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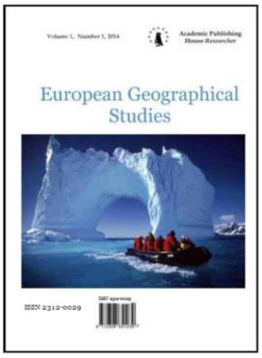

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Air Pollution Determination Using Remote Sensing Technique: A Case Study In Quangninh Province, Vietnam

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Abstract

Vietnam is a country rich in mineral resources, including coal, copper, oil, natural gas etc. Coal reserves, located mainly in the Quang Ninh province, have been estimated as high as 8.6 billion tons. Alongside with 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 for evaluation of air pollution influence on the mining area of Quang Ninh province, the northeastern coast of Vietnam, using multispectral image LANDSAT 5 TM. The results 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, Nguyen, 2009). As the other coal producing countries, Vietnam also has serious air pollution problem. Air pollution from coal mines is mainly the consequence of 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, 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 (Martin, 2008). In the studies (Partha, 2009; Martin, 2008; Hashim, Sultan, 2010; Lim et al., 2004; Wald, Baleynaud, 1999). Landsat and MODIS multispectral images were used for calculating of air pollutant concentrations (PM10, NO_2, CO_2, CH_4) (Wijeratne, 2003; Mozumder et al., 2012; Tran, Vuong, 2014; Tran et al., 2014; Nguyen et al., 2004; Akumu et al., 2010; Othman et al., 2010) Air pollution index (API) and ground truth data were utilized to develop air quality assessment model in urban area of Hyderabad city (India) based on Landsat and IRS multispectral images (Wijeratne, 2003).

In Vietnam, there have been some research in the application of the remote sensing

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technique to evaluate air pollution level (Mozumder et al., 2012, Tran, Vuong, 2014). In (Mozumder et al., 2012) MODIS data were used to calculate concentration of PM10 in coal mine area of Quang Ninh province (Northern of Vietnam). Based on SPOT multispectral images, in (Tran, Vuong, 2014) spatial distribution of PM10 in Ho Chi Minh city (Southern of Vietnam) were determined. This paper focuses on air pollution assessment in 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 (Tran et al., 2014):

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

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 (Wijeratne, 2003).

2.2 Radiometric and Atmospheric correction

On the first step, image processing started with radiometric and geometric correction. Radiometric correction was carried out 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:

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

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 (($W/m^2.sr.\mu m$)/DN)

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

On 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 reflectivity

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 (*$W/m^2.sr.\mu m$*);

θs – solar zenith angle (degree).

The surface reflectivity value can be calculated using atmospheric correction method DOS – "dark object subtraction". The basic assumption of this method 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).

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 obtained in red and NIR band by equation:

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad . \tag{4}$$

The Transformed Vegetation Index is used for the purpose of eliminating negative values and transforming NDVI histograms into a normal distribution.

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

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

$$VI = \rho_{NIR} - \rho_{RED} \tag{6}$$

3. Study area and materials

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 etc. Annual coal production in Quang Ninh ranges between 5 and 6 millions tons. Alongside with economic development, the province faces with air polluting by PM10, CO, CO_2, NO_x, SO_2, NH_3 and CH_4 (Tran et al., 2014). 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).

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

4. Results and Disscusion

The reflectivity 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 was calculated using Landsat 5 TM multispectral image on 01 November 2010 is shown in Fig 2.

