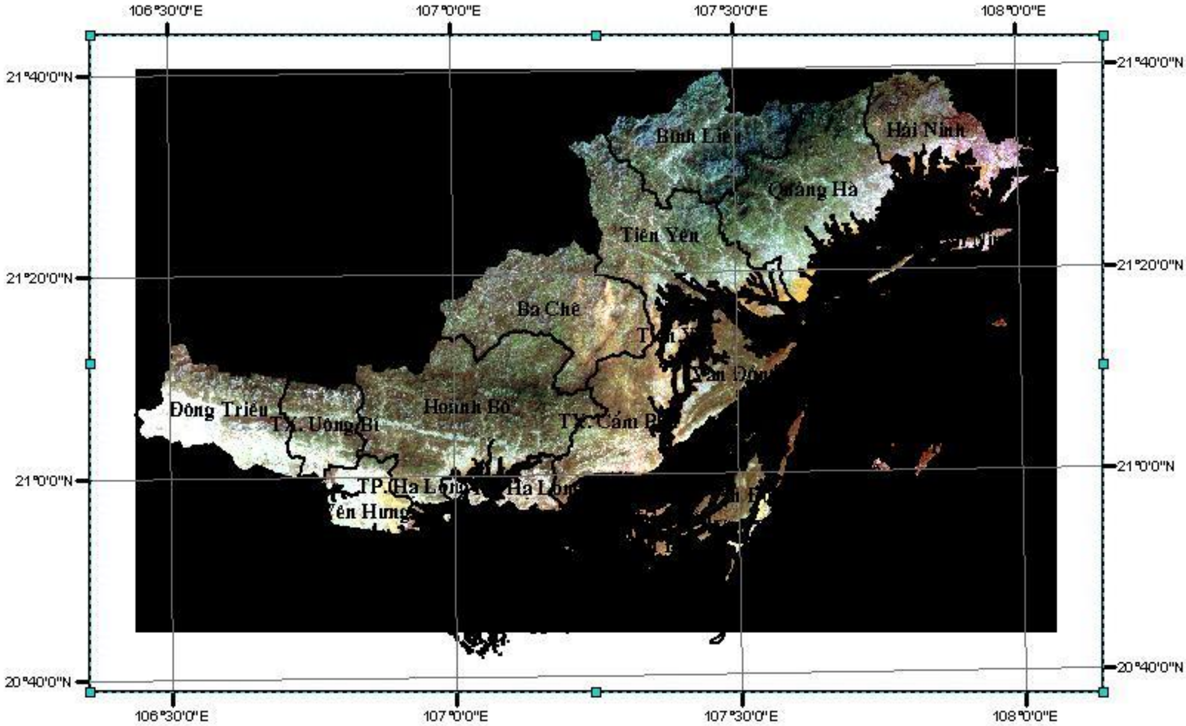


Figure 1. Quang Ninh Province

3. METHODOLOGY

In the spectral region covered by Landsat ETM+ band 3, iron oxides and clays have high reflectance while vegetation has strong absorption. In the spectral region covered by Landsat ETM+ band 4, vegetation has strong reflectance while iron oxides and clays show absorption features. Landsat ETM+ bands 3 and 4 can thus be used to differentiate areas of iron oxides and/or clays from areas of vegetation. Clay minerals have strong reflectance in the spectral region covered by Landsat ETM+ band 5 and an absorption feature in the spectral region covered by Landsat ETM+ band 7. Landsat ETM+ bands 5 and 7 are thus potentially useful in detecting clay zones. However, similarities in shape and relative intensities of the reflectance curves of vegetation and clay minerals in the spectral regions covered by Landsat ETM+ bands 5 and 7 make their differentiation difficult. Therefore, the ratio image of band 5 divided by band 7 does not separate clay minerals and vegetation. A question arises: How can we highlight spectral information of clays from vegetation.

Principle component analysis transforms initial image bands into PC images in which the PC1 concentrates almost common terrain characteristics. The other PC images represent some private specific surface features. In the area with abundance of vegetation PC1 image is vegetation. Our main purpose is to highlight clay minerals from vegetation so we chose two ratio images that keep common information about vegetation. First of them is ratio image of band 4 divided by band 3 and the second one is ratio image of band 5 divided by band 7. An issue remains: These two ratio image have very low contrast. Here, we accept one interesting approach. That is adaptively increasing these two images by adaptive coefficients: band 4 and band 5. The last image processing step is applying PCA analysis to two adaptive ratio images and the PC2 will keep private information of clay and hydrothermal minerals, Figure 2.

