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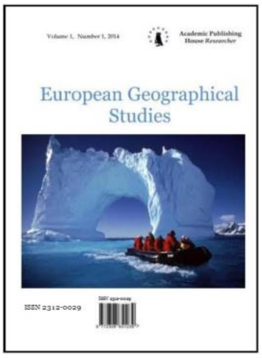

Relevant Topic

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Air Pollution Determination Using Remote Sensing Technique: a Case Study in Quangninh Province, Vietnam

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Abstract

Vietnam is a country rich in mineral resources, including coal, copper, oil, natural gas... Coal reserves, located mainly in the Quang Ninh province, have been estimated at 8.6 billion tons. Besides the economic and social benefits, coal mining has negative impacts on the environment, such as air and water pollution. This article presents study on application of remote sensing technique to evaluate air pollution on the mining area of Quang Ninh province, the northeastern coast of Vietnam, using multispectral image LANDSAT 5 TM. The results which are obtained in this study can be used to create air quality map, and to reduce environmental impacts of mining.

Keywords: air pollution, remote sensing, coal mine, multispectral image, Landsat.

1. Introduction

Located in Southeast Asia, Vietnam is rich in mineral resources – precious potential resource for the country. Vietnam has big reserves of fossil energy with 10 billion tons of anthracite coal, more than 200 billion tons of brown coal in the northern delta area (Luu Duc Hai, Nguyen Thi Hoang Lien, 2009). As the other coal producing countries, Vietnam also has serious air pollution problem. Air pollution from coal mines is mainly due to emission of particulate matter and gases including methane (CH_4), sulfur dioxide (SO_2), and oxides of nitrogen (NO_x), as well as carbon monoxide (CO) (Partha Das Sharma, 2009). Ground-based observations reflect only air quality of local area around the station and in fact cannot establish the number of meteorological stations with expected density due to the high cost. Remote sensing technology with many advantages such as wide area coverage and short revisit interval has been used effectively in the study of air pollution monitoring (Randall V. Martin, 2008). Hashim et al (2010), Lim et al (2004, 2010), Martin (2008), Wald and Baleynaud (1999), Wijeratne (2003) used Landsat and MODIS multispectral images for calculating of air pollutant concentrations (PM10, NO_2, CO_2, CH_4) (Hashim, Sultan, 2010; Akumu et al., 2010; Nadzri Othman et al., 2010; Chitrini Mozumder et al., 2012; H.S. Lim et al., 2004; Wald, Baleynaud, 1999; Wijeratne, 2003). Mozumder et al (2012) used air pollution index (API) and ground truth data to develop air quality assessment model in urban area of Hyderabad city (India) based on Landsat and IRS multispectral images (Chitrini Mozumder et al., 2012).

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In Vietnam, there have been some research in the application of remote sensing technique to determine air pollution, among which we can mention the study by Tran and Vuong (2014) and Tran et al (2015) (Tran et al., 2014; Nguyen Thi Phuong Thao et al., 2004). Tran and Vuong (2014) used MODIS data to calculate concentration of PM10 in coal mine area of Quang Ninh province (Northern of Vietnam). Based on SPOT multispectral images, Tran et al (2015) determined the spatial distribution of PM10 in Ho Chi Minh city (Southern of Vietnam). This paper focused on air pollution assessment on the mining area of Quang Ninh province (Vietnam) using Landsat 5 TM multispectral image.

2. Methodology

2.1 Air pollution index (API)

The air pollution index (API) is calculated from observed TSPM (Total suspended particulate matter), RSPM (Respirable suspended particulate matter), NO_x and SO_2 values following equation (Chitrini Mozumder et al., 2012):

$$API = \frac{1}{4}\left(\frac{TSPM}{S_{TSPM}} + \frac{RSPM}{S_{RSPM}} + \frac{SO_2}{S_{SO_2}} + \frac{NO_x}{S_{NO_x}}\right)*100 \quad (1)$$

Where TSPM, RSPM, NO_x and SO_2 – individual values of TSPM, RSPM, oxides of nitrogen and sulphur dioxide; S_{TSPM}, S_{RSPM}, S_{Nox} and S_{SO2} – standart values of ambient air quality of the respective pollutants (Chitrini Mozumder et al., 2012).

