Identification of Air Pollution Potential Areas and its Temporal and Spatial patterns of the City of Colombo – Applying GIS and RS

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Abstract:

Air pollution is a universal problem. All nations are answerable for this problem in different levels. Human activities, which are not properly prearranged, whether primary secondary or tertiary degraded the quality of air in any area. This study attempted to identify the spatial and temporal patterns of the air quality of the city of Colombo and influences of the socio-economic factors, using secondary data available in different government organizations. It has identified that there is a spatial concentration and temporal variations of the No_2 in the city of Colombo. Among the socio-economic factors, traffic density has been identified as the most contributing factor for the degraded the air quality.

Key words: Spatial interpolation, Grid transformation, Air quality

1. Introduction

The effects of air pollution are universal. They are common phenomena in both developed and developing countries. They are continuously experienced all over the world not only in congested urban areas but also in remote rural areas. Evidences of air pollution are even experienced as far as the coldest continent, the Antarctic Ocean.

Effects of air pollution aggravated recently, because of four sectors of development: increasing traffic, growing cities, rapid economic development, and industrialization, which are directly related with Urbanization. The Industrial Revolution in Europe in the 19th century saw the beginning of air pollution, as we know it today, which has gradually become a global problem

The world has experienced unprecedented urban growth in recent decades. In 2000, about 47 percent of the world's population lived in urban areas, roughly, 2.8 billion people. There are 411 cities over 1 million population. More developed nations are about 76 percent urban, while 40 percent of residents of less developed countries live in urban areas. However, urbanization is occurring rapidly in many less developed countries. It is expected that 60 percent of the world population will be urbanized by 2030, and that most urban growth will occur in less developed countries

Three million people die of air pollution in each year worldwide. 2.8 million of the 3 million die from indoor air pollution. 90% of the 3 million are deaths in developing nations. 70,000 die each year in the U.S. (Some estimates are as low as 50,000 or as high as 100,000). They die specifically from agitated asthma, bronchitis, emphysema and heart diseases (The U.S. Department of Air Quality Management). Deaths from air pollution are compared to deaths from second hand smoke and chemical weapons, in the U.S, more people die from air pollution than from vehicular accidents (http://www.free-definition.com/Air-pollution.html

2. Study Area

The study area is the City of Colombo, capital of Sri Lanka. The city of Colombo has been identified as a primate city by the urban Geographers based on the magnitude of the concentration of the population in the city compare to the city

system of the country. The city of Colombo (CMC) covers a total area of 37.3 sq Kilometers, which is about 5.7 per cent of the land area of Colombo district. The population of Colombo has expanded rapidly from 154,691 in 1901 to 647,100in 2001 and indicated the most populated city in the island with 17,200 persons per sq. kilometer in 2001. Colombo is the capital city and the commercial center of the country. High population concentration, large number of daily commuters, City center oriented traffic flows and traffic congestions, large number of slum and shanty population is very significant characteristic of the city, which is said to be negatively affected the air quality of the city. Several studies were carried out by government agencies to examine the air quality. The study carried out by the CEA (Central Environmental Authority) showed that NO_2 concentration of the Colombo Metropolitan area is way above the safety level (Chandrasiry, S, 2005). Another study carried out by Mathes et al. established very significant correlation between TSP (Total Suspended Particles) levels and traffic density in Colombo (Mathes et al. 1993).

3. Objectives of the study

The main objective of this study is to identify the spatial and temporal patterns of the air quality and the impact of the socio-economic factors for the spatial and temporal patterns of No_2. The specific objectives of this study are:

- Identify the spatial pattern of the No_2 (Nitrogen Dioxide) of the study area;
- Examine the Monsoon and sea breezes effectiveness for changing spatial pattern of the air quality;
- Examine the significance of the socio-economic factors for spatial pattern of the air quality.

4. Methodology

The methodology adopted in this study describe in three sub-topics below.

4.1 Data collection

This study was carried out using secondary data collected from different government agencies. The air quality data collected by the National Building Research Organization (NBRO) was the main data source for $No_{2.}$ The Significant number of air quality observation points (16) have been installed by the NBRO through out the city of Colombo and No_2 data were collected daily for 18 months (From. November.2001 to April 2003).