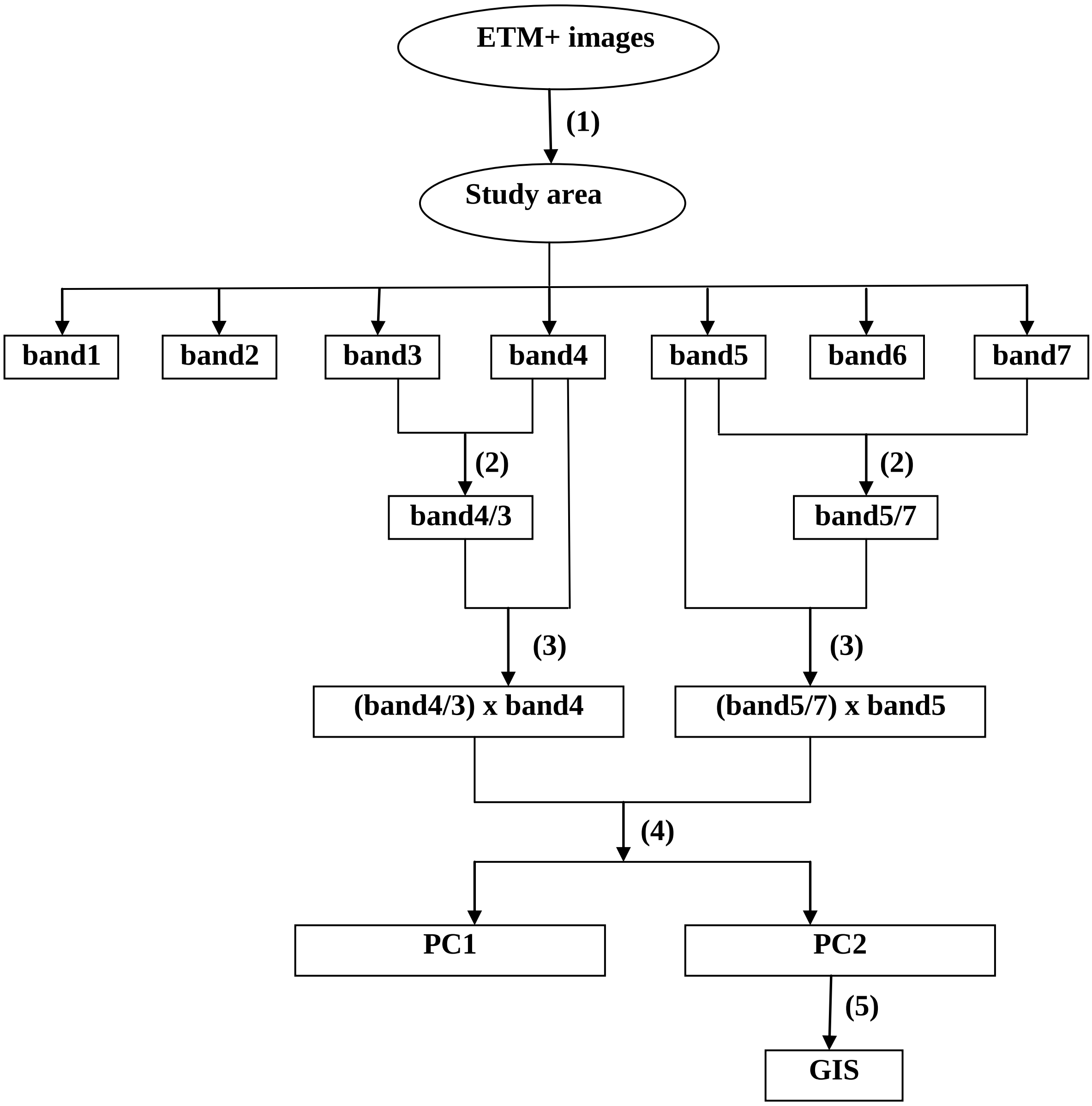


Figure 2. Image processing scheme

In GIS environment result image is classified and distributions of clay and hydrothermal minerals are assessed.

