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ESASGD 2016

GIS-IDEAS (2016)

Conference Title: International Conference on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS)

Remote sensing application for monitoring urban environment quality in case of dust in Ho Chi Minh City

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Abstract

Urban development can lead to many implications for environmental quality, as well as the lives of urban dwellers. Among them, the air environment is often to influence in the quickest way to humans through inhalation. This article presents the results of research and application of remote sensing monitoring air quality through PM10 dust for the northern part of Ho Chi Minh City. Research has implemented procedures for satellite image processing, and has calculated the value of AOT on Landsat to monitor the evolution of PM10 dust concentration in the period 1995-2015. The study results showed that concentrations of PM10 dust tends to scatter to suburban areas, and focus on increasing concentration in urban areas. The areas with PM10 high concentrations exceeding the standards were found on industrial parks and traffic intersections. The research results are a good reference for urban planning and environmental management effectively.

Keywords: AOT, PM10, reflectance, relative radiation normalization, urban environment quality

1. Introduction

The problems of the urban environment have become increasingly more serious and prominent with the rapid development of urbanization process. Urbanization has changed the face of the urban becoming better, but it also means that altered the quality of the urban environment. This change could be better, but it could be worse without the proper care of the management of the urban environment. Urbanization leads to industrialization which has been developed to cater to the needs of human consumption. Many industrial parks, export processing zones has grown, and consequently the problem of environmental pollution in general and in particular air pollution is becoming increasingly serious in our country. The excessive increase of waste concentrations in the atmosphere as CO_2, SO_x, NO_x, PM10... are becoming a threat to human health.

Many studies have used aerosol optical thickness (AOT) to assess the state of urban air pollution. Optical thickness is a measure of the radiation transmitted by a column of air vertically per unit cross-sectional area. Large optical thickness means less transmission of radiation through the atmosphere. The transmission of atmospheric radiation has a value from 0 to 1, where 0 corresponds to an opaque atmosphere and 1 corresponds to an atmosphere completely transparent. Optical thickness is the result of the combined effect of the scattering and absorption in vertical, caused mainly by aerosols and air molecules.

The sensor in the optical remote sensing satellites recorded the information of the ground from the radiation values as solar energy passes through the atmosphere thick layer 2 times. The energy conversion of solar

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radiation in the atmosphere is scattering and absorption of electromagnetic waves by atmospheric components and suspended particles. Atmospheric scattering caused fog on remotely sensed imagery, and reduces contrast and sharpness of images. This process takes place in the visible spectrum to the near infrared. Thus, the remote sensing in the visible spectrum will be used, tested, to find out the relationship with the suspended particles less than 10µm size, otherwise known as PM10.

This paper presents the results of research on the possibility of detecting airborne PM10 dust from remote sensing technologies in urban areas, based on correlation and regression between AOT values calculated on satellite imagery and ground measurements from monitoring stations. Thereby establishing distribution maps of dust pollution to support the observation ground. Area of application is the inner city of Ho Chi Minh City.

2. Methodology

2.1. Structure

Techniques used to calculate AOT developed by Sifakis and Paronis (Sifakis & D. Paronis, 1998). According to this method, aerosol optical thickness (AOT) should be calculated from remote sensing to detect PM10. Then uses regression analysis to establish the relationship between PM10 data obtained at the stations on the ground and AOT values from the processed image. Two types of data must have the same date and time acquisition. Method of determining the AOT is determined based on the standard deviation reflection on pollution days, and reference date (day clean). In this study, two satellite images were compared according to the value of radiation. One image in terms of pollution and other called reference images obtained in clean air conditions. The origin of calculations based on basic equations of reflection in satellite and AOT values are determined by the formula (Sifakis & Deschamps, 1992)

$$\Delta\tau = \tau_2 - \tau_1 = ln\left[\frac{\sigma_1(\rho)}{\sigma_2(\rho)}\right] \quad (1)$$

Where, $\Delta\tau = \tau_2 - \tau_1$ - Optical thickness (not units) of clean days and days corresponding pollution; $\sigma_1(\rho)$ - The standard deviation of the reflectance of clean days; $\sigma_2(\rho)$ - The standard deviation of the reflectance of polluted days.

On the other hand, the optical thickness is approximately equal to 0 days clean, because there is no or very little pollution components, while $\tau_1 = 0$, formula (1) becomes:

$$\Delta\tau = \tau_2 = ln\left[\frac{\sigma_1(\rho)}{\sigma_2(\rho)}\right] \quad (2)$$

Or, $\tau_2 = ln\left[\frac{\sigma_1(\rho)}{\sigma_2(\rho)}\right]$ only remaining component τ_2 which is AOT on the image of pollution day.