The socio-economic data were classified into two categories according to their contribution to the air quality, namely positive factors and negative factors. Population density, housing density, traffic density, underserved housing density and underserved population density were considered as positive factors and NDVI (Normalized Difference Vegetation Index) was considered as a negative factor.

The necessary ancillary data has been collected form different government agencies such as Department of Census and statistics, Urban Development Authority (UDA), Housing Authority (HAD) and Colombo Municipal Council (CMC). NDVI has been considered as a very good indicator of whole negative factors and NDVI extracted from Landsat 7 ETM+ data in year 2003.

4.2 Data Processing

Before proper analysis, full spectrum of data have been transformed to a same format to avoid the complications from different feature types in the analysis process, data has been transformed (Spatial and Attributes) into a 0.5 km grid using techniques available in GIS. Finally, cells represented spatial data and each cell has contained several attributes, which classified broadly into positive and negative factors.

The No_2 observation points which were in point features transformed to interpolated surface using Inverse Distance Weighted Method (IDW) and estimated the No_2 for the cells in 0.5 km grid. Population density was in municipal wards, which were in polygon features transformed into 0.5 km grid and estimated population density for the cells. In the same manner, each data layer has been transformed to 0.5 km grid.

4.3 Data Analysis

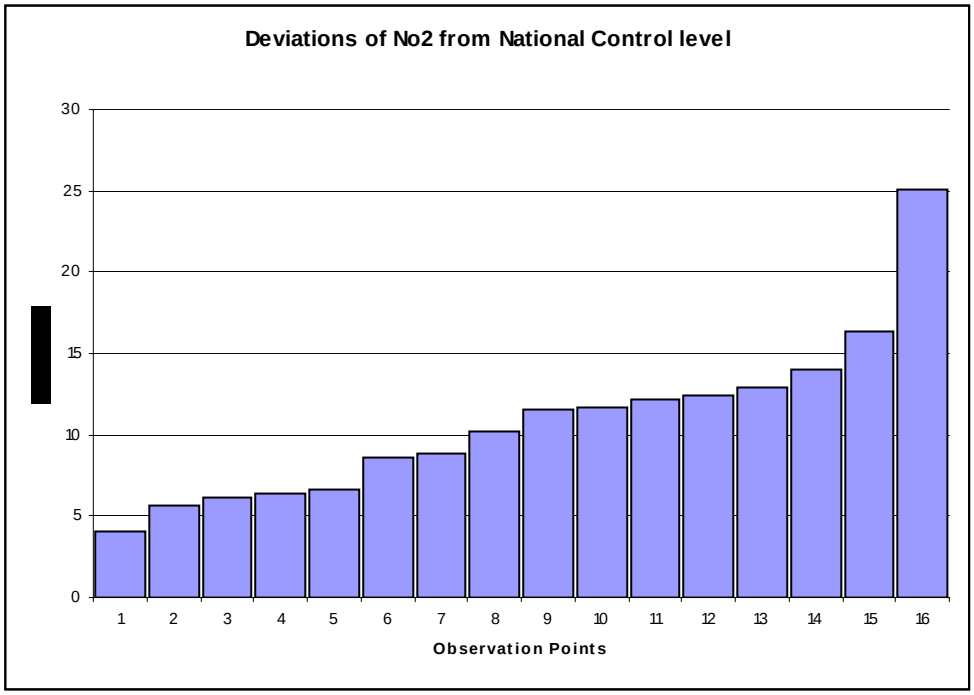
Finally statistical analyses have been done based on the cell (grid) values to study the relationships between air quality and attributes represented the socio-economic characteristics of the city (Diagram 01). Relationship analysis was carried out using Simple Correlation in two independent aspects. First, attempt was made to examine the relationships between No_2 and other socio-economic factors. Secondly same relationship pattern was studied by different rainy seasons in Sri Lanka.