4. IMPLEMENTATION STEPS

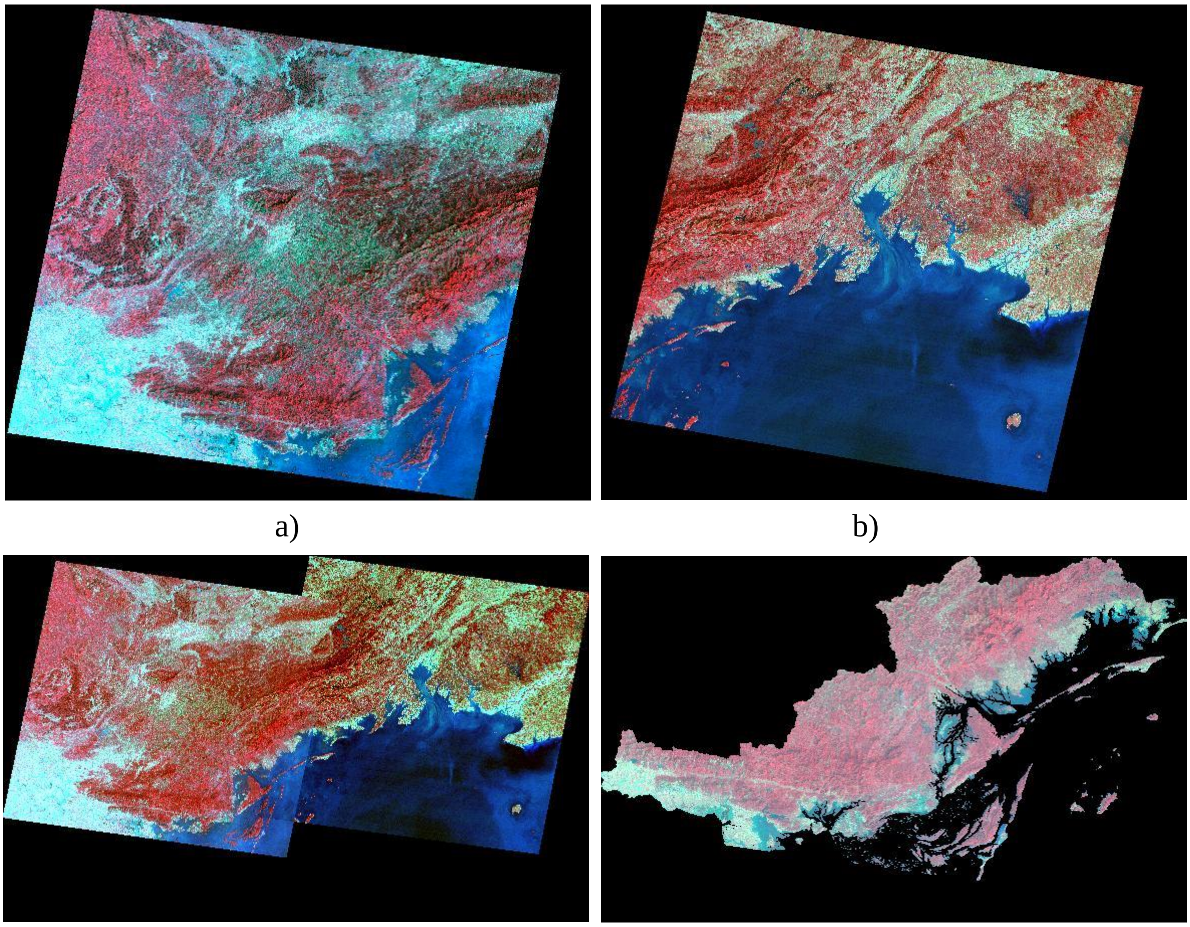
In this section the practical implementation is presented step by step. The image processing steps are accomplished in ERDAS 9.2 software and the GIS techniques are accomplished in ArcGis 9.3 software.

Step 1: Image preparation - The data used in current study is Landsat ETM+ images acquired on 22nd February, 2008. Landsat ETM+ images with seven bands were mosaic and geo-rectified using topographic map on 1:50.000 scale. The RMSE value for rectification was found less than one pixel. Then the image region of study area was extracted.