From AOT values as the dependent variable and the concentration of PM10 as independent variables in the regression analysis to find out the empirical coefficients. The best regression function will be determined in the process of statistical analysis to determine the estimated value of PM10 on the entire image and mapping PM10. As mentioned above, studies have inherited regression equation (Tran Thi Van *et al*, 2014) to simulate the value PM10. Equation as follows:

$$y^2 = 117.2x^2 - 420.3x + 413.6 \quad (3)$$

The equation was developed for satellite imagery in 2003. The images in 2005 and 2015 will be normalized relatively radiation under the conditions of the atmosphere and environment of the image 2003. Then, apply the regression equation to calculate values for PM10 in 2005 and 2015 images, finally mapping the spatial distribution of dust PM10.

Satellite images taken in studying were the Landsat TM, Landsat ETM +, Landsat / OLI & TIRS. Time data and images collected as follows: LANDSAT / TM - 02/02/1995; LANDSAT / ETM - 04/01/2005; LANDSAT / OLI & TIRS - 24/01/2015, 29/03/2015, 07/10/2015. In addition, in order to map the concentration of PM10, research has inherited PM10 measurements at 7 auto monitoring stations acquired on 02/16/2003 from the Environmental Protection Agency of HCMC. Besides, topographic base maps at 1: 25,000 were collected to provide topographical information such as hydrographic network, roads and industrial zones, administrative boundaries.

3. Results and Discussion

3.1. Distribution map of dust concentration in the urban areas of HCMC

Spatial distribution map of PM10 dust concentration from the Landsat image was established for the middle of HCMC (Figure 1). This is a picture that shows ambient air at 10 am, the time of transport and the plant went into operation, the truck was allowed to flow in the inner city area.

Results on the map show the distribution of the contour of the PM10 values are localized shape, not spread far, and there are many directions. This is explained by the process of dispersal of suspended matter in the air affected by the wind, but the urban area has quite large surface roughness of terrain, several buildings in close proximity with other high. Therefore, seasonal prevailing wind does not much impact in urban areas, but only "vicious wind." Features of this wind are blowing in different directions under the action of the flow of the vehicles as well as the heat waste from the process of living.

Assess the overall picture across the region showed that PM10 concentrations with values <150 μg/m^3 was found on moist areas, agriculture lands, croplands away from traffic lanes, the areas with a high density of trees. Areas with high PM10 values distributed focus on the intersection points of the inner city, the traffic roads, industrial zones and residential areas with buildings.

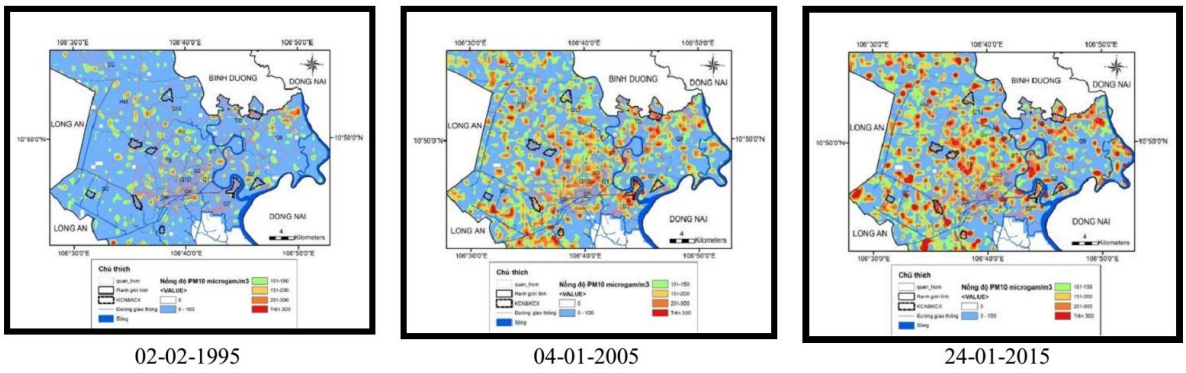

Fig. 1. Map of PM10 concentrations simulated for the urban area of HCM City at the time of image acquisition

3.2. Trends analysis of PM10 dust on urban area

According to a map of 1995, the air quality by dust component on urban area is pretty good, most places are not contaminated with the PM10 <150μg/m^3, only few places speckled with pollution levels PM10 > 200 μg/m^3, while the PM10 values > 300 μg/m^3 almost was undetectable. This can be explained, because at this stage, the industrial parks springing up no more, while the pace of urbanization and the flow of immigrants into the city is not high, as well as the activities of transportation, and the level of living of the people is not much. Therefore, environmental quality ingredients PM10 dust pretty well this time.

On the map of 2005, in general, the space of areas with concentrations of PM10 values < 150 μg/m^3 is quite broad, areas with concentrations of PM10 values > 200 μg/m^3 is only a few points speckled, and areas for PM10 values > 300 μg/m^3 is almost negligible distribution concentrated in the key traffic and industrial zones.