5. Results and discussion

5.1 Air quality of the city of Colombo

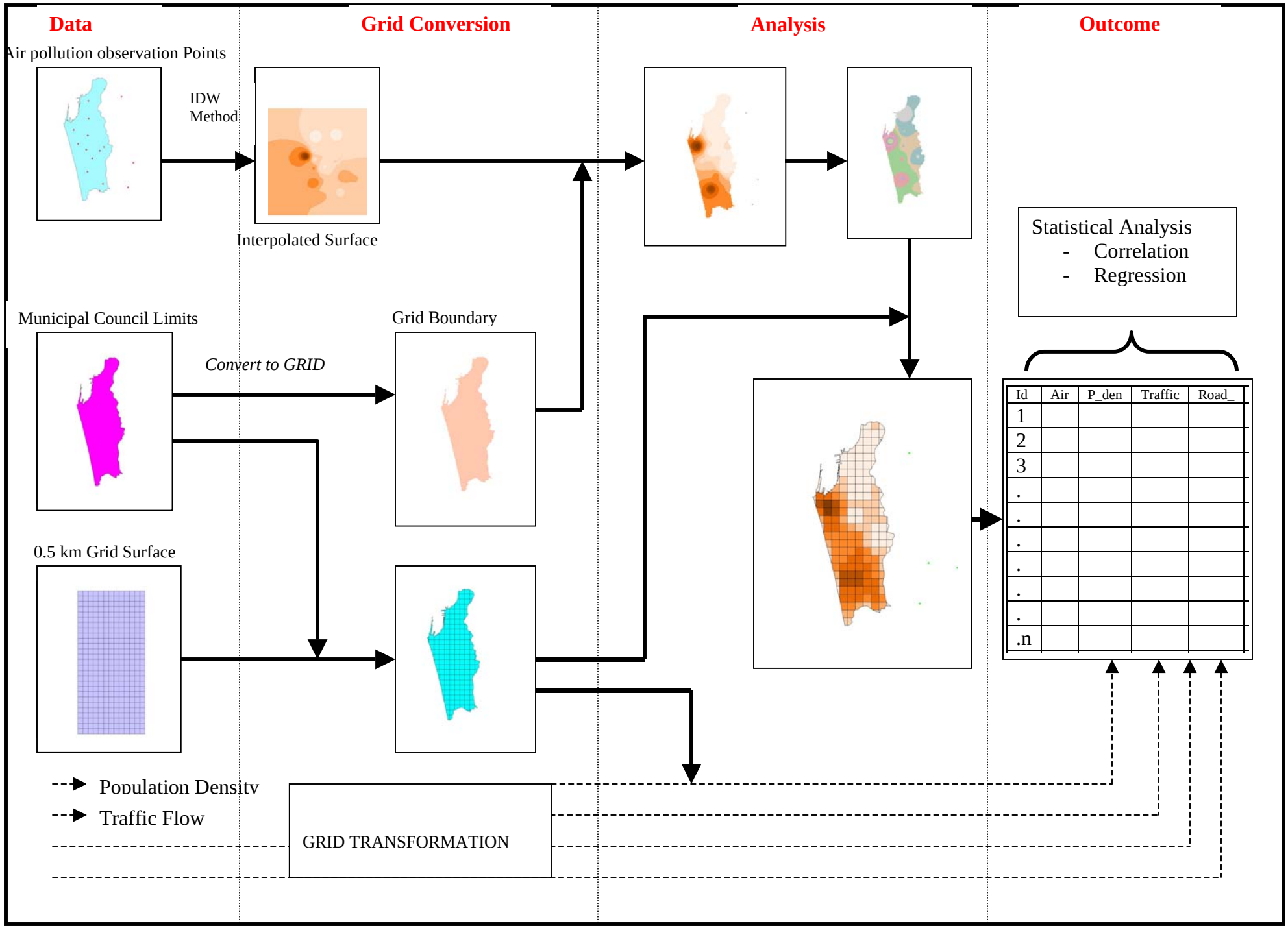
The average contamination of No_2 of the air of the city is 0.0108 ppm. (Based on the 16 sample points). This average value is well above of the national pollution control level of the country (National Control level of No_2 of the country is 0.001 ppm). All observation points indicated higher concentration of No_2 than that of the National pollution control level of No_2 Colombo Fort area is 25 times higher than the national control level of No_2 (Figure 01).

Figure 01: Deviations of No_2 of the city of Colombo from the average value



1 Elli House
2 Kelaniya
3 Borella_p
4 Jetawana
5 Borella_T
6 Maradana
7 Kotte
8. Kirulla_1
9 Central Environmental Authority
10. Dept. of Meteorology
11. Kirula_2
12. Gangarama
13. Battaramulla
14. Colombo Municipal Council
15. Thimbirigasyaya
16 Fort

Diagram No. 01: GIS Analysis



Though, there is a high concentration of $N_{o2,}$ seasonal variation of the N_{o2} can be seen (Figure 02).