Step 2: Creating ratio images.

Step 3: Adaptively increasing ratio images - Ratio images from step 2 are not contrast enough for following PCA analysis. We need to improve spectral characteristics of both vegetation and minerals on these images. If we simply scale them with a scalar value it does not give the effect. Each pixel is needed to be scaled with a unique value that reflects the magnitude difference of the pixel with its neighbor. Herein, we found that the pixel values are adaptive with themselves. So, each pixel now is scaling with itself.

Step 4: Principle Component Analysis with input images from step 3.



a) b)

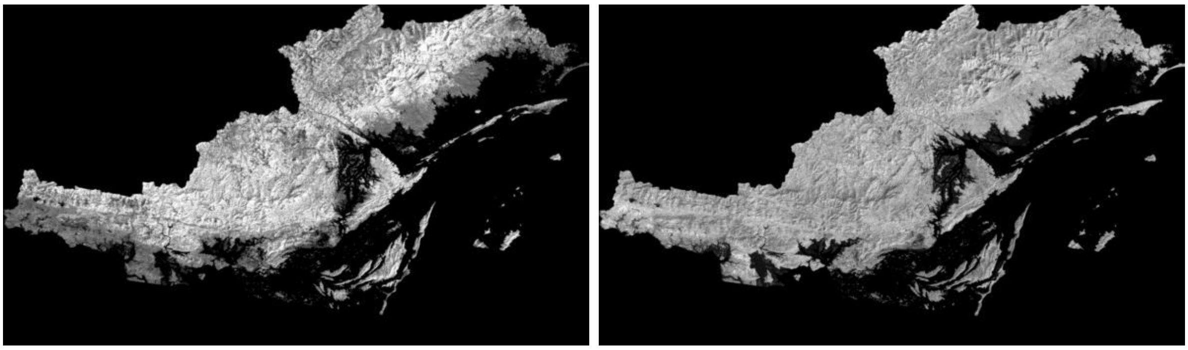
c) d)

Figure 3. Image mosaic, rectification and subset

a – image1, path=126, row=45; b – image2, path=125, row=45;
c – mosaic, rectified image; d – Quang Ninh region.

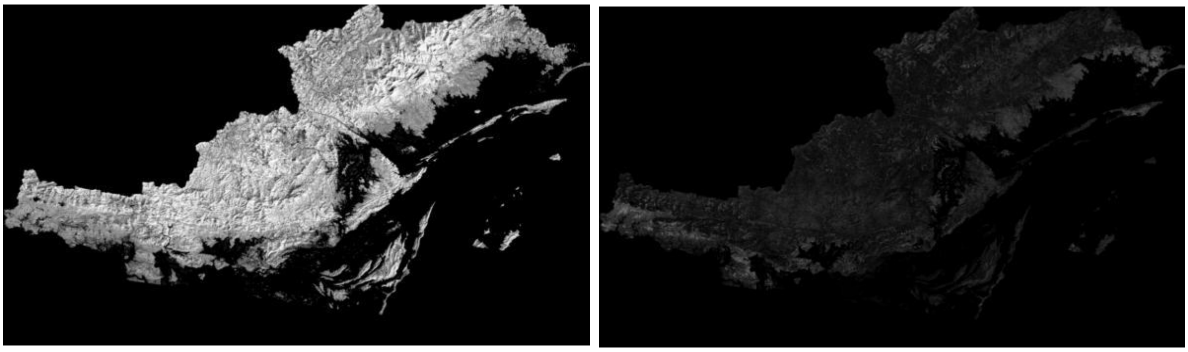
Step 5: Spatial analysis in GIS environment - PC1 image from step 4 is imported to ArcGis 9.3. An additional boundary topographic map layer on 1:50.000 scale is overlayed. Image classification was implemented with Natural Break algorithm and four output classes (Table 1). The output classes were symbolized with appropriate colors. Clay and hydrothermal distributions were accounted on two levels: Province and districts of Province, the result is showed on Table 1and Diagram 1.