2.2 Radiometric and Atmospheric correction

In the first step, image processing started with radiometric and geometric correction. Radiometric correction done by converted the digital number value to radiance value (*spectral radiance, $Wm^{-2}\mu m^{-1}$*). Based on NASA model, the digital values of thermal band Landsat 5 TM were converted to spectral radiance using following equation (National Aeronautics and Space Administration (NASA)):

$$L_\lambda = G_{rescale}.DN + B_{rescale} \quad (2)$$

Where

L_λ - spectral radiance at the sensor's aperture

DN – the quantized calibrated pixel value in digital number

$G_{rescale}$ – band specific rescaling gain factor ((W/m^2.sr.μm)/DN)

$B_{rescale}$ – band specific rescaling bias factor (W/m^2.sr.μm).

In the second step, for relatively clear Landsat scenes, reflectance (the TOA reflectance) can be determined from the spectral radiance data. The TOA reflectance is computed according to the equation:

$$\rho_\lambda = \frac{\pi.L_\lambda.d^2}{ESUN_\lambda.\cos(\theta_s)} \quad (3)$$

Where

ρ_λ – planetary TOA reflectance

π – mathematical constant approximately equal to 3.14159

L_λ – spectral radiance at the sensor's aperture

D – Earth – Sun distance (astronomical units)

ESUN – Mean exoatmospheric solar irradiance (*W/m^2.sr.μm*);

θs – solar zenith angle (degree) (National Aeronautics and Space Administration (NASA)).

The surface reflectance value can be calculated using atmospheric correction method DOS – "dark object subtraction". The DOS is a family of image base atmospheric correction method proposed by Chavez (1988). The basic assumption is that within the image some pixels are in complete shadow and their radiances received at the satellite are due to atmospheric scattering (path radiance) (National Aeronautics and Space Administration (NASA)).

2.3 Vegetation indices

In this study, three different vegetation indices were used, namely NDVI (Normalized Difference Vegetation Index), TVI (Transformed Vegetation Index) and VI (Vegetation Index). NDVI is calculated per pixel value obtainedin red and NIR band by equation:

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (4)$$

The Transformed Vegetation Index proposed by Deering et al (1975) is aimed at eliminating negative values and transforming NDVI histograms into a normal distribution.

$$TVI = \sqrt{(NDVI + 0.5)} \quad (5)$$

A simple vegetation index (VI) can be obtained by taking difference of pixel values in red from near infrared (NIR):

$$VI = \rho_{NIR} - \rho_{RED} \quad (6)$$

3. Results and Disscusion

Study area. Quang Ninh is large province along the northeastern coast of Vietnam. The province covers an area of 5938 km^2 and has rich natural mineral resources of coal, limestone, clay...The annual production of Quang Ninh ranges between 5 and 6 millions tones of coal. With the economic development, the province is faced and facing to air pollutants, such as PM10, CO, CO_2, NO_x, SO_2, NH_3 and CH_4 (Nguyen Thi Phuong Thao et al., 2004).

Materials. In this study, Landsat 5 TM multispectral data of mining area in Quang Ninh province (Northern of Vietnam) was used (Fig. 1). The LANDSAT 5 TM data was the standard terrain correction products (L1T), downloaded from United States Geological Survey (USGS – http://glovis.usgs.gov) website (http://glovis.usgs.gov).

Figure 1. Landsat 5 TM multispectral image of Quang Ninh area, 01 November 2010

The reflectance values for red and near infrared channels of Landsat 5 TM data were used to calculate vegetation index (VI), normalized difference vegetation index (NDVI) and transformed vegetation index (TVI) using formula (4), (5) and (6). The TVI image, which calculated from Landsat 5 TM multispectral image on 01 November 2010 is shown in Fig 2. below.