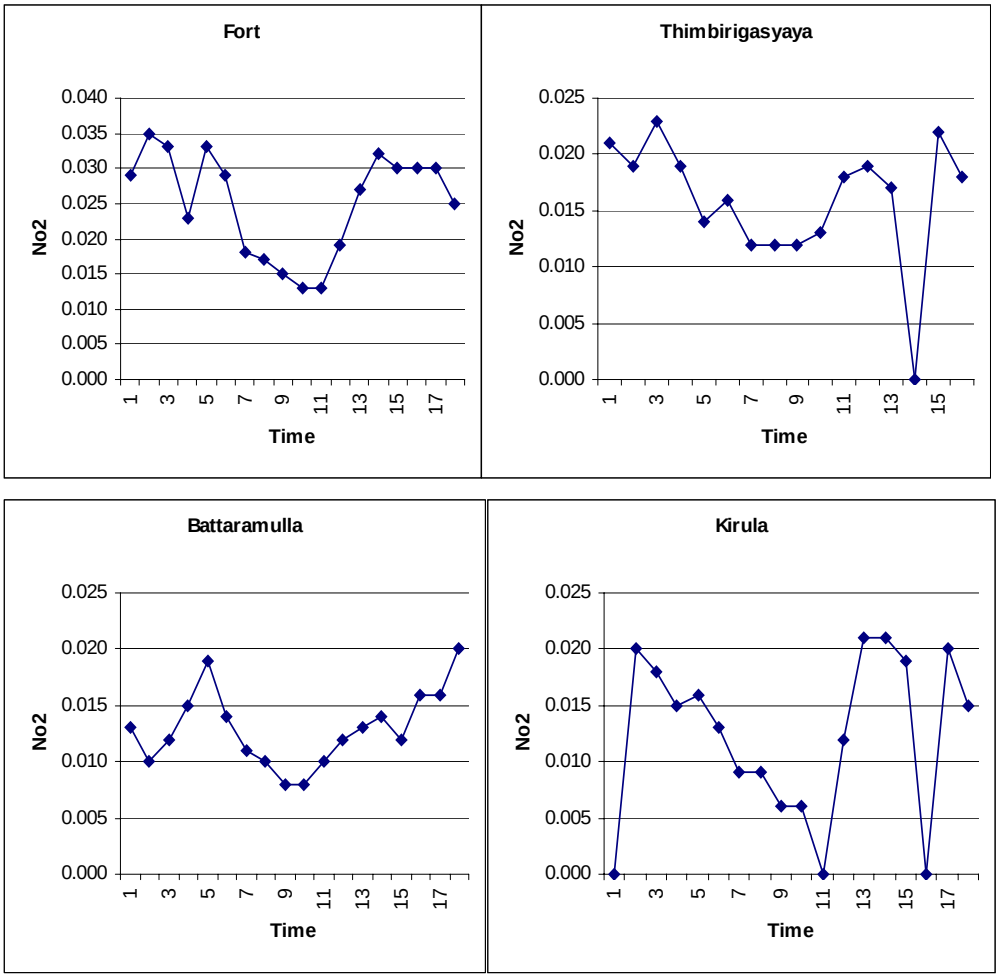


Figure 02: Seasonal Variation of the N_{O2} of some selected sample points of the city

Note: Period is from November 2001 to April 2003.

In general, beginning of the year and the end of the year, No_2 concentration of all four places is relatively high. However, middle part of the year, which is Northwest monsoon period, (May to August) concentration of No_2 decline drastically. It can be interpreted as

5.2 Spatial Variation of N_{o2} of the city of Colombo.

It can be observed through the figure No. 03, that high concentration of N_{o2} can be seen around three observation points, namely, Fort, Colombo Municipal Council Area and Thimbirigasyaya.

