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CONCENTRATION DISTRIBUTION MAPPING OF PARTICULATE MATTER(PM_{10}) AND SULPHUR DIOXIDE(SO_2) FOR AIR QUALITY MONITORING USING REMOTE SENSING AND GIS

***Miss.S.Vanmathy, **Mrs.G.Devi.**

**PG student: Department of Civil Engineering ,*
Anna University Regional Campus
Tirunelveli, India
***Assistant Professor: Department of Civil Engineering*
Anna University Regional Campus
Tirunelveli, India

ABSTRACT

Mapping of urban air pollution dispersion is very complex; recently Satellite image data present a wide applicability for air pollution studies. The research used the Landsat 7 ETM+ to determine the PM_{10} and SO_2 concentration over an area of interest. The aim of this study is to present and apply the proposed algorithm derived from atmospheric correction concept to determine concentration of PM_{10} and SO_2 over an area. Satellite and ground station data were correlated to select a best suited algorithm and it provide a good result of R^2 =0.992 and 0.995 for PM and SO_2 respectively. The results showed significant linear relationships between ground and satellite data and also indicated that satellite imagery was capable for mapping of the pollution parameters concentrations.

***Keywords**: Air pollution-PM_{10} and SO_2 algorithms-Ground data-Correlation-PM_{10} and SO_2 Concentration map*

INTRODUCTION

Our environment is composed of atmosphere, earth, water and space. In absence of pollution it remains clean and enjoyable. Environmental pollution become more and more serious due to today's development all around the world. Environmental pollution is our concern nowadays because all the daily activities are related to the environment. Air pollution is one of the most important environmental problems, which concentrates mostly in cities. The hazardous gases that leads to pollutions are oxides of carbon, nitrogen, sulphur and particulate matter. Air pollutants can be measured from ground base stations with different type of instruments .Further the limited number of the air pollutant stations and scarcely distribution not allowed a proper mapping of the air pollutants. So, they cannot provide a detail spatial distribution of the air pollutant over a city. Remote sensing technique was widely used for environment pollutant application such as air pollutant (Ung, et al., 2001b). Satellite data can aid in the detection, tracking, and understanding of pollutant transport by providing observations over large spatial domains and at varying altitudes. Several studies have shown the possible relationships between satellite data and air pollution for more information's see Ung, et al, (2001a)]. Thoothukudi, is one of the most polluted city in the region due natural and artificial sources. Its geographical location made the city affected by heavy dust storms many times in year. Therefore, there is a layer of aerosols and other particulate matter in its atmosphere. Artificial sources of air pollution in Thoothukudi are due to the highly population growth, the exhaust from more than million vehicles and heavy traffic in the city, private electric generators and pollutants from industrials.

The **objective** of this study is to investigate the possibilities of satellite data for mapping air quality by establish a relationship between ground base measurements of major primary pollutants concentrations from Landsat 7 ETM+ satellite data. The main aim is to understand the influence of pollutants in the upper layer and to find out an important atmospheric pollutant which are affecting the surroundings and also finding the best suited algorithm for the selected study area to map PM_{10} and SO_2 concentration.

STUDY AREA

Thoothukudi is situated in the Gulf of Mannar about 125 km (78 mi) North of Cape Comorian. Thoothukudi district is located on south east of Tamil Nadu state. The district covers an area of 4,621 sq. km It lies between 8030' and 90 of the northern latitude and 780 and 78015' of the eastern longitude. The city mostly has a flat terrain and roughly divided into two by the Buckle channel. The city experiences tropical climatic conditions characterised with immensely hot summer, gentle winter and frequent rain showers. Summer extends between March and June when the climate is very humid. The coolest month is January and the hottest months are from May to June. The city has a very high humidity being in the coastal sector.

MATERIALS

This study involved the usage of two types of data namely; ground base measurements and satellite data.

GROUND BASE MEASUREMENT

The State Pollution Control Board (SPCB) is collecting data for PM_{10},SO_2, NO, NO_2, NH_3, CO concentration on hourly and daily average basis, which could be used for inference to the satellite based estimation of air pollution for residual error. The table I shows the SO_2 and PM_{10} concentration in ground station over the study area.