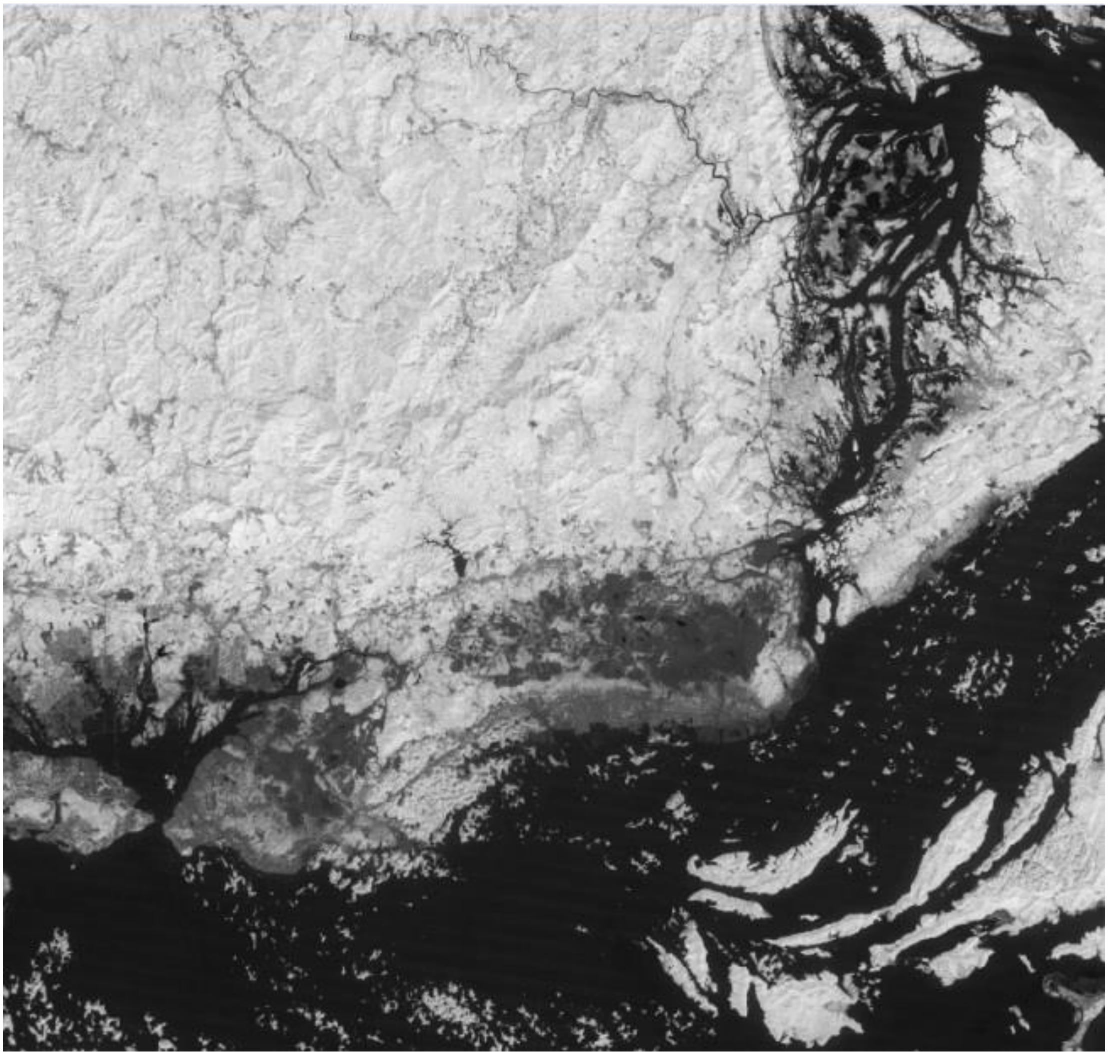

Figure 2. TVI index of Quang Ninh area, 01 November 2010

From reflectance values for NIR, SWIR1 channels and vegetation indices (VI, TVI), the air pollution index (API) was obtained by using method of Mozumder et al (2012) (Chitrini Mozumder et al., 2012):

$$API_{Landsat} = -460.0 - 10.4 * SWIR + 1.0 * NIR - 6.4 * VI + 851.6 * TVI \quad (7)$$

API image has been shown in Fig.3. It is displayed in air quality categories using API ranges given by Rao et al (2004) (Rao et al., 2004). These ranges are clean air (0 – 25), light air pollution (26 – 50), moderate air pollution (51 – 75), heavy air pollution (76 – 100) and severely polluted (> 100) (Fig. 4).

Table 1. Ranges of air pollution

No.	Ranges	API values	Legend
1	Clean air	0 – 25	
2	Light air pollution	26 – 50	
3	Moderate air pollution	51 – 75	
4	Heavy air pollution	76 – 100	
5	Severely air pollution	>100	

The obtained results showed that large part of study area at "clean air" and "light air pollution. This can be explained by large area forest and sea occupies of the study area. The areas at "moderate" air pollution concentrated in urban area with low vegetation cover. The areas at "heavy air pollution" to "severely air pollution" are distributed mainly in the Quang Ninh's mining industry (Fig. 4).