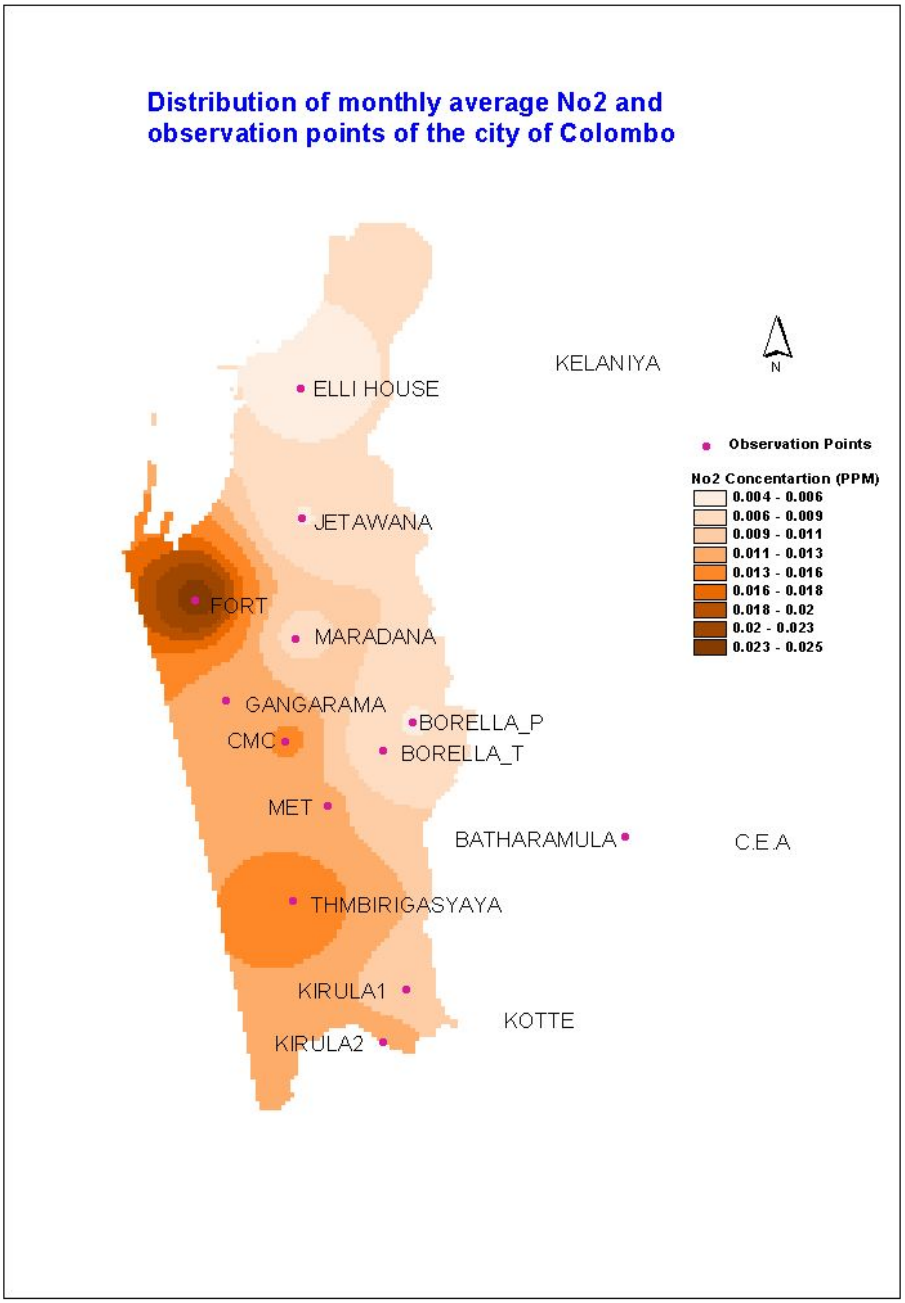


Figure 03: Distribution of No_2 and observation points of the city of Colombo

Almost western part of the city has been highly concentrated of No_2 as compared to the eastern part of the city. This may be due to the urban morphology (Spatial Structure of the city) of the city. Western part of the city is highly overcrowded especially with the sky scrappers. This morphological pattern of the city is preventing the sea wind circulation of western part of the city. On the other hand, building heights of the Eastern part of the city is not significant compare to the western. Location of the Kelani river mouth, which is the northern boundary of the city, allows the ocean winds to circulate freely in to the Eastern part of the city.

