DETERMINATION OF AEROSOL PARTICLES AND RISK ANALYSIS OF ASTHMA IN THE CITY OF COLOMBO

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ABSTRACT

Air Pollution is one of the major environmental problems which has increased due to urbanization in the world. It has no variation in the Sri Lankan context where it has created number of problem in its capital City of Colombo. It has created lots of problems in their capital as well as commercial cities. This paper is to determine PM10 concentration in Colombo Municipal Council area using algorithm model. PM10 has been extracted from the Landsat images using algorithm model which is considered as one of the simplest algorithm models. In this model, the tasks are statically or semi-statically mapped onto processes and each task performs similar operations on different data sets.

PM10 measurements locations have been demarcated by using GPS at random, then PM10 value were extracted from these locations. A maximum concentration of PM10 ranging 86.88 µg/m3 – 106.66 µg/m3 has been covered 26.88% of the total area of the city which shows high risk for the health of city dwellers. According to the Clinic data asthma patients have been increased from 51% to 61.81%, within the city limit during the period of 2005 to 2007.

Results of the study revealed that the highest concentration level of PM10 can be observed in the central part of the city. This is due to high traffic flow towards to the city center from the periphery. And also number of asthma patients in middle part of the city have been increased from 33 to 122 in year 2005 to 2007, because of these areas were identified as highly vulnerable for air pollution.

Furthermore, the results demonstrate that satellite images can be useful tool measurement of air quality in urban area. And also predicted that PM10 level very high within city limit. Final results have exposed that there is a strong relationship between the people who have lived in vulnerable areas have suffered from Asthma and level of PM10 as well as other air pollutants.

Introduction

Urban air pollution is particularly one of the serious environmental problems which has occurred in developed and developing countries. As a result of industrial revolution it has expanded into more composite, threat to the eco systems as well as it directly effects to increase health problems. In general, the concentration of ambient pollutants is high enough to cause increased mortality, disease occurrences, deficits in pulmonary function, cardiovascular and neurobehavioral effects. Many of these invisible pollutants penetrate to air by human activities, in most of the mega cities of the world, mainly, the people who are in industrial countries add higher amount of pollutants. Although air pollution traditionally has been related to industrial emissions, motor vehicles are considered as a major source of pollution in urban areas.

In Sri Lanka Colombo with a population of around 555,152 million, and a daily floating population of 400,000, making it a city of over one million population (Department of Census and Statistics, 2011) more than one million vehicles enter the city of Colombo through the eight entrances, and the number of vehicles leaving the city of Colombo is 173, 611 per day. 80% of thermal power generation plants, 70% of highly polluting industries, 30% of population, highest number of motor cycles and three wheelers enter the city daily. Diesel vehicles released 89 % of PM10 emissions (Chandrasiri.2011). People have faced health related issues such as asthma & relevant diseases and some areas have become vulnerable. Due to high concentration of Particular Materials (PM_{10}) in Colombo, Asthma, cough and bronchitis have been increased from 30% to 35%. 90% of land area is covered by the buildings which have directly caused high air pollution levels in the city of Colombo and suburbs.

Urban air pollution is increasing in the city and it has directly influenced the people and changed their life style. The surface temperature is higher than in the past, which has changed the spatial pattern of pollution causing vulnerability of the city. Those areas have been converted to environmental pollution sites in the city due to that the people who are living in the areas, are suffering from many diseases such as dengue and other respiratory illnesses.

