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Aerosol Optical Thickness (AOT) Assessment Using GIS & Remote Sensing

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***Abstract*— Atmospheric aerosol particles are one of the significant agents of air quality degradation. MODIS, GIS and Remote Sensing techniques have made the way of AOT assessment easiest over historic manual systems. This paper concerns itself with the AOT assessment using GIS and Remote Sensing over Dhaka, Bangladesh in 2017. Required observations for AOT assessment are taken considering seasonal variability. Considered three seasons for this research are winter (January, February and December), Pre-monsoon (March and April) and Post-monsoon (October and November). Monsoon variations are not considered to avoid excessive cloud correction. The multispectral algorithm model is used to detect AOT considering the surface condition homogenous. Basically, Landsat 8+ OLI images are used for AOT assessment and NASA Earth Observation (NEO) data are used for data validation. It is found that the winter season has the highest concentration of AOT compared to pre and post monsoon. This is due to the meteorological factors like cloud, rainfall, humidity, wind pressure and speed, temperature etc.**

***Index Terms*— Aerosol Optical Thickness (AOT), Geographic Information System (GIS), Remote Sensing, Landsat, Image processing.**

I. INTRODUCTION

Global temperature has increased about 6°C in the last century due to 1% shift in energy (emanation and absorbing of sunlight) balance (Kaufman et al., 2002). Along with the greenhouse gases, aerosols are one of the major agents of this global warming effect and air quality degradation. Aerosols comprise of various harmful pollutants like black carbon, suspended particulate matters ($PM_{2.5}$ and PM_{10}), sulfates, nitrates, shoots, dust, etc. Aerosol concentration in urban areas is considered one of the major anthropogenic pollution sources in the world due to rapid urbanization (Luo et al., 2014). Basically, Aerosol Optical Thickness (AOT) is the most common unit of aerosol concentration measurement. It refers to a ratio of aerosol particles (e.g., urban haze, smoke particles, desert dust, and sea-salt) which are circulated within a column of air from the Earth's surface to the top of the atmosphere (Holben et al., 1998). Advancement of computer science and applications has opened a new door for AOT measurement. Researchers prefer computer simulation models for measuring aerosol loading over statistical modeling due to the fact that statistical models are capable of providing additional accuracy merely for smaller region. GIS and Remote Sensing is the part of this advancement. These can provide more accurate results of atmospheric aerosol concentration.

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II. PREVIOUS WORKS

This research follows the same algorithm that Hashim et al. (1990), Othman et al. (2010) and Nguyen and Tran, (2014) have used and all of these three studies certifies Landsat imagery as a convenient and efficient technique for monitoring Air Pollution. Hashim et al. (1990) found a high correlation (0.9673) between AOT measured by Landsat TM and Spectro radiometer. Othman et al. (2010) used Landsat 7 ETM+ images and Nguyen and Tran (2014) used Landsat 8 OLI images for measuring AOT. Their recommended for increasing accuracy is to use more satellite stations and value added ancillary data. Some researchers have preferred comparative AOT analysis for seasonal variations with spatial and temporal variability. Henriksson et al. (2011) have observed seasonal variation of aerosol loading over India and China and found heavy durable aerosol in winter because of less precipitation and wet removal of aerosols. This paper also shows seasonal variability of AOT analysis for pre-monsoon, post monsoon and winter.

III. STUDY AREA PROFILE

Dhaka the capital of Bangladesh is a rapidly urbanizing city with severe concentration of aerosols in its environment. Moreover, this city is a large contributor to 'Asian brown cloud', which creates haze concentration by travelling far into the Asian continent (Begum et al., 2013). It is the third most polluted region in Asia with a yearly average of 90 μg/m^3 of $PM_{2.5}$ (Roychoudhury, 2017). The Air Quality Index (AQI) value is increasing day by day for high degree of aerosol loading. As a result, about 98.83% dwellers of Dhaka are suffering from health hazards because of aerosol fine particles as well as air pollution (Khalikuzzaman, 1995). This city has been selected as the study area for this paper considering an area of 1.46 Km^2. Fig. 1 is showing the geographical location of selected study area.