5.3 Seasonal variation of N_{o2} of the city

Four rainy seasons experience in Sri Lanka. Two Monsoon periods and two inter Monsoon periods. Four months from May to August, southwestern monsoon effect can be seen all over the country and from November to February, northeastern monsoon can be seen. In between these two monsoon periods, two inter monsoon periods exist. Winds direction of the Southwest monsoon period is from Southwest to northeast of the country and period of Northeast monsoon wind direction is from Northeast southwest. These rainfall patterns and periods are highly influenced for the human activities and the wind circulation of the city. The

N_{o2} concentration of the city has been changed from rainfall season to season based on the wind directions (Figure 04).

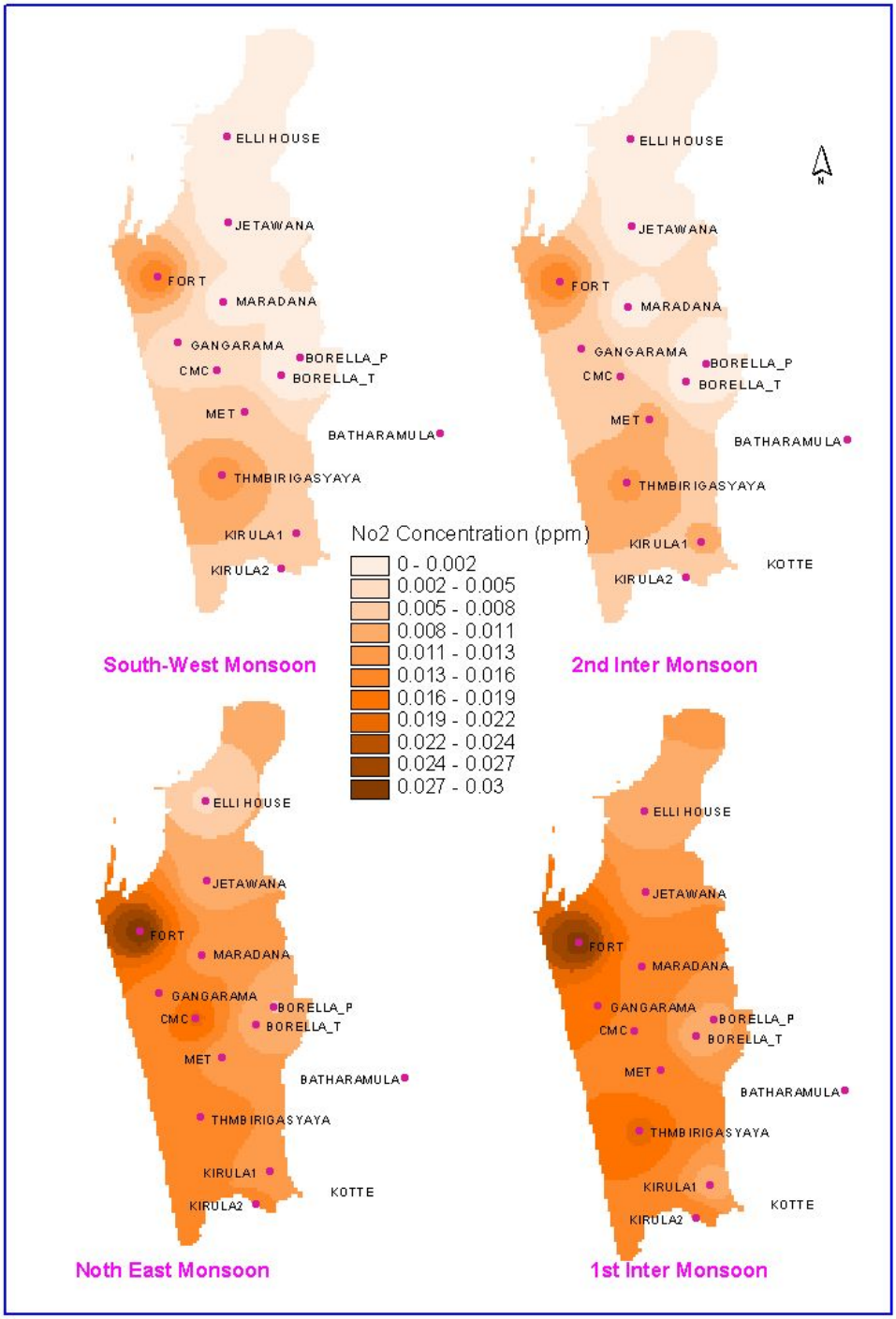


Figure 04: Seasonal Variation of concentration No_2 of the city of Colombo

Throughout the whole year, two No_2 concentration pockets can be seen, namely, Colombo Fort and Thimbirigasyaya except Northeast Monsoon period. In the Northeast Monsoon period, second concentration point; Thimbirigasyaya has been shifted to Colombo Municipal Council area.