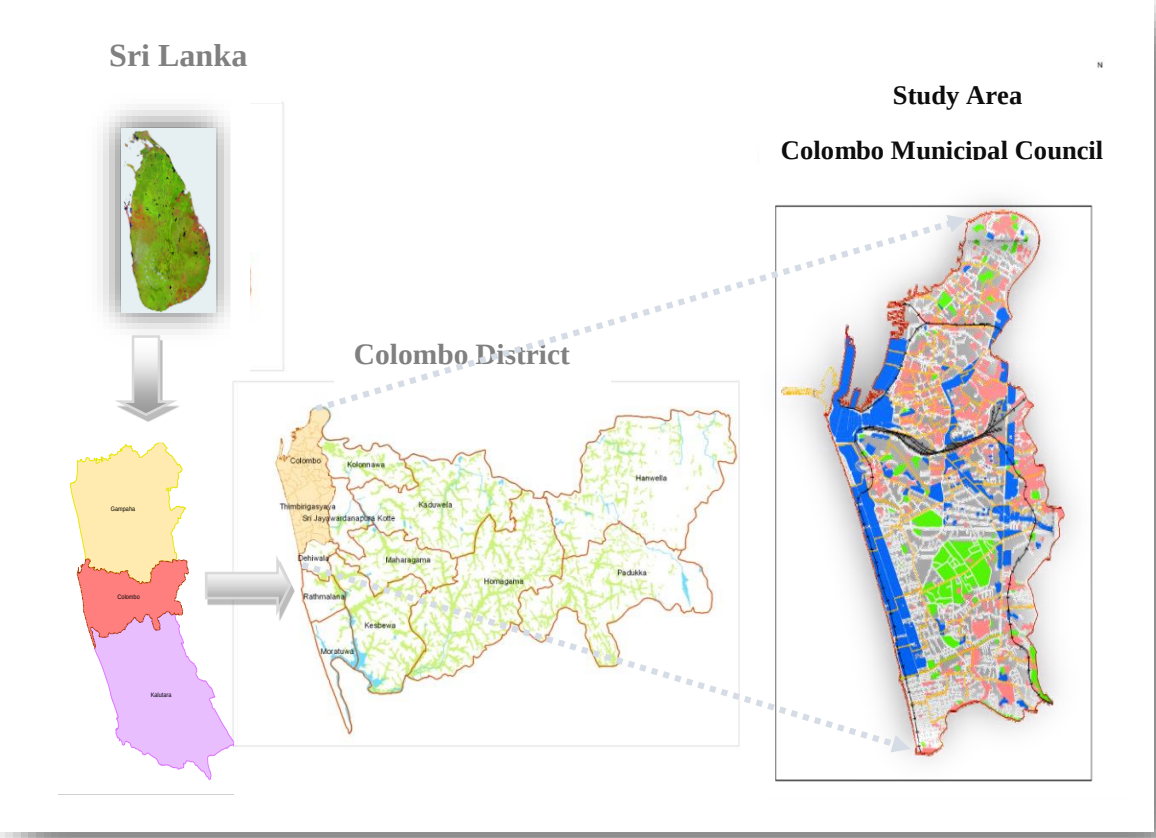
Air quality monitoring has been predicted using a dispersion model. It can display using high resolution satellite images and also it is strong enough to identify the relationship between air pollution & diseases. Having considered the critical issues, this study attempts to justify the importance of analysing air pollution and vulnerable areas for the purpose of planning, to demarcate the high risk areas for residences and other activities.

In this study, Geo statistical method is applied to show the air pollution distribution pattern. Algorithm model is applied to estimate PM10 using Land sat 7 TM image and calibrate with ground data (GPS) PM10 values can be acquired by running Python programming language. This study focused on the distribution pattern of air pollution, to identify vulnerable areas in relation to air pollution and how it effects health of people, using GIS Analysis and remote sensing techniques.

2. STUDY AREA

The study area is located in the western part of the Colombo district. The northern part of the city is bordered by the Kelani river; western boundary of the city is the coast line, eastern and southern parts of the city are covered with three Divisional Secretariat Divisions (DSD) such as Kolonnawa, Sri Jayawardenapura and Dehiwela. It consists of 47 wards; total land extent is 37.3 Sq km, now it has been increased 41.35 Sq km due to expansion of harbour. Land use pattern mainly consist of mixed residential, commercial, administration, industrial and recreational activities.

Figure 1: Location of Study Area



Source: Prepared by the author based on UDA Data, 2012

Hundred years ago city population was only 35,000; in 1871 it was increased to 98,847 and 40 people per hectare. According to the census in 2001, daily floating population is 4 million of the total population. Gross density of 230 persons per sq. km in 1981 which has increased to 2,605 persons per sq. km in 2001, total population has increased up to 642,000 million and now it has declined 555,152 million (figure 3.2). Highest population can be seen in northern part of the city such as Newbazaar, Kuppiyawatte, Grandpass, Maligawatte west, Bluemendhal, Borella and

Maradana. Several population groups who have lived in those areas are more vulnerable to effects of indoor and outdoor air pollutants specially children and elderly people have faced health problems.

3. OBJECTIVES

The main objective of this research was to apply GIS & Remote Sensing technique to discover air pollution pattern, vulnerable area as well as it was applied algorithm model to get overall picture of PM10 level of the city finally Geo spatial and statistics analysis has been carried out to identify the relationship between air pollution and Asthma diseases.

Objectives

- To examine the distribution pattern of Air pollution and analyse

  its relation with the health issues in the city of Colombo

Specific Objectives

- To identify the vulnerable areas in relation to air pollution
- Determination of Aerosol particles (PM10) in the urban environment & analysis risk of Asthma.

4. METHODOLOGY

Methodology mainly consisted of data collection, data processing and data analysis. Numbers of methods were used to process the collected data or information. The study used some Following methodology is adopted in this study.

