SATELLITE BASED ESTIMATION OF PM10 FROM AOT OF LANDSAT 7ETM+ OVER CHENNAI CITY

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ABSTRACT

In this study we discuss about the calculated AOT, the relationship function between AOT and estimated Particulate matter with diameter less than ten micrometre (PM10) in the atmosphere from the satellite imagery of LANDSAT 7 ETM+ slc-off. The main objective of this study to determine Particulate Matter (PM10) concentration has been exceed that annual mean value of NAAQS value with huge variation. Estimated PM10 concentration were also compared with the Ground PM10 data estimated from different location of Chennai region during 2011-2012. The retrieval result gives the accuracy of correlation coefficient of (R>0.9) over Chennai region. The derived result provide confidence that multispectral algorithm PM_{10} model can make accurate prediction of PM10 concentration of various locations.

Keywords: Aerosol optical thickness (AOT), PM10, Landsat 7ETM+, NAAQS

INTRODUCTION

Air Pollutants are substances which released from various sources which when present at high concentrations, produce directly or indirectly harmful effects on people and/ or the environment.

Air pollution in mega cities arise from different various sources although they are mainly a result of combustion process. As a result of these activities Particulate maters PM10& PM2.5 and Noxious gases like Sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) etc are released into Atmosphere. Consequently, suspended tiny Particulate Matter (PM10) of diameter smaller than 10µm diameter (PM10) and liquid droplet from aerosol is considered to be one of the major criteria pollutants to indicate the air quality (World Health Organization 2006).

Studies worldwide show that the use of multispectral satellite images absolutely can detect air pollution. Effectively brought from the application of remote sensing technology in the field of environmental monitoring of air pollution. Atmospheric Turbidity due to aerosol is considered as an overall indicator of air pollution and it is measured by calculating the aerosol optical thickness (AOT) followed by PM10 mass concentration.Therefore in this study we presents the potentiality of retrieving concentration of particulate matter with diameters less than 10µm (PM10) in the atmosphere using the Landsat 7 ETM+ satellite imagery over Chennai region.

STUDY AREA

Chennai is one of the important costal mega cities in India. Chennai is situated on the north-east end of Tamil Nadu on the coast of Bay of Bengal. It lies between 12º 9' and 13º 9' of the northern latitude and 80º 12' and 80 º 19' of the southern longitude on a `sandy shelving breaker swept beach'. It stretches nearly 25.60 kms along the Bay coast from Thiruvanmiyur in the south to Thiruvottiyur in the north and runs inland in a rugged semi-circular fashion. It is bounded on the east by the Bay of Bengal and on the remaining three sides by Chengalpattu and Thiruvallur Districts. The area that falls under Chennai overlaps with three districts (Chennai, Kanchipuram and Thiruvallur) show in figure 1.

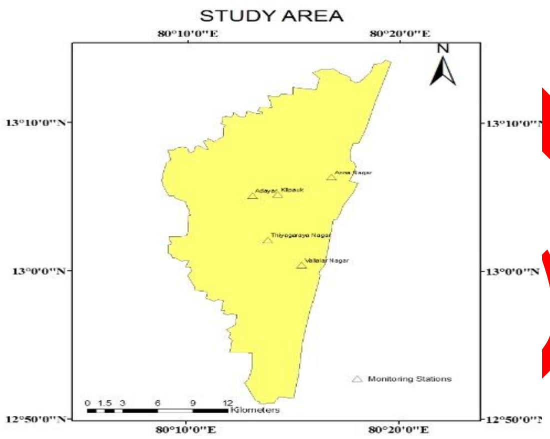


Figure 1 Location map of the study area

MATERIALS

Landsat 7 (ETM+) Enhanced Thematic Mapper plusis a sensor equipped on Landsat-7. It generates 8 spectral bands in blue, green, red, NIR and mid-infrared (MIR). Bands 1-5 and 7 have 30 meter resolution. The panchromatic (band 8) has 15 m resolution. The thermal band has 60 meter resolution.

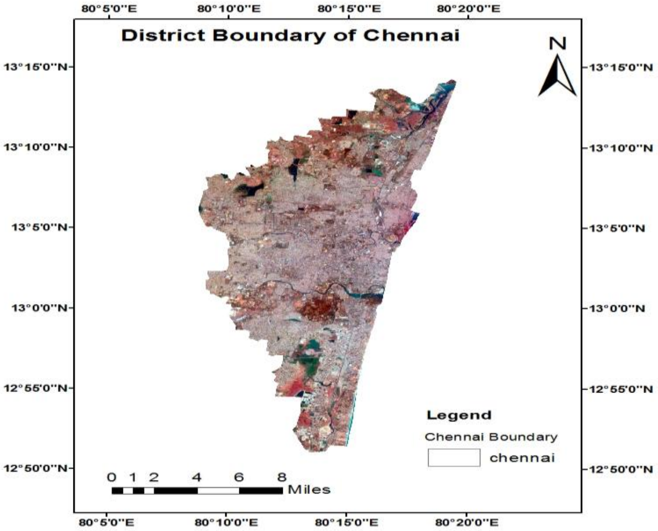


Figure 2. Landsat 7 Image

METHODOLOGY

IMAGE PROCESSING

In this section, Landsat-7 ETM+ satellite imageries (i.e. band 2, band 3 and band 7) are processed for deriving the Aerosol Optical Thickness, particulate matter concentration and to apply the meteorological correction respectively.