Though, No_2 content of these two pockets are highly imagined in different rainy seasons, levels are changing form seasons to seasons depends on the wind directions.

Since Colombo city is directly facing to the wind of Southwest monsoon, level of No_2 content is relatively low compare to the other rainy seasons. No_2 concentration in Fort area is 0.0133 (ppm) in the Southwest Monsoon period. However No_2 contamination of the city is relatively low in Southwest Monsoon period when compare to the other rainy seasons.

Seasonal variation of No_2 in two concentration points in the city is given the table 01.

Table 01: Seasonal variation of No_2 in highly concentrated points in city of Colombo.

Center	No_2 concentration (ppm)			
	Southwest Monsoon period	Northeast Monsoon period	1st Inter Monsoon period	2nd Inter Monsoon period
Colombo Fort	0.0156	0.0299	0.0293	0.0160
Thimbirigasyaya	0.0133	0.0207 (CMC)	0.0205	0.0125

Both places are indicating the same pattern in four rainy seasons. Lowest concentration can be seen in Southwest Monsoon period and highest concentration can be seen in Northeast Monsoon period.

5.4 Influencing socio-economic factors for the air quality of the city

Air quality depends on several factors, broadly, can be classified into physical factors and man-made factors. In this section some of the selected man-made factors have been examined against to the air quality of the city. As mentioned earlier, socio-economic factors affecting to the air quality of any area can be divided into two categories, contributing factors and (air pollution sources) negative factors (snicks).

In order to examine the relationships among the air quality (N_{O2}), contributing factors and negative factors, data have been transformed to a 0.5km grid (Figure 05). There are 196 cells (Some cells are not rectangular since grid theme has been clipped with the city boundary). Each cell contains relevant information to the particular theme.