Table I SO_2 and PM_{10} Concentration Measured on 14th January 2015

Sr.No	*Location*	*Category*	*Station Code*	*PM_{10} Concentration At Ground Station($\mu g/m^3$)*	*SO_2 Concentration At Ground Station($\mu g/m^3$)*	*National Ambient Air Quality Standards (24hrs) ($\mu g/m^3$)*	
						SO_2	PM_{10}
1	Raja Agencies	Industries	240	140.01	8.01		
2	AVM Building	Mixed	366	126.26	7.45	80	100
3	Fisheries College	Industries	239	138.16	10.88		

SATELLITE DATA

LANDSAT 7 satellite is equipped with Enhanced Thematic Mapper Plus (ETM+), the successor of TM. The observation bands are essentially the same seven bands as TM, and the newly added panchromatic band 8, with a high resolution of 15m was added. The study area (Thoothukudi district) comes under the path of 143 and row of 54 is noticed and the satellite data of level1 product are collected. The image data are radiometrically and geometrically corrected and are available in GeoTIFF. The figure 1 shows the image of the Thoothukudi taluk.

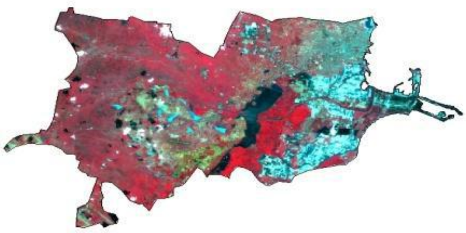

Figure 1 Satellite image of Thoothukudi of January 2015

METHODOLOGY

To map urban air pollution using remote sensing techniques and GSD, it is important to select a method. First, the required data was collected and then created relationship were selected to estimate PM or SO_2 concentrations by using the regression analysis proposed by Pet Techarat (2013). The methodology flow chart is described below.

BAND SELECTION

To determine air pollution concentration, bands are selected from visible and infrared region of Enhanced Thematic Mapper (ETM+) sensor of Landsat-7.Those band ranges from 0.63µm – 12.5 µm. Band 3 is selected for retrieval of PM10 concentration, the wavelength range of band 3 is 0.63µm-0.69µm. Band 4 and 6 is selected for retrieval of SO2

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concentration, the wavelength range of band 6 is 10.4µm-12.5µm. Band 3 and 4 has the spatial resolution of 30m and band 6 has the spatial resolution of 60m.

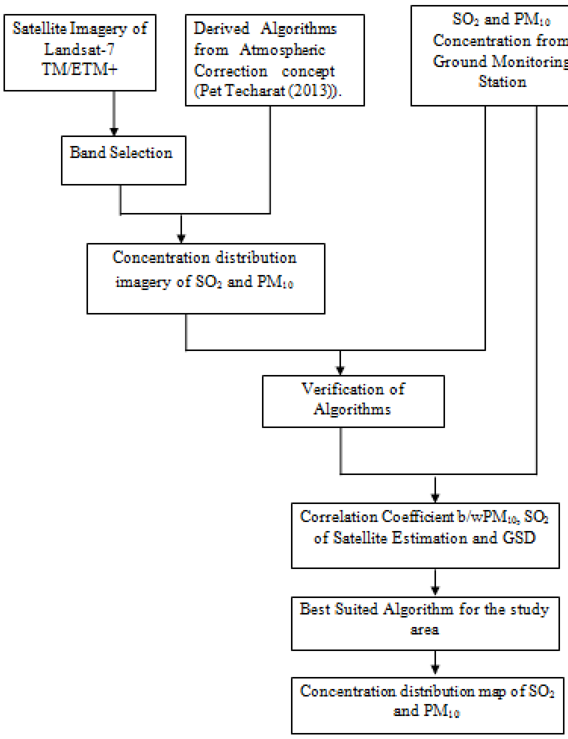

Figure 3 Methodology Flow Chart

ALGORITHMS FOR PM_{10} AND SO_2 CONCENTRATION ESTIMATION

The algorithms derived from atmospheric correction concept (Pet Techarat (2013).) to estimate the PM and SO_2 concentration are listed in table II and table III respectively.