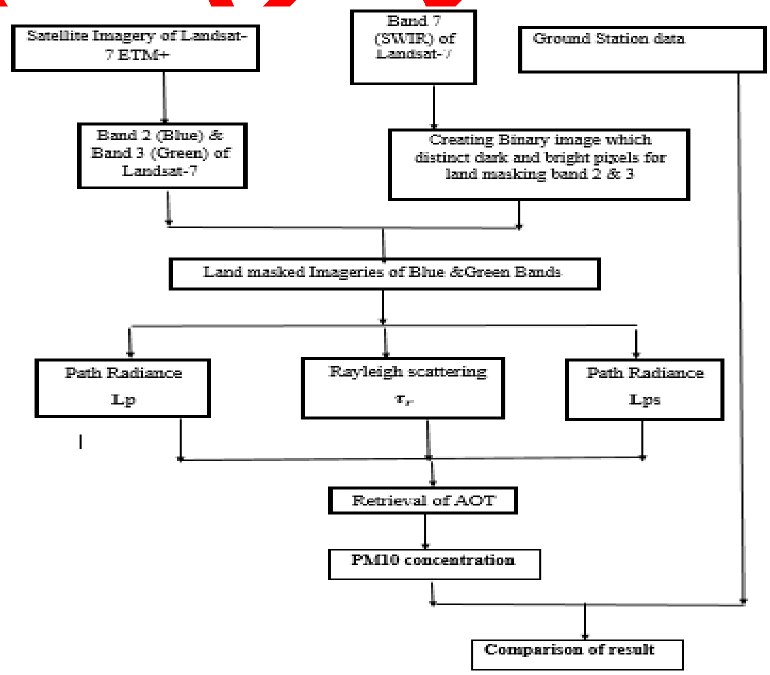


Figure 2 Methodology Flowchart

BAND SELECTION

To determine air pollution concentration, bands are selected from the visible region Landsat-7 ETM+. Those bands should be in the range of 450 nm to 600 nm. And so the band 2 and band 3 of sensor is selected for retrieval of Aerosol Optical Thickness. The wavelength range of band 2 (Blue) is 450 nm to 515 nm and the wavelength range of band 3 (Green) is 525 nm to 600 nm. And both band slices have the spatial resolution about 30 m. band 72100nm to 2300 nmband 7 of sensor (i.e. SWIR 2) is used in generating Land Mask binary image file by discriminating those land and water bodies.

RADIOMETRIC AND ATMOSPHERIC COREECTION

Radiometric correction is applied by transforming the values of DN to radiance of reflectance values.

First converts the sensor DN to at-sensor radiances and requires sensor calibration information (Mather, 2004). The second is the transformation of the at-sensor radiance to radiances at the Earth's surface.

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{QCALMAX - QCALMIN}\right) * (QCAL - QCALMIN) + LMIN_\lambda$$

Where:

L_λ = Spectral Radiance at the sensor's aperture in $W/m^2/sr/\mu m$

QCAL = the quantized calibrated pixel value in DN

$LMIN_\lambda$ = the spectral radiance that is scaled to QCALMIN in $W/m^2/sr/\mu m$

$LMAX_\lambda$ = the spectral radiance that is scaled to QCALMAX in $W/m^2/sr/\mu m$

QCALMIN = the minimum quantized calibrated pixel value (corresponding to $LMIN_\lambda$) in DN

Then optical thickness of Rayleigh scattering (τr) was determined by equation proposed by Strum,(1982)

$\tau r = 0.00879(\lambda c)^{-4.09}$ (2)

the combined surface and atmospheric reflectance of the Earth also know as top of atmospheric reflectance (TOA) is computed with the following formula (Mather, 2004)

$$\rho p = \frac{\pi L\lambda d^2}{ESUN\lambda \cos\theta s} \quad (3)$$

where:

ρp= Unitless planetary reflectance

Lλ= Spectral radiance at the sensor's sperture

d = Earth-sun distance in astronomical units (Appendix C, Chander et al., 2009)

ESUNλ = Mean solar exo-atmospheric irradiances (Appendix B, Chander et al., 2009)

θs = Solar zenith angle in degree(Meta data of Landsat 7 ETM+)

DATA PROCESSING

After undergo Radiometric correction the reflectance measured from the satellite (reflectance at the top of atmospheric, TOA) was subtracted by the amount given by the surface reflectance to obtain the atmospheric reflectance. The atmospheric reflectance was then related to the PM10 using the regression Algorithm analysis. PM10 maps were generated using proposed algorithm based on the highest R and lowest RMSE values. So the algorithm of AOT for single band or wavelength(λ) is simplifies as:

$$AOT(\lambda)=a0\ R\lambda1+ a1\ R\lambda2+ a2\ \ R\lambda3 \qquad (4)$$

where Rλ1 is the atmospheric reflectance (i= 1,2,3 corresponding to the wavelength of satellite) the relation between PM and AOT is derived for a single homogeneous atmospheric layer containing spherical aerosol particles.