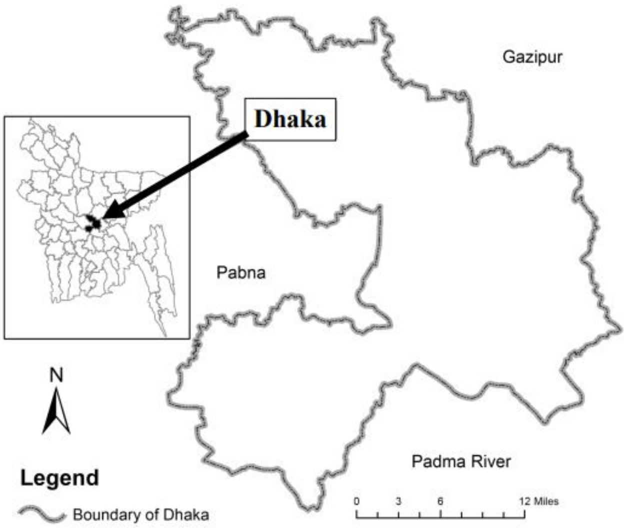

Fig. 1: Study area location

IV. Method & Materials

Clear observation method is employed to select Landsat 8 OLI satellite images in this research. Clear observation refers to a simplest way of selecting image with the lowest cloud coverage. The highest cloud coverage is found 4.6% and the lowest is about 0.02%, which also allows avoiding lengthy cloud correction process.

A. Image Preprocessing

The first step is radiometric calibration of satellite images that means conversion of sensor Digital Number (DN) to Top of Atmospheric (TOA) reflectance. This step is done through using (1) which is further associated with a correction for the sun angle of TOA reflectance using (2).

$$\rho\lambda' = M_\rho * Q_{cal} + A_\rho \qquad (1)$$

$$\rho\lambda = \rho\lambda' / \cos(\theta_{SZ}) = \rho\lambda' / \sin(\theta_{SE}) \qquad (2)$$

Where, $\rho\lambda$ = TOA planetary reflectance; $\rho\lambda'$ = TOA planetary reflectance (without correction for solar angle); M_ρ = Band-specific multiplicative rescaling factor from the metadata; A_ρ = Band-specific additive rescaling factor from the metadata and Q_{cal} = Quantized and calibrated standard product pixel values (DN); θ_{SE} = Local sun elevation angle; θ_{SZ} = Local solar zenith angle and θ_{SZ}= 90° - $\theta_{SE.}$ The last step is atmospheric correction of images using Dark Object Subtraction (DOS 1) method.

B. AOT Calculation

Nguyen and Tran's (2014) 'AOT algorithm model' has been used for this paper as shown in (3).

$$AOT(\lambda) = a_o R(\lambda) \qquad (4)$$
$$R(\lambda) = \rho a (\theta_{SZ}, \theta v, \Phi)$$
$$a_o = 4\mu\mu_o / \omega o * \rho a (\theta_{SZ}, \theta v, \Phi)$$

Where, $R(\lambda)$ = atmospheric reflectance corresponding to wavelength (λ) for satellite; $\rho a(\theta_{SZ}, \theta v, \Phi)$ = aerosol scattering phase function; θ_{SZ} = Local solar zenith angle; θv = Viewing zenith angle; Φ= Relative azimuth angles; μ = Cosines of the view directions; μ_o = Cosines of the illumination directions and ω_o = single scattering albedo.

After getting the required AOT values for all the selected months of year 2017, the mean values are calculated for pre-monsoon, post monsoon and winter period. Then a comparative seasonal variability has been described.

C. Image Profile

In this research, 6 Landsat+ 8 OLI imagery is applied to calculate AOT. Images are collected from official website of the United States Geological Survey (USGS). The Landsat 8 OLI satellite passes through the Worldwide Reference System (WRS) Path 137 and row 44 with 185 km wide swath. The satellite images have total nine 9 bands. These bands and their wavelengths (micrometer) are: (1) Coastal/Aerosol [0.43 – 0.45], (2) Blue [0.45 – 0.51], (3) Green [0.53 – 0.59], (4) Red [0.64 – 0.67], (5) Near Infrared [0.85 – 0.88], (6) Short wave Infrared 1 [1.57 – 1.65], (7) Short wave Infrared 2 [2.11 – 2.29], (8) Panchromatic [0.50 – 0.68] and Cirrus [1.36 – 1.38].