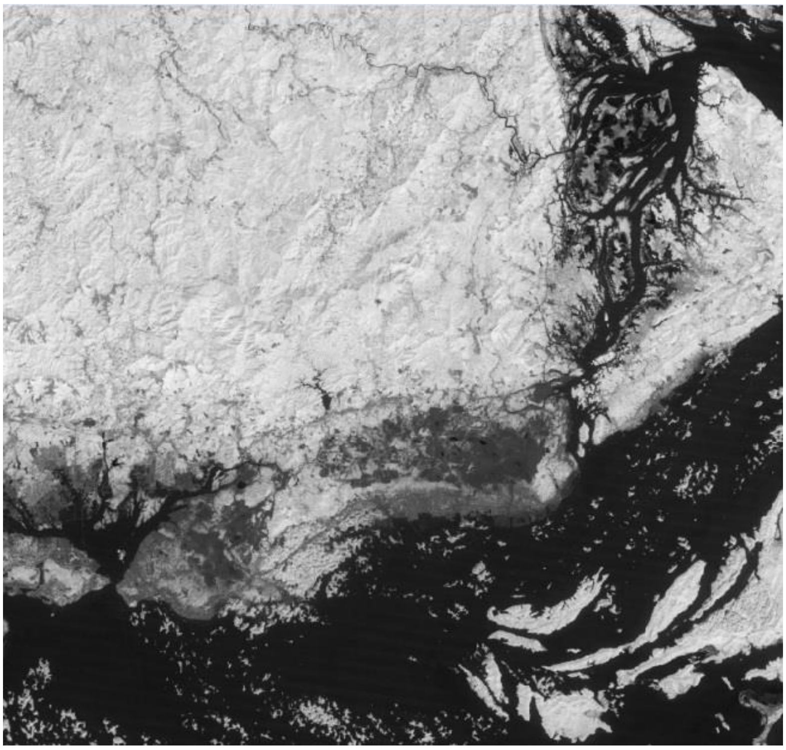

Fig. 2. TVI index of Quang Ninh area, 01 November 2010

From reflectivity values for NIR, SWIR1 channels and vegetation indices (VI, TVI), the air pollution index (API) was obtained by using method described in (Wijeratne, 2003):

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

API image is shown in Fig.3. It is displayed in air quality categories using API ranges given in (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).

The obtained results show that the large part of the study area are 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 the urban area with low vegetation cover. The areas characterized as from "heavy air pollution" to "severely air pollution" are distributed mainly in the Quang Ninh's mining industry (Fig. 4).