4.1 Methods of Data Collection

The study is based mainly on secondary data which can be divided as air quality data, satellite data, socio economic and health data. Data were obtained from different government institutions namely National Building Research Organization (NBRO), Central Environmental Authority (CEA), Department of Census & Statistics (DCS), Building Department (BD), Meteorology Department (MD) Urban Development Authority (UDA), General Hospital (GH), Lady Ridgeway Hospital (LRH) and some web sites. Land sat image data(ETM+) have been downloaded from the web site to extract the NDVI (Normalize Difference Vegetation Index) using Land sat (ETM+) /band 6 was used to estimate the surface temperature. Land sat (ETM) band1; band 2 and band 3 were used to derive PM10 in the city of Colombo.

The socio & economic data related to the air quality such as density of population, traffic flow, building floor area density, land use pattern and number of Asthma patients (Clinic data) were collected from the relevant institutions.

4.2 Data Processing

4.2.1 Software used for Data Processing

The collected data were in different types and in different formats. In order to transform the data into the form enabling the analysis, defined in terms of spatial features and related attributes, the following soft ware's were applied. ArcMap 9.2, ERDAS Imagine 9.2 & Python Programming Language

Traffic data and air quality data (NO_2, SO_2) also were analyzed using the Geo Statistic Analysis ,method which is Grid Regression so that it would develop positive relationship where the results could be explained by using ANOVA table.Python programming language has been used to run the algorithm model for image processing, to create PM10 maps over the study area.

4.2.2 Satellite Data Processing

Satellite dataset of Land Sat 7 ETM+ in the city of Colombo on 07th February, 2006 (path/row 142/55) have been used to extract the vegetation cover (NDVI) and surface temperature in the study area from the web site (www.GLFC.GOV.org). The images were geometrically rectified to a common universal system and resample to get spatial resolution using the nearest neighbour algorithm.

4.3 DATA ANALYSIS

Procedure of Algorithm Model for determination of PM10

Following equation was used to determine the PM10 in the study area.

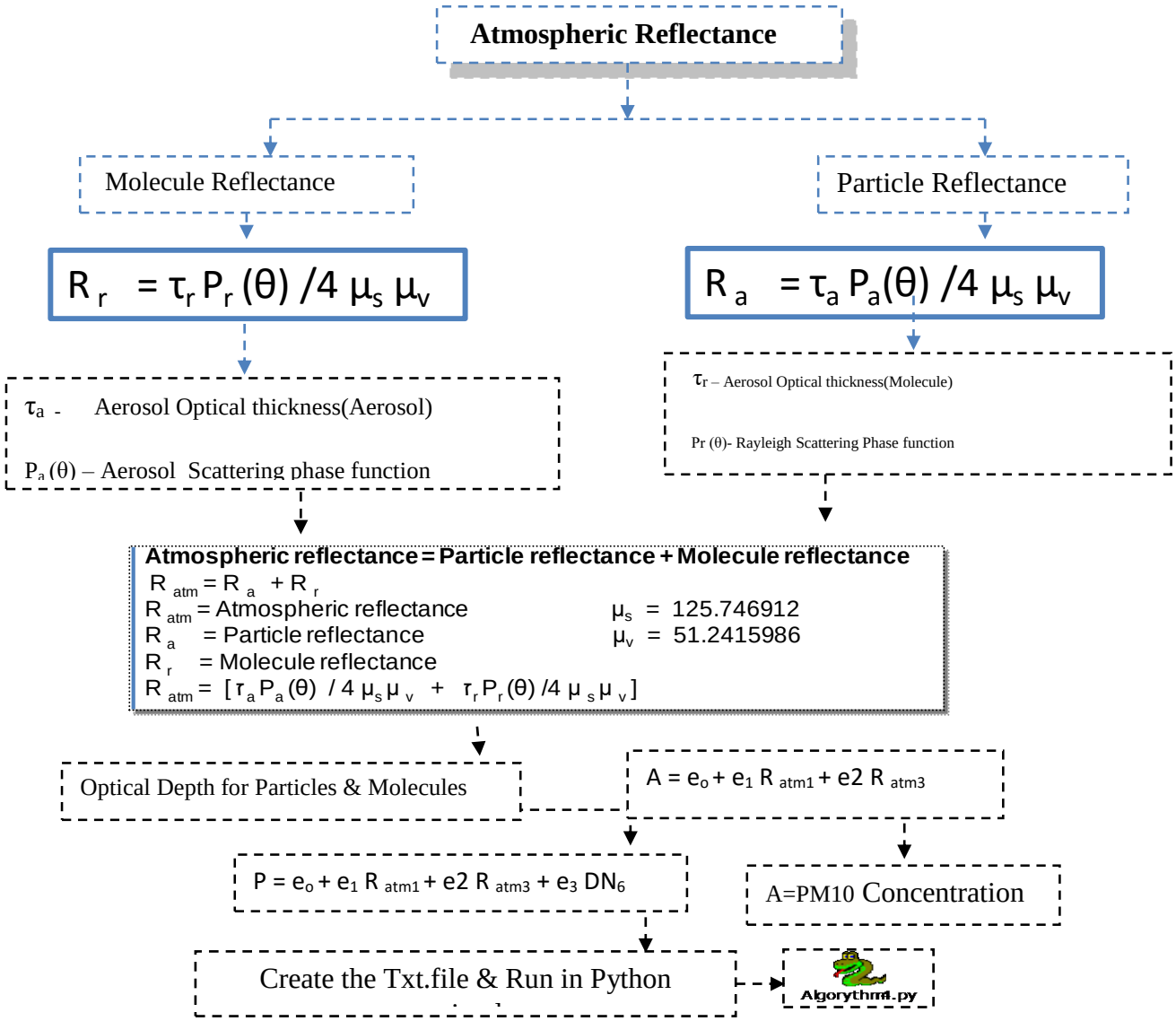
Atmospheric reflectance = Molecule Reflectance + Particle Reflectance