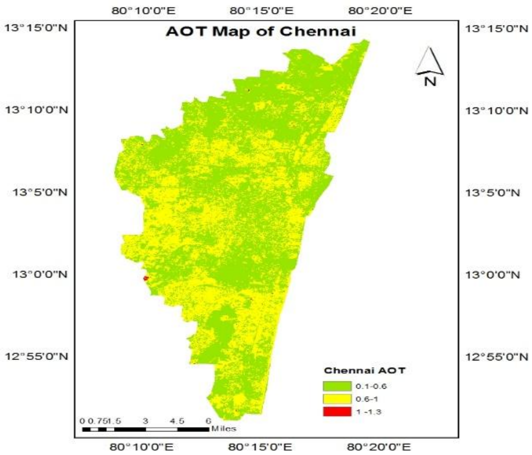
$$PM10= a0\ R\lambda1+ a1\ R\lambda2+ a2\ \ R\lambda3 \qquad (5)$$

where aj is the algorithm coefficient (j=0,1,and 2) are empirically determined.

RESULT & DISCUSSION

Table 2. Calculated AOT and PM10 concentration from satellite image data and PM10 ground measurement at different location of chennai region

Ground Station	**Calculated TOA from satellite Imagery**	**PM10 Concentration estimated from satellite imagery (μg/m³)**	**Monthly Average PM10 Concentration measured at Ground station (μg/m³)**
Anna Nagar	0.76	180	136
Adayar	0.51	84	40
Kilpauk	0.86	142	112
T.Nagar	0.92	200	128
V.Nagar	1.101	290	216



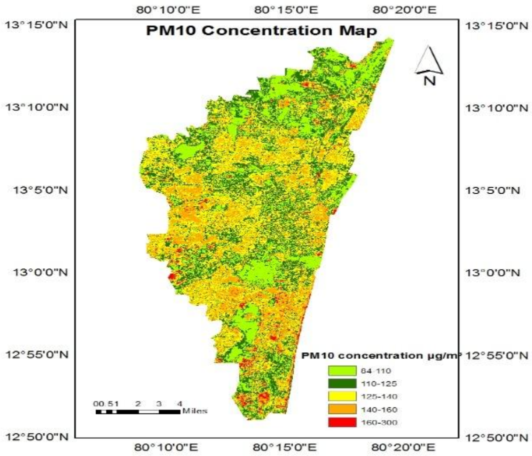


Figure 3 AOT map of chennai region during 2011-2012. Figure 4 Spatial distribution of PM10 concentration map

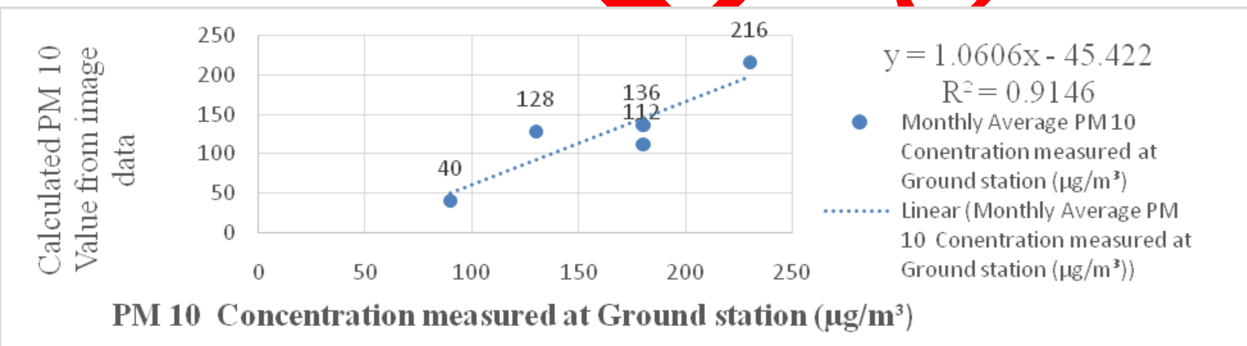


Figure 5 Correlation between the PM10 Concentration of satellite and ground station data

CONCLUSION

The result of this study indicates that sir pollution can be mapped using satellite information to provide a bigger area of coverage. Landsat 7 ETM+ image was sucesssfully used for the calculation of PM10 concentration over Chennai region. Our proposed multispecrtral algorithm of PM10 is based on the aerosol optical reflectance model. The result indicates that air pollution PM10 can be calculated, by purpose on, using the visible bands reflectance value of Landsat 7 ETM+. Future study will consider of using more air pollution stations and other value-added ancillary data, since then calculating a regression model to determine PM10 calculated from Landsat 7 for the area to be studied. As well as the method of atmospheric correction of Landsat 7 ETM+ in order to gain better and reliable accuracy.

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