Table II PM_{10} Algorithms

TM/ ETM+ Bands	Algorithm
3	$PM_{10} = 4.18669 + (0.00371 \times L_{p,3}^2)\ln L_{p,3} + (-9.05\times10^{-5} L_{p,3})$
3	$PM_{10} = 0.6749 + (0.0149 \times L_{p,3}^2) - 6.5736\times10^{-5} \times L_{p,3}^3$
3	$PM_{10} = -7.14134 + (0.05204 \times L_{p,3}^2) - (0.00924 \times L_{p,3}^2 \ln L_{p,3})$
3	$PM_{10} = -9.8754 + (0.14495 \times L_{p,3}^{1.5}) + (-5.554\times10^{-4} \times L_{p,3}^{2.5})$

Table III SO_2 Algorithms

TM/ ETM+ Bands	Algorithm
4,6.1	$SO_2 = 0.1774 - 0.0443 \times Ln(DN_4) + 2.311 \times 10^{-8} \times DN_{6.1}^3$
3	$SO_2 = 0.1846 - (4.66 \times 10^{-2} \times LnDN_4) + (2.808 \times 10^{-6} DN_{6.1}^2)$
3	$SO_2 = (5.086 \times 10^{-2}) + (\frac{2.365}{DN_4}) + (2.241 \times 10^{-2} \times DN_{6.1})$
4,6.1	$SO_2 = (-2.58 \times 10^{-2}) + (2.364 \times 10^{-4} \times DN_{6.1}^2) + [EXP(DN_4)(0.2134, 21.67688)]$

RESULT AND DISCUSSION

PM_{10} Concentration Determination

The derived algorithms from atmospheric correction concept are used to determine the PM_{10} concentration. Firstly the radiance of band 3(Lp) has to be determined which is determine using the following formula

$$L_p = [(L_{max} - L_{min})/255] * DN + L_{min} \quad (1)$$

L_{min} = spectral radiance scales to QCALMIN,
L_{max} = spectral radiance scales to QCALMAX
QCALMIN = the minimum quantized calibrated pixel value (typically = 1) ,
QCALMAX = the maximum quantized calibrated pixel value (typically = 255) ,
DN- Digital Number.

BAND MATH is used to find the concentration imagery of PM_{10} and then it is correlated with the Ground station data to determine the best suited algorithm for the study area. Table IV shows the correlation coefficient for the derived algorithms. The figure 3 represents the PM_{10} concentration map. The map represents the concentration distribution of PM_{10} which ranges from <70 to 150µg/m^3. From the correlation result it is found that algorithm 2 is best algorithm with 0.9958 correlation coefficient and figure 4 shows the correlation coefficient graph.

Table IV Correlation coefficient (R^2) for the Algorithms

TM/ ETM+ Bands	Algorithm	R^2
3	$PM_{10} = 4.18669 + (0.00371 \times L_{p,3}^2) \ln L_{p,3} + (-9.05 \times 10^{-5} L_{p,3})$	0.8037
3	$PM_{10} = 0.6749 + (0.0149 \times L_{p,3}^2) - 6.5736 \times 10^{-5} \times L_{p,3}^3$	0.9958
3	$PM_{10} = -7.14134 + (0.05204 \times L_{p,3}^2) - (0.00924 \times L_{p,3}^2 \ln L_{p,3})$	0.5538
3	$PM_{10} = -9.8754 + (0.14495 \times L_{p,3}^{1.5}) + (-5.554 \times 10^{-4} \times L_{p,3}^{2.5})$	0.4098

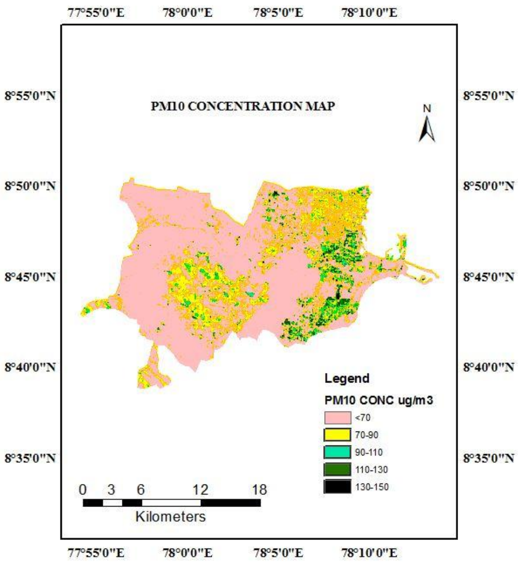

Figure 3 PM_{10} concentration map

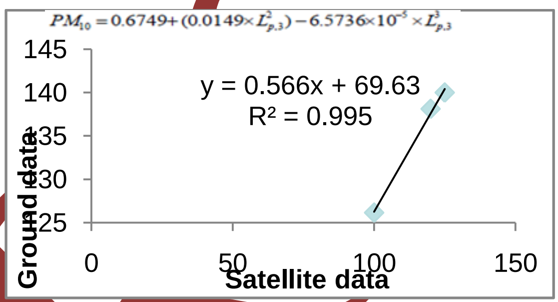

Figure 4 Correlation between satellite and ground data

SO_2 CONCENTRATION DETERMINATION

Steps involved to determine the concentration distribution of SO2 over an area of interest is determined by following 2 steps.