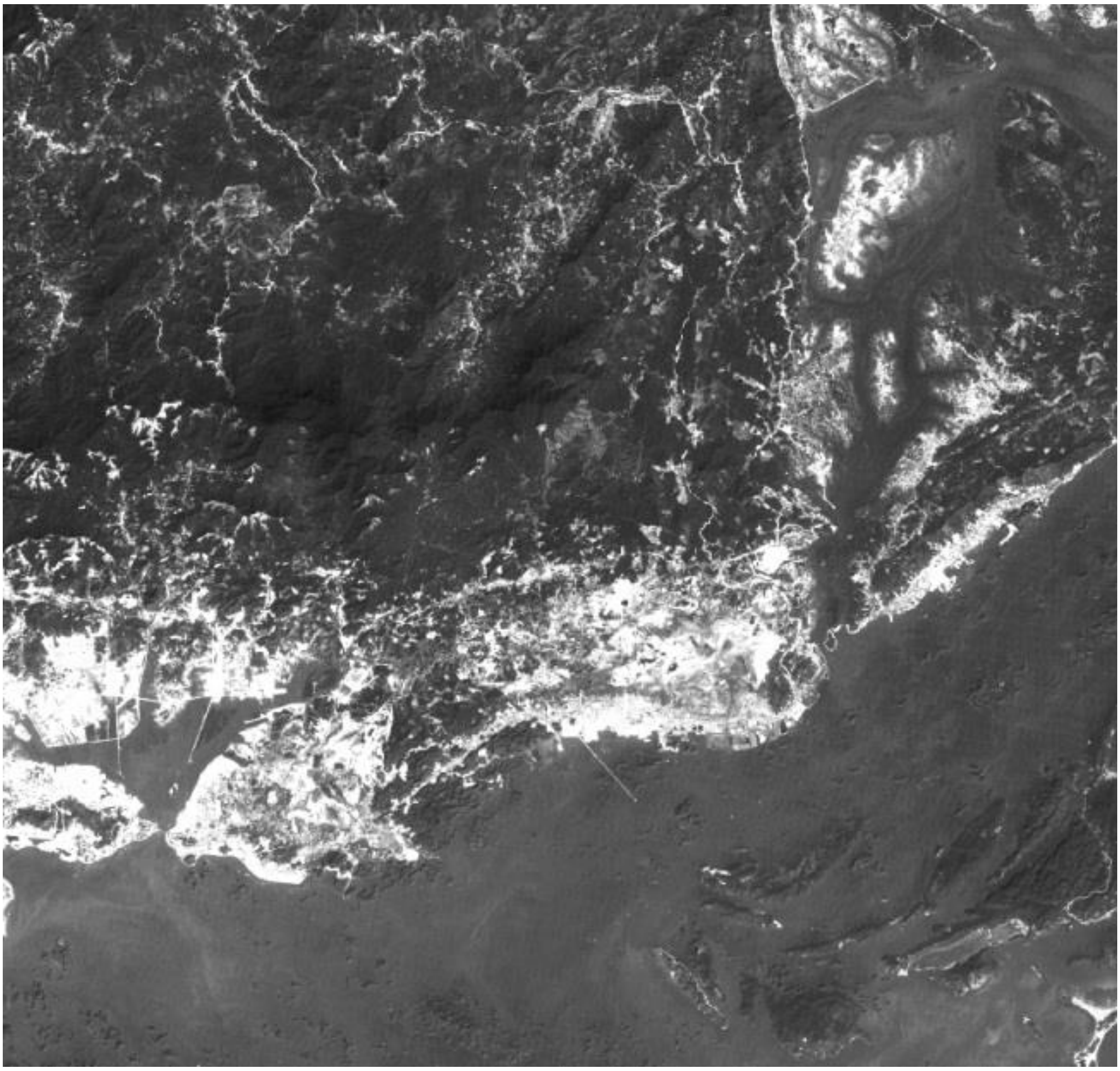

Fig. 3. API index of Quang Ninh area, 01 November 2010

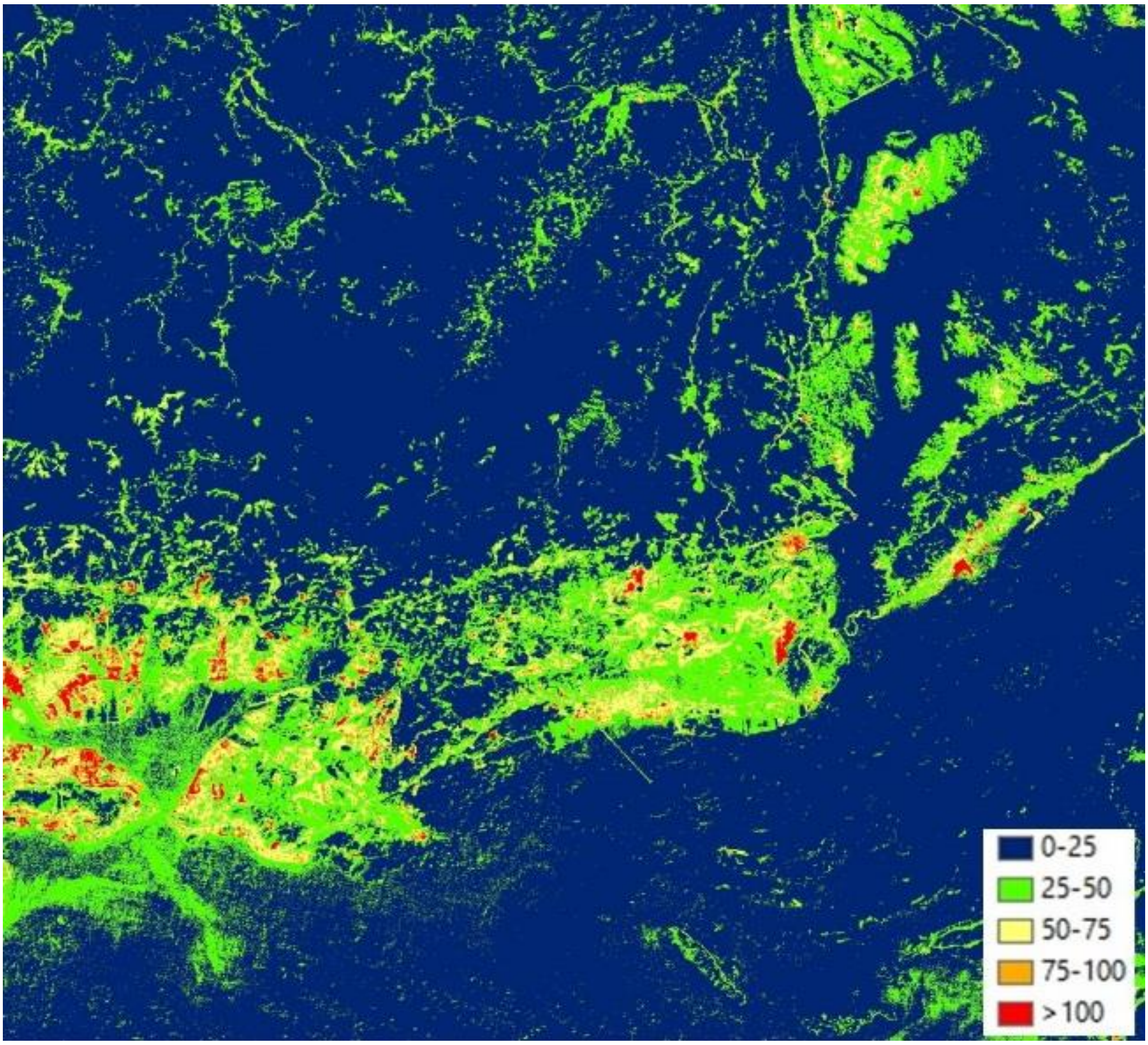

Fig. 4. Spatial distribution of air pollution over study area using LANDSAT 5 TM data, 01 November 2010

Table 1. Ranges of air pollution

No.	Ranges	API values	Legend color
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	

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Аэрокосмические методы мониторинга загрязнения воздуха: пример провинции Куанг Нинь, Вьетнам

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Аннотация. Вьетнам является страной, богатой минеральными ресурсами, в числе которых 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, загрязнения воздух и воду. Данная работа посвящена проблеме мониторинга загрязнения воздуха в 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: загрязнение воздуха, дистанционное зондирование, угольная шахта, многозональная съемка, Landsat.

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