$$R_r = \tau_r P_r(\theta) / 4 \mu_s \mu_v \qquad R_a = \tau_a P_a(\theta) / 4 \mu_s \mu_v$$

The above equation can be used to create text file, which can be used to process the PM10 image by using Python programming language. Every formula and text was defined one by one; otherwise it was not able to process the relevant images. Then the process image has to do the atmospheric correction by using one of the formula in Python programming language.

The digital value for location of PM10 has been determined for Band1 and Band3 for the calculation of empirical value and then converted into radiance and reflectance values using the above method. Those values are applied to the algorithm model to process the images; these steps are included in the Python.

Diagram 1: Process for Determination of PM10



Source: Prepared by the author - reference Air quality Mapping using based on Landsat TM Band ratio technique Lim HS, Matjafri MZ, Abdullah K, Mohd N and Saleh , School of Physics, Malaysia, 2007.

Note: Diagram 3.3 is described in following section. It was summarized according to this study.

This model is considered as one of the simplest algorithm models. In this model, the tasks are statically or semi-statically mapped onto processes and each task performs similar operations on different data.

Particularly the following Algorithm has been developed to achieve the PM10 determination over the study area. To run the algorithm visible bands reflectance and Thermal infrared band signals have been considered as independent variables. Basically these equations applied to find out atmospheric reflectance which can be calculated due to molecule and particle reflectance (diagram 1). Above equations are used to obtain the solutions.

In addition to these equations, following values were calculated using the equation. Calculation of Atmospheric optical thickness for particles and molecule, and the scattering phase function are very important for the atmospheric correction. This is because the variations of atmosphere aerosol properties are not in fixed wavelength. There is empirical relationship between the scattering phase function and atmosphere optical thickness. In this study, some algorithm is applied to simplify the atmospheric correction. Even though some algorithm created to obtain results there is not enough experimental data for the observation of relationship of these functions. Due to that this study has been able to measure the value by using Python software, which has the ability to run the algorithm from OSGeo(Open Source Geospatial Foundation)gdal. Math library. All following functions should have defined in Python programming language as a txt.file.

According to the above algorithm all image processing has been carried out using Python programming language. The digital numbers are obtained from each band in reference target; 07th February 2006 image has been used as reference images. This value was fixed as a coefficient value. Landsat Band 1 and 3 are used to get DN values in reference target. Then all DN values had to convert into radiance and reflectance value for each band using following method (Lim, 2003).

4.3.1 Analysis of health issues

Kriging is one of the interpolation methods which can be used to identify the spatial pattern of traffic flow as well as it is closely related with PM10 concentration level in the study area. Finally, Number of Asthma patients were collected from Colombo General hospital & Lady Ridgeway children hospital. This data were used to show the distribution pattern of Asthma patients of the city. Socio & economic factors are linked with air pollution. Population density, increased traffic flow, large number of shanties is covered by the city of Colombo.