I. Band 4 and 6 are selected and its ranges from (0.75µm-0.95µm)& (10.4µm-12.5µm) respectively.
II. Using BAND MATH the algorithms are inserted to determine the SO2 concentration map.

Figure 4 shows the concentration map of SO_2. The map represents the concentration of SO_2 which ranges from <4.5 to 13µg/m^3. The red colour represent the high concentration of SO_2. From the correlation coefficient result algorithm 3 gives the good correlation of R^2=0.992and it is the best suited algorithm for the study area and figure 6 shows the correlation coefficient graph.

Table V Correlation coefficient (R^2) for the Algorithms

TM/ ETM+ Bands	Algorithm	R^2
4,6.1	$SO_2 = 0.1774 - 0.0443 \times Ln(DN_4) + 2.311 \times 10^{-8} \times DN_{6.1}^3$	0.8687
3	$SO_2 = 0.1846 - (4.66 \times 10^{-2} \times LnDN_4) + (2.808 \times 10^{-6} DN_{6.1}^2)$	0.7604
3	$SO_2 = (5.086 \times 10^{-2}) + (\frac{2.365}{DN_4}) + (2.241 \times 10^{-2} \times DN_{6.1})$	0.992
4,6.1	$SO_2 = (-2.58 \times 10^{-2}) + (2.364 \times 10^{-4} \times DN_{6.1}^2) + [EXP(DN_4)(0.2134,21.67688)]$	0.5516

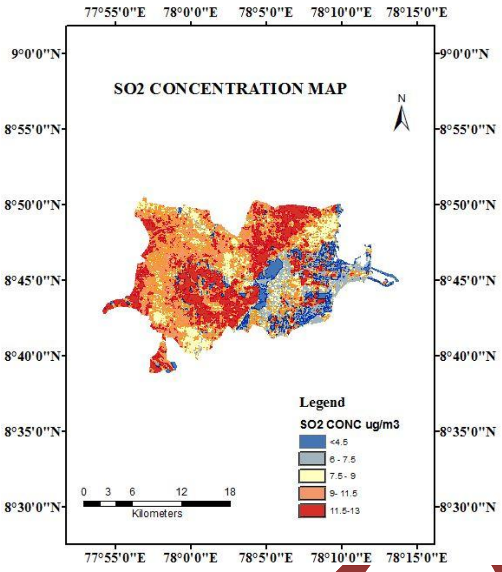

Figure 5 SO_2 concentration map of Thoothukudi

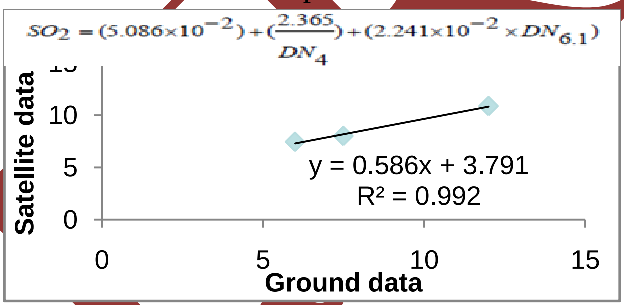

Figure 6 Correlation between satellite and ground data

CONCLUSION

From this study, we conclude that the mapping of the pollution parameters concentrations is possible using Landsat image. This mapping is not very accurate but acceptable approximation of the pollutant concentrations. A comparison of the estimated imagery with measuring stations will improve the results. The best suited algorithms were selected for the study area and also the concentration map of PM_{10} and SO_2 of Thoothukudi taluk. Satellite and ground station data were correlated and provide a good result of R^2 =0.992 and 0.995 for PM_{10} and SO_2 respectively. The results showed that 92% significant linear relationships between grounds based measurements of air pollution parameters from Landsat satellite data. Also, this study indicated that satellite imagery was capable for mapping of the pollution parameters concentrations.

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