Table 1: Collected Landsat 8 OLI image angle profile

Image No.	Azimuth	Elevation	Zenith
01	148.6668	39.1003	50.8997
02	153.5150	38.7722	51.2278
04	153.5150	38.7722	51.2278
05	135.9226	50.5938	39.4061
06	150.1262	49.5228	40.4771
07	153.7597	44.4261	45.5754

D. Data Validation

AOT mean value of month January, 2017 has preferred for result validation. This research has found mean AOT as 0.9325 using Landsat 8 OLI. But NASA (National Aeronautics and Space Administration) has measured the mean AOT as 0.8682 for January, 2017 using Aqua MODIS (Moderate Resolution Imaging Spectroradiometer). Therefore, this research is approximately 93% validated with the result of NASA. The reasons behind this 7% variation of result are many; however, among them the image cell size and used AOT algorithm variance are major. Landsat 8 provides images of cell size 30x30m, whereas, available MODIS imagery used by NASA Earth Observatory provides cell size of 11160x11160m.

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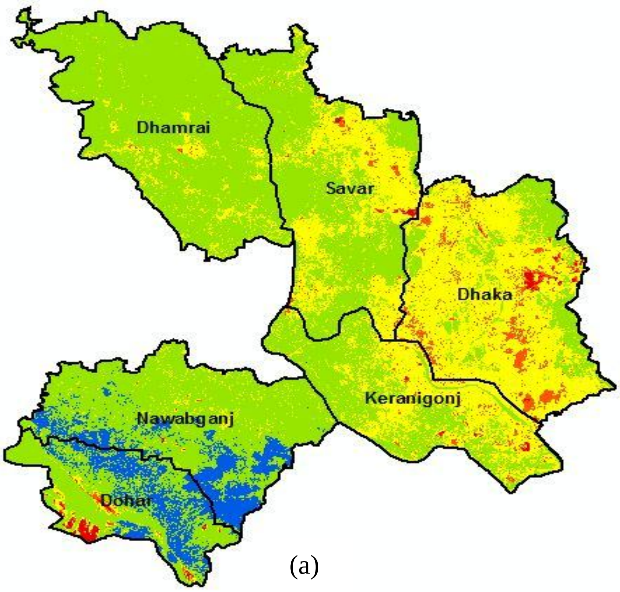
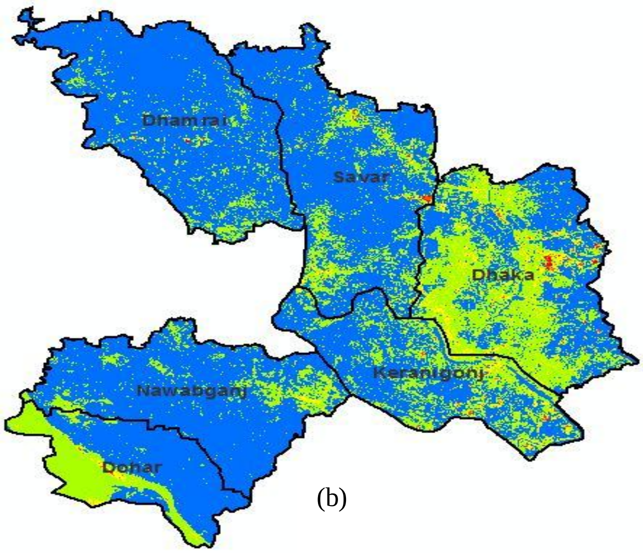
V. AOT & SEASONAL VARIABILITY