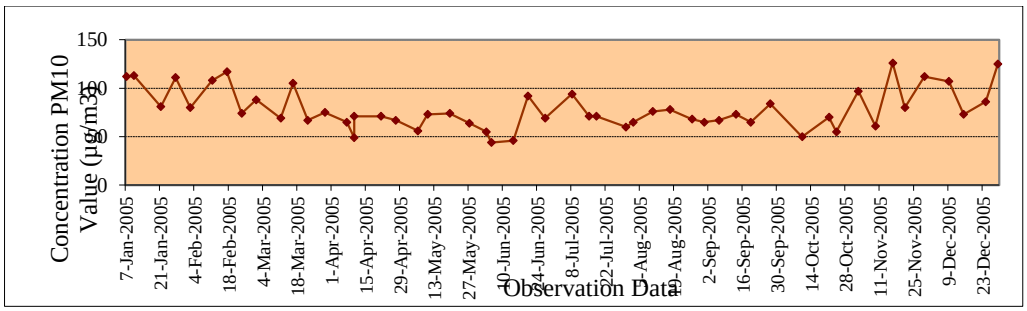
According to the above analysis it has been proved that polluted air is not good for health of people. Clinical data have been used to identify the number of Asthma patients. Health statistics data show that the people who have been in that area suffered from respiratory system diseases in relation to air pollution. This can be displayed using geo spatial analysis method. Zonal Statistics method has been applied to display the Asthma patients within the zone. Buffer operation was carried out to find the relationship with number of schools and traffic flow. When these layers are overlay with PM10 map it clearly showed that the numbers of Asthma patients have lived in vulnerable areas of the city, as well as they have suffered from many diseases in relation to the air quality.

5. RESULTS OF THE ANALYSIS

5.1 PM10 in the city of Colombo

The values obtained from one observation point which is situated near the Fort Railway Station, PM10 126 (mg/m3) is the highest value of the city, in 2005. Colombo city is becoming more vulnerable to particulate matter and other pollutants.

Figure 5.1: Distribution Pattern of PM10 in Fort Monitoring Station, Colombo, 2005

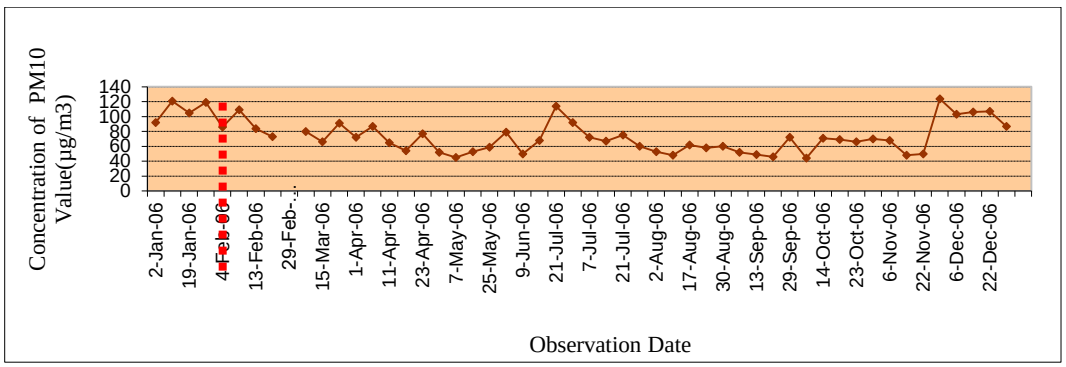


Source: Prepared by the author using the data from the Central Environmental Authority, 2005

Figure 5.1 indicated that the PM10 in Fort station ranged from 80 mg/m^3 to 124 mg/m3 due to Northeast monsoon period as well as other social and economic factors.

Figure 5.2 shows that the PM10 value in 2006, Fort station has exceeded during Southwest monsoon period when compared to 2005. It may have occurred due to wind direction of the monsoon period and it has fluctuated from place to place. Red line of the graph is indicating the date of land sat image, which was used to determination of PM10.

Figure 5.2: Distribution Pattern of PM10 in Fort Monitoring Station, Colombo, 2006



Source: Prepared by the author using the data from the Central Environmental Authority (2006)

5.2 Spatial distribution pattern of the PM10 according to the Land sat image.

As a result of the algorithm model following maps were generated to show the spatial distribution pattern of the PM10. Finally followings maps were classified in order to show the output.

Figure 5.4 is indicated that the PM10 concentration level is very high in the area of Bloemendhal, New Bazaar, Kochchikade and especially the central part of the city due to commercial activities, density of buildings, lack of green coverage, increased usage of fuel wood for domestic purposes and vehicle emission. It clearly revealed that the highest concentration of PM10 in the central part of the city as well as some small plots can be seen in edge of the city limit such as Pamankada, Wellawatte South and some patches are displayed in Kirulapana because those areas are transforming into build up areas. The traffic flow is also higher than the past and green coverage has declined due to human activities.

Table 5.1 shows that the results have been obtained by the image classification. A maximum concentration of PM10 ranging from 106.66 µg/m3 -137.6210 µg/m3, it covers 269.31 hectares of total land. Those areas can be identified as a high risk area. It shows the quantities of land cover area due to categories of PM10 value in spatially. A maximum concentration of PM10 ranging 86.88 µg/m3 – 106.66 µg/m3 has covered 26.88% of the total area. It is a risk for the health of city dwellers. According to the results PM10 range of 101 – 150 unhealthy specially for sensitive people.