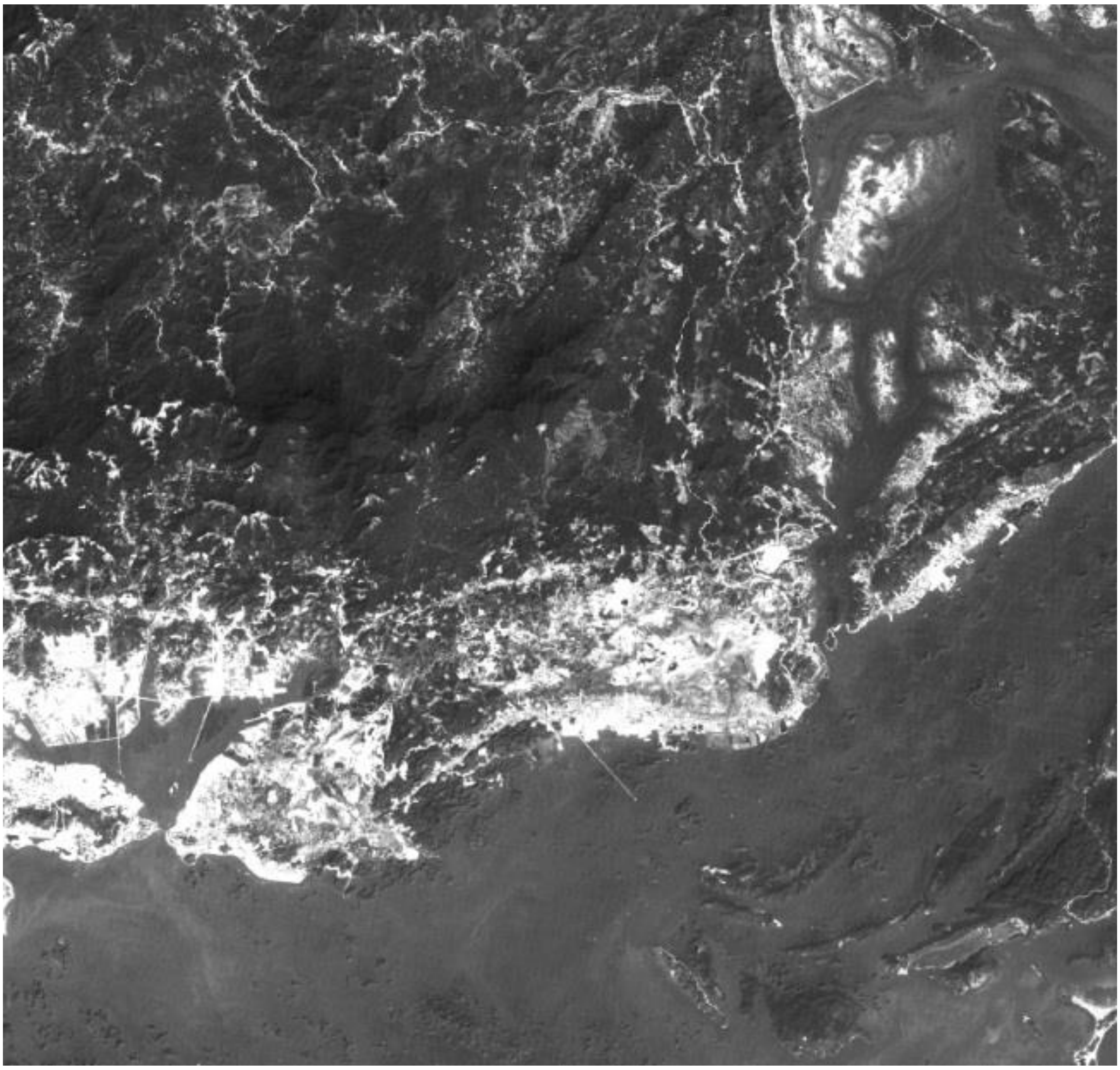

Figure 3. API index of Quang Ninh area, 01 November 2010

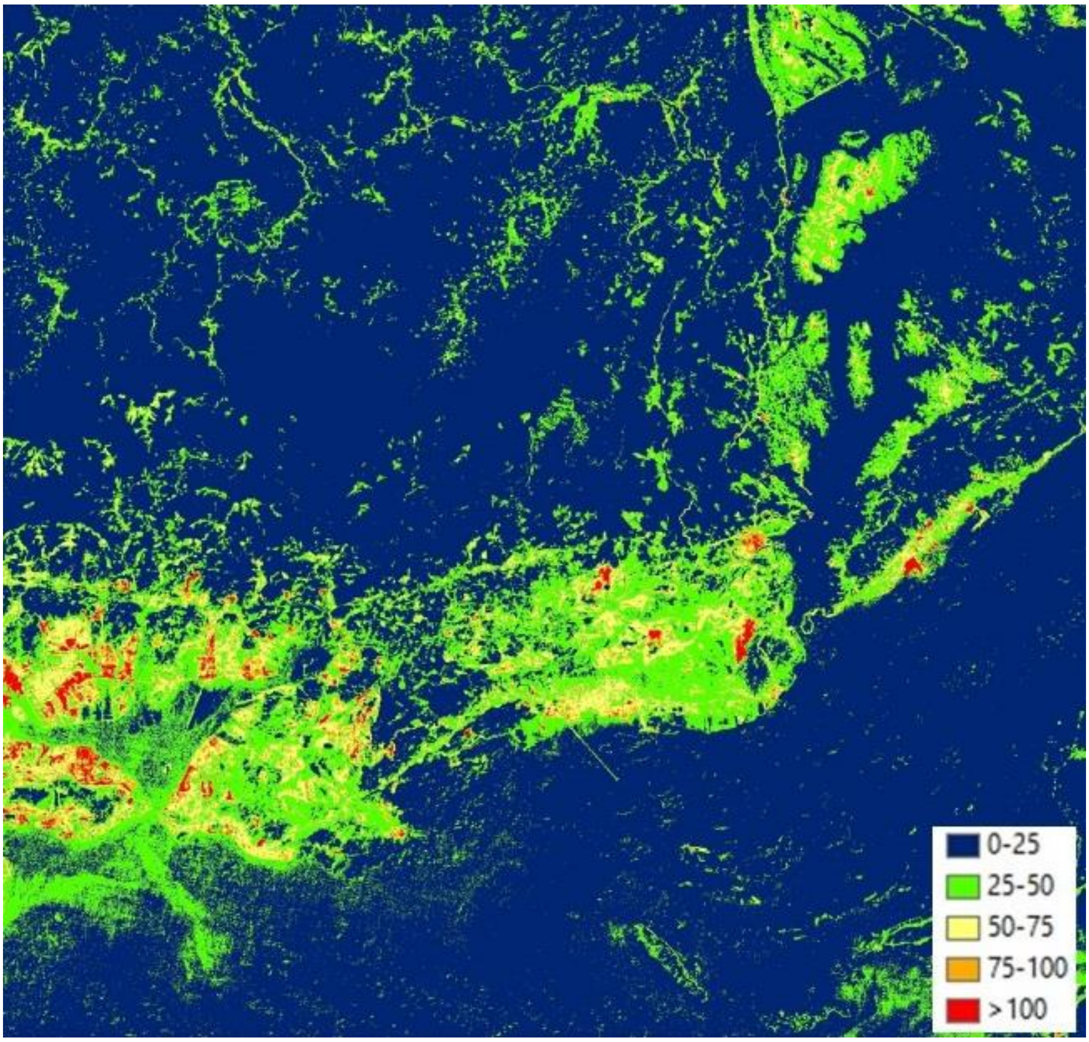

Figure 4. Spatial distribution of air pollution over study area using LANDSAT 5 TM data, 01 November 2010

4. Conclusion

Coal is one of the most important sources of energy in Vietnam. Besides the economic benefits, the environmental impact of the coal industry such as air pollution, caused by the coal mining, processing and the use of its products. An estimation of air pollution from coal industry area of Quang Ninh province (Vietnam) has been carried out using Landsat 5 TM multispectral image. The obtained results showed that the API index is an effective tool for air quality assessment and management.

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Аэрокосмические методы мониторинга загрязнения воздуха:
на примере провинции Куанг Нинь, Вьетнам

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Аннотация. Вьетнам является страной, богатой минеральными ресурсами, в том числе уголь, медь, нефть и природный газ. Запасы угля, расположенные в основном на провинции Куанг Нин, были оценены в 8,6 млн тонн. Помимо экономических и социальных выгод, добыча угля оказывает негативное воздействие на окружающую среду, такие как загрязнение воздуха и воды. Данная работа посвящена проблеме мониторинга загрязнения воздуха на горной области провинции Куанг Нинь, на северо-восточном побережье Вьетнама по данным многозональной съемки LANDSAT 5 TM. Полученные результаты могут быть эффективно использованы для создания карты качества воздуха, а также для снижения воздействия добычи полезных ископаемых на окружающую среду.

Ключевые слова: загрязнения воздуха, дистанционное зондирования, угольная шахта, многозональная съемка, Landsat.

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