Meanwhile, comparisons on the map in 2015, the area has good quality environment PM10 significantly decreased, instead the areas with concentrations of PM10 area exceeded the standards increased, and there were areas doubles as Tan Thuan, Linh Trung and Tan Tao Industrial Park and a number of key transport. Most PM10 concentrations with values > 300 μg/m^3 is to dominate the entire region. Some areas with good quality PM10 concentrations mostly concentrated in riparian areas and some areas with trees growing as District 12 along the Saigon River, southwest of District 7, and the Southeast District 9. Region with area density PM10 pollution is virtually unchanged over the 2 study times in District 1 and District 5.

Environmental trends PM10 dust from the results of three maps show that environmental quality through indicators PM10 dust of the city was reduced markedly and scattered everywhere. Generally, expansion space PM10 pollution in 2015 compared to 2005 is dispersed tends county suburbs, suburban areas, and focus on increasing concentrations in urban areas, while the border between them is not likely to change significantly

3.3. PM10 dust environmental developments in 2015

According to dust distribution map PM10 in January and March 2015, the same pollutant distribution with most pollution levels exceeding 150 μg/m^3, the level of pollution is distributed in urban areas and spread out the suburban districts. This shows quite clearly the nature of the "vicious wind." Due to limited space in urban

areas, PM10 dust gathered a vicious way in urban areas, on the other hand in rural areas, suburban areas along with more open spaces, evenly distributed wind blows everywhere, leading to PM10 dust scattered everywhere. Pollution levels exceeding 300 μg/m^3 are concentrated in industrial parks as Tan Thuan Export Processing Zone, Tan Tao Industrial Zone, Linh Trung Export Processing Zone, suburban Binh Chanh district and the traffic key. January and March are the months characterizing dry season, little rain, low air humidity. Transportation activities, industrial production and daily life are normal. Thus, the image acquisition time is specific to the pollution in the dry season in the inner city. In two satellite images, especially in district 9, the results show, in the southeast area of District 9 PM10 concentrations are generally lower than in the North District 9 because it is a center of the industrial area and traffic lanes, such as high-tech zone of District 9, Linh Trung industrial park, traffic routes Thu Duc intersection ... Photos show dust PM10 in March with the specific location of the pollution extended on 300 μg/m^3 as Tan Thuan District 7, District 2 Tan Tao Industrial Zone, Ha Tien cement plant 1, latch traffic as Thu Duc, An Suong intersection, roundabout Go Vap ...

October is the month of the rainy season, characterized humid air, the wind blowing, and the nature of leaching and dissolved air pollutants especially PM10 dust components. Map of simulation of PM10 dust components in October 2015 showed that the air quality is better than in January and February 3. The pollution is mainly less than 300 μg/m^3, and more than 150 μg/m^3 micrograms of pollution levels is only scattered speckled few places.

In summary, simulation maps PM10 between years and between the months of the year showed an overall picture is the inner city and urban areas concentrate, closing traffic and industrial areas are densely distributed high PM10 and scattered in the suburbs. (Figure 2)

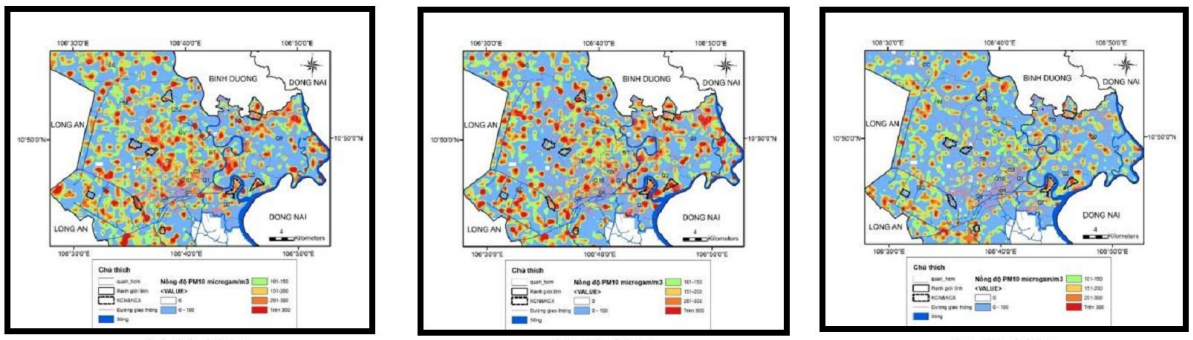

Fig. 2. Map of PM10 concentrations simulated for urban area at times of image acquisition in 2015

4. Conclusion

Currently, in terms of air monitoring stations on the ground automatically no longer work, the environmental assessment of the city's atmosphere can only be based on the semi-automatic monitoring points. With the number of monitoring locations semiautomatic quite limited, it is difficult to assess the pollution across the city. Investing more automatic monitoring stations will be quite expensive. Thus, the advantages of satellite images, can take on a wide area, with the processing methods, calculations have been tested all over the world for many years, remote sensing methods can complement in such a useful tool in service of monitoring and evaluation of air pollution for the city today.

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