Figure 5.4: Determination of PM10 concentration (µg/m3) in the city of Colombo

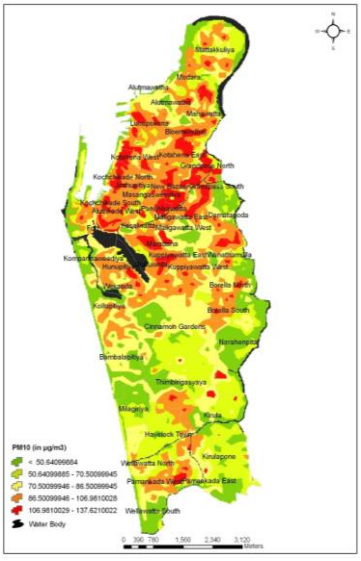
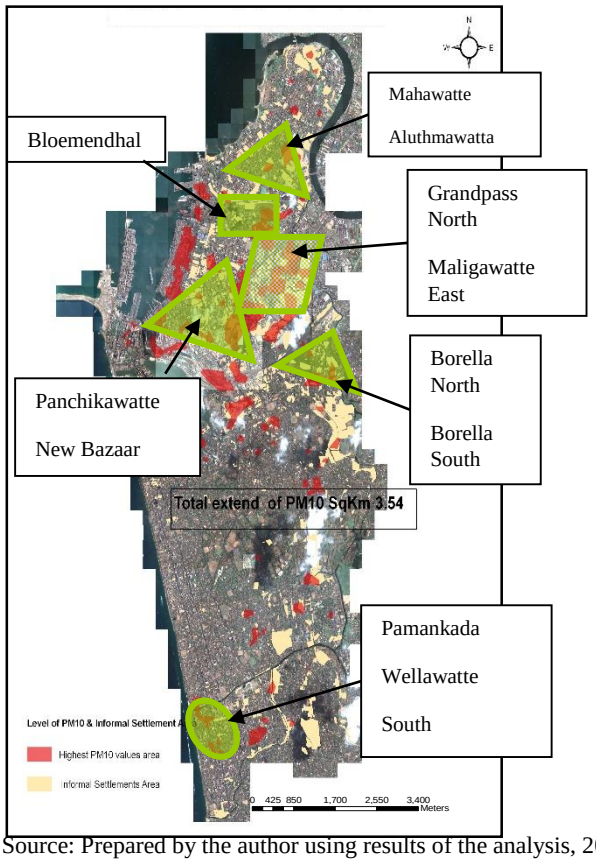


Table 5.1: Total extend of PM10 covered area

ID	PM10 Categories µg/m3	Covered area in hectare	%	Covered area in Sq(km)
1	27.98399 - 52.06114	819.21	21.69	8.19
2	52.06114 - 70.11900	725.12	19.20	7.25
3	70.11900 - 86.88701	948.34	25.11	9.48
4	86.88701 - 106.66467	1015.12	26.88	10.15
5	106.66467 - 137.62100	269.31	**7.13**	**2.69**
	Total	3777.1	100	37.7600

Source: Prepared by the author using research data, 2006

5.5 Spatial distribution pattern of the highest patches of PM10 value in relation to informal settlement in the city of Colombo.



Source: Prepared by the author using results of the analysis, 2006

Having considered the results of the image classification, it clearly revealed that the highest PM10 level is shown within the green triangle which has been filled up with informal settlements and also these areas are highly vulnerable to air pollution. Population density is very high when compared with other wards, this leads to increase number of diseases.

Extraction of the PM10 according to the GPS Location

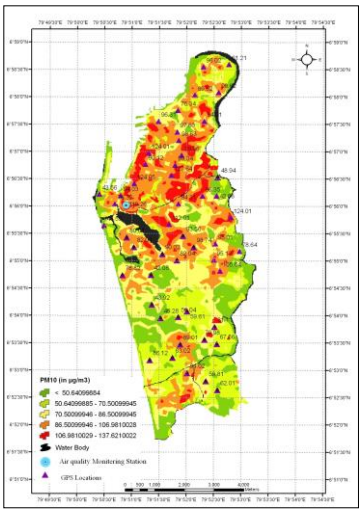
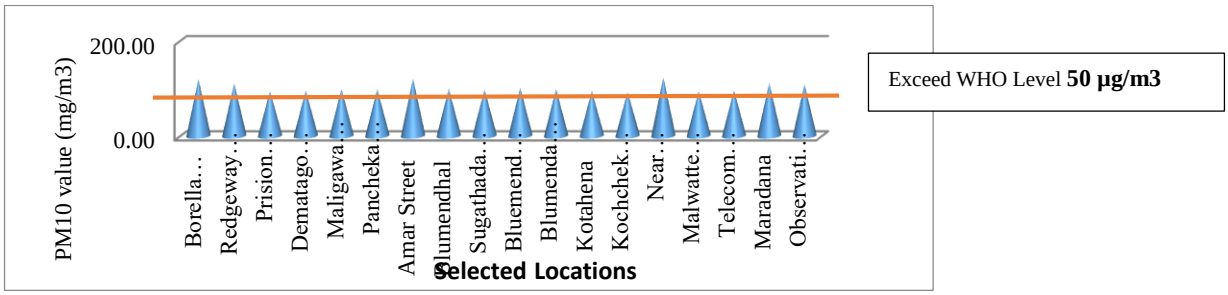