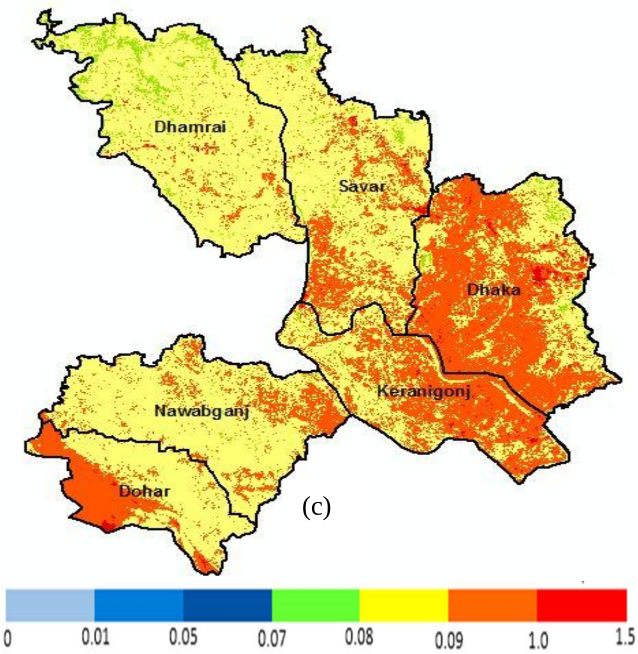
Usually, world's northern hemisphere shows high ranges of AOT (average 0.30 to 0.60) than southern hemisphere. As Dhaka lies in northern hemisphere, its average yearly AOT is expected to be high. But when the value is closer to 1 (reddish) it termed as the worst air quality condition according to NASA Earth Observatory. The temporal variation of AOT has been observed over entire Dhaka District comprising of six sub districts. These are Dhamrai, Savar, Dhaka, Dohar, Keraniganj and Nawabganj. Fig. 2 shows AOT mapping for three seasons with value ranges.



(a)



(b)



(c)

Fig. 2: Seasonal variation of AOT in (a) Pre-monsoon, (b) Post monsoon and (c) Winter

Fig. 2 defines that visually the winter is distinct with high AOT than other two seasons. If the three seasons were ranked from high to low AOT loading, it would be winter, pre-monsoon and post-monsoon, respectively. This result is more cleared in Table. 2 with calculated value driven from satellite images.

Table 2: AOT value driven for seasons

Month		Mean AOT	Seasonal Average
Winter	December	0.8265	0.9476
	January	0.9325	
	February	1.0837	
Pre-monsoon	March	0.8852	0.8852
Post monsoon	October	0.6618	0.6702
	November	0.6786	

The reasons behind this seasonal variation of AOT is meterological factors like temperature, precepitation, wind speed and pressure, humidity etc. The winter of Dhaka is cherecterized by such meterological condition which boost longibility of fine aerosol paticles in the atmosphere. Thus the AOT increases. For example, Dhaka has recorded only seven rainy days in winter period (World Weather Online, 2017). During monsoon (June to September), fine aerosol particle's concentration decreases due to washout of particles by rainfall and cloud (DoE, 2012). Dhaka has recorded 242.7 mm precipitation in post monsoon and 57.3 mm in pre-monsoon ((World Weather Online, 2017). That represts how precipitation influences aerosol loadings in atmosphere of Dhaka.

VI. CONCLUSION

This paper has measured AOT and seasonal variability over Dhaka, Bangladesh using GIS and RS techniques. Landsat 8 OLI satellite images are used to analysis AOT over six months of year 2017. Research results have found 93% validated with observation of NASA Earth Observatory observation. The major finding of this paper is that winter is highly risky to human being in case of respiratory diseases as the air pollution gets high. And precipitation modifies the seasonal variability of AOT a lot for Dhaka. Besides this finding, the analytical procedure of AOT calculation has faced some limitations. First one and more important is cloud correction in RS. Its data complexity has forced to avoid monsoon variability observation. That's why pre-monsoon, post monsoon and winter are only considerable. Furthermore, secondary information availability in Bangladesh is quite questionable in its accuracy. Department of Environment should pay attention to continuous AOT observation as well air quality monitoring, which can help adopting appropriate policy options indeed.

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AUTHOR'S PROFILE

Shuvra Sikder, is Lecturer at Department of Urban and Regional Planning in Khulna University of Engineering & Technology, Bangladesh. She had her Master's and Bachelor's Degree in Urban and Regional Planning at Khulna University of engineering and Technology. She used GIS and RS to develop atmospheric aerosol modeling in her undergraduate thesis. Her research interest is software applications and model preparation for air quality monitoring. She is researching on this fact from year 2016.

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