Step 6: Model validation - To validate the proposed model a geological map on scale 1:250.00 was selected as reference map. The final experimented map with quantified statistics in Table 1 and Diagram 1 showed that Clay and hydrothermal minerals are distributing sparsely in many districts but the big amounts and density are concentrated mainly in Dong Trieu, Mong Cai, Hoanh Bo, Yen Hung, Ha Long Districts. These data are positively and highly correlated with the reference map.



a) Image ratio1 multiplied by band4 b) Image ratio2 multiplied by band5

Figure 4. Adaptively increased ratio images

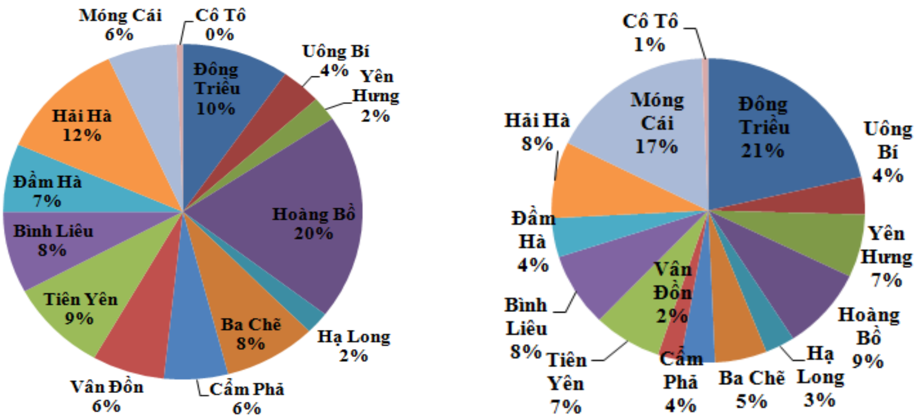


a) PC1 image b) PC2 image

Figure 5. PC images

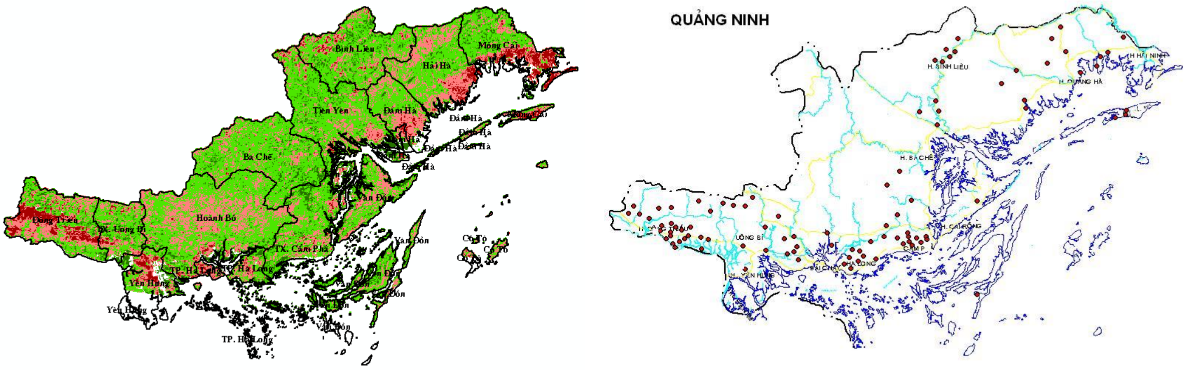
Table 1. Clay and hydrothermal distributions on Province level

Color	Class name	Cover objects	Area(computed by pixels)	Percents on Province
	Veg1	Vegetation	1917833	34,63%
	Veg2	Vegetation	1996100	36,04%
	Min1	Clay, Hydrothermal	1257373	22,70%
	Min2	Clay, Hydrothermal	367399	6,63%



a) b)

Diagram 1. Distribution on District level: a) Class Min1; b) Class Min2.



a) b)

Figure 6. a) Final experimented map; b) Geological map.

5. CONCLUSION

Some main conclusions were made from this research: 1) Combination of DPCA technique and adaptive ratio images from two sets of ETM+ bands: 4,3 and 5,7 enables highlighting the clay and hydrothermal minerals distribution in vegetation developing regions; 2) GIS systems with spatial analysis and geo-processing tools give a good choice for quantifying and visually analyzing and post-processing geological images; 3) In combination with other models discussed from introduction section proposed model in this research gives a promise solution for mineral investigating in vegetation developing regions.

6. REFERENCES

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