Figure 5.6 : PM10 value mapping - extracted from GPS locations

Figure 5.6 indicated that the value of PM10 which was extracted from the Land sat image, as GPS Locations. A minimum concentration value of PM10 ranged from 21 µg/m3 – 48 µg/m3, has been gathered within open spaces, playgrounds and low density of build up areas. Even though some of lands consisted of green coverage areas they are to be converted to risk areas. The minimum concentration of PM10 in south part of the city such as Thibirigasyaya, Narahenpita, Kirulapana and Cinnamon gardens.

Model Validation

After generating the algorithm model results should be validated to get accuracy maps and information.



Source: Prepared by the author using research data, 2006

Figure 5.7 indicated that the PM10 value extracted from the 18 GPS locations. It is clearly displayed that highest amount of value at the Borella junction, Lady Ridgeway Hospital, near the harbour, Bloemendhal and Maradana. It has exceeded the WHO level.

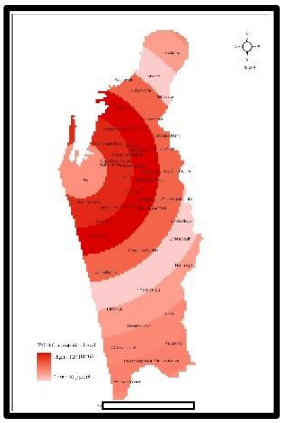
Table 2: PM10 concentration from satellite imagery data and PM10 ground measurement location of the study area.

Ground Stations	PM10 concentration estimated from imagery(µg/m3)	Weekly average PM10 concentration measured at ground station
Fort Railway Station	108.210	109.00

Source: Prepared by the author using research data, 2006

Table 2 shows the maximum concentration of PM10 was estimated based on Land sat imagery, 108.210 µg/m3 as well as it has not shown a big difference with measured at ground stations.

Figure 5.8: Distribution of PM10 value (µg/m3) according to the Zonal Statistics Method in the city of Colombo



This map shows the highest value changes between the core and periphery area. PM10 value of zone 3 is very high due to high density of population, horizontal and vertical build up areas, number of shanties, less green coverage, harbour and the railway station.

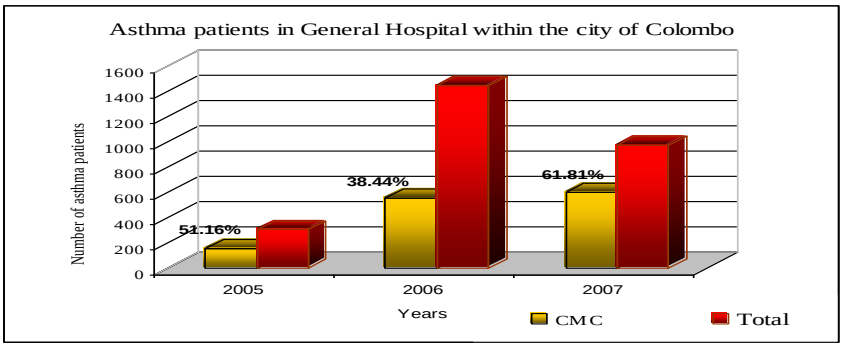
Source: Prepared by the author using research data, 2006

6 Relationship with air pollution & Asthma patients in the city dwellers

After determination of PM10 value it has been displayed in figure 5.7 that the highest level of PM10 in the city. When it overlays with underserved settlement sites it clearly shows the relationship between air pollution and Asthma patients. According to statistical data which were reported in the General hospital, it has been verified that most of them have suffered from Asthma diseases. Several population groups have suffered from a variety of health problems that the numbers of Asthma patients have increased than the past decades.

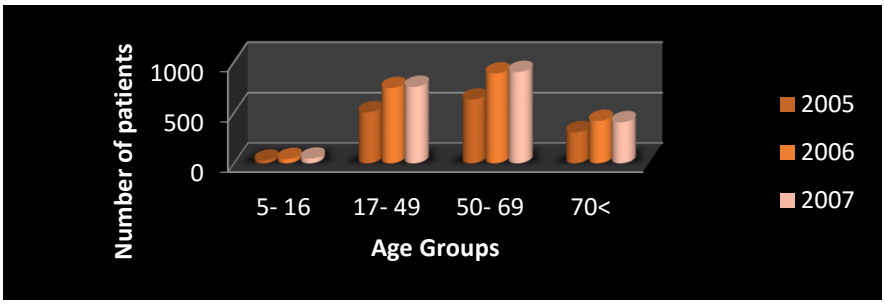
6.1 Percentage of Asthma patients in the city of Colombo

The number of Asthma patients has increased during the period of 2005 to 2007. Most of them are reported in Maradana, Grandpass, Panchikawatte, Bloemendhal and Borella. Due to green coverage fewer numbers can be seen in Narahenpita and Cinnamon gardens.



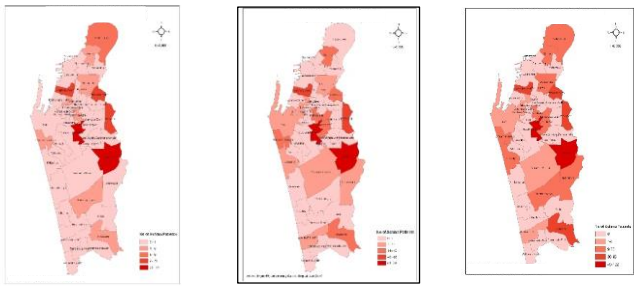
Source: Prepared by author using General Hospital clinic data

6.2 Number of Asthma patients in the city of Colombo by age groups 2005-2007



6.3 Distribution pattern of the Asthma patients

Number of Asthma patients in the city of Colombo 2005 - 2007

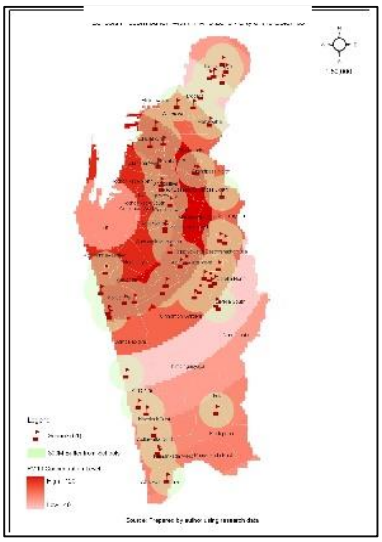


Source: Prepared by the author using research data

6.4 Relationship between air pollution & Asthma patients (Children)

In addition, the school children have faced many problems in relation to air pollution. Most of them have suffered from respiratory system diseases, because of many schools were located in the city limits and also along the main roads.

As analysis indicates, highest amount of Asthma patients are recorded in the middle part of the city, these areas which have been identified as highly vulnerable for air pollution as well as PM10 is very high because these areas comprise number of shanties, lack of green coverage, traffic flow and commercial activities.



Conclusion

The study has demonstrated the air pollution pattern, vulnerable areas and concentration level of PM10 which were extracted from the Land sat images using GIS and Remote Sensing techniques. It provides high resolution satellite images. These high resolution images can be easily applied to obtain high accuracy data from image processing by using other software. It has been concluded from the study that the air quality data and Land sat images were successfully used to identify spatial distribution pattern of air pollution, vulnerable areas and distribution pattern of

the PM10 and health issues of city dwellers. Analysis revealed that number of asthma patients have increased due to air pollution.

The findings of this study can be summarized as follows:

- During the Southwest monsoon season the pollution concentration is very high in the central part of the city. During the northeast monsoon season the pollution spread from Sapugaskanda and Kelanitissa power station areas in the Northern part of the city.
- Along the Colombo - Negombo, Kandy, Galle, low level and high level roads pollution is relatively higher than the other areas during the Northeast monsoon season.
- An analysis in this study showed that the highest concentration level of air pollution is found in Colombo Fort, Kotahena, Panchikawatte, Borella and Maradana. And also highest value of PM10 can be seen in the central part of the city as well as Wellawatte and Maradana. This is due to traffic flow, harbour, railway station and other socio economics factors.
- Colombo Fort, Maradana and Borella areas have been identified as the most vulnerable areas in terms of concentration of NO_2 as well as SO_2
- Level of concentration of PM10 in the city area has exceeded the recommended levels by the World Health Organization.

In addition, results of the analysis are suggested as the following factors can be applied to minimize the pollution level, control the increase of Asthma patients in the city.

- To encourage urban agro forestry in the city to minimize pollution
- Minimize height of buildings by enforcing low and building regulation
- According to the UDA building regulations should be introduced air pockets between two nodal points of the western part of the city to allow the sea breeze.
- Vehicle parking sites to be located outside of the city limits.
- Public transport system should be developed in the city
- Legal action should be taken to control private vehicles to control traffic congestion. This will help to reduce vehicle emissions.

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