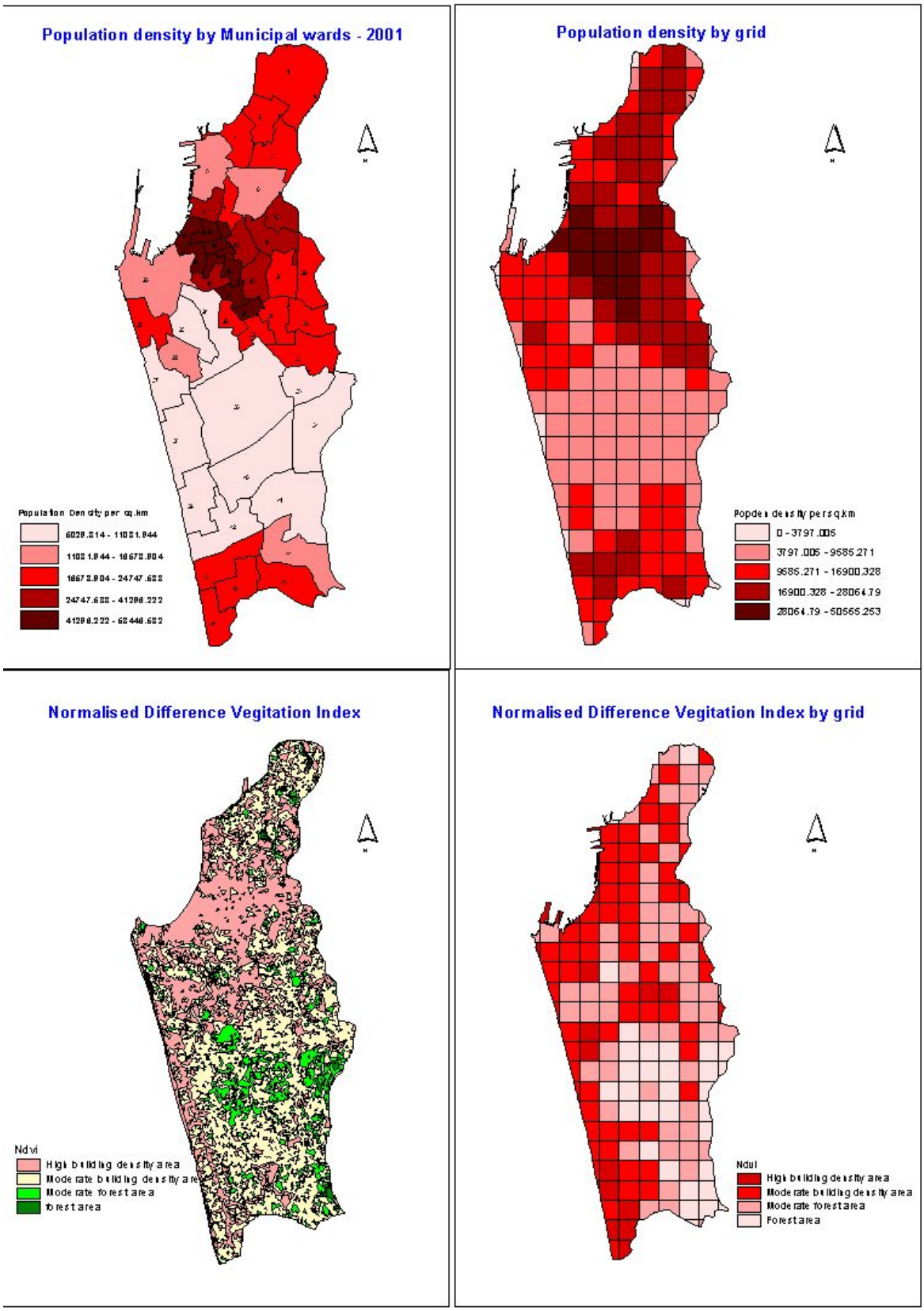


Figure 05: Grid Transformation of some of the selected variables

Correlation coefficients between No_2 and other socio-economic variables are given in table 02. There is no significant relationship between No_2 and any variable except traffic density. Therefore it can be concluded that traffic density is a prominent factor of the depletion of the air quality of the city of Colombo.

Table 02: Relationship between No_2 other socio-economic factors

Variables Rainfall Season	Population density (Underserved settlements)	Housing Density (Underserved settlements)	Population Density (Total population)	Housing density (Total Population)	Traffic density	NDVI
Nitrogen Dioxide	0.0550	0.0048	-0.2443	-0.2662	0.5361	0.0355

5.5 Monsoon and sea breezes effects for changing spatial pattern of the air quality

It can be examine through the correlation analysis, that there is a significant relationship between rainy seasons and traffic density (Table 030.

Table 03: Correlation coefficients between No_2 and other socio-economic factors by rainy seasons

Variable Rainfall Season	Population density (Underserved settlements)	Housing Density (Underserved settlements)	Population Density (Total population)	Housing density (Total Population)	Traffic density	NDVI
South West	-0.2088	-0.2720	-0.3541	-0.3129	0.3651	0.0607
North East	0.1211	0.0722	-0.2133	-0.2515	0.5631	0.0388
1st Inter Monsoon	0.2005	0.1718	-0.1441	-0.1704	0.5721	0.0057
2nd Inter Monsoon	-0.2000	-0.2679	-0.3795	-0.3675	0.3642	0.1019

Out of six variables, only traffic density shows a significant positive relationship in No_2 concentration for all four rainy seasons. Lowest correlation coefficient shows in South West Monsoon period while 1st Inter Monsoon showing highest correlation coefficient.

The relationship between traffic density and No_2 concentration is fluctuating from rainy season to season. During the south west monsoon period, though there is a building barrier in the western side of the city, highly humid sea breezes enters to the city, mixing up and flushes the toxic emission produced by the vehicles in the city area.

The southwestern monsoon period followed by the 2nd inter monsoon period. Still the relationship between vehicle density and No_2 concentration is relatively low, because, still the southwest monsoon effects are there. Still the wind direction is from the northwestern seaside to the countryside.

In the northeast monsoon period, winds enter to the country from Northeast side, which is the opposite of the location of the city of Colombo. Therefore, the effect of see breeze in this period will not be a significant factor to reduce the No_2 concentration or reduce the vehicle emission of the city.

In the 2nd inter monsoon period, still the relationship between No_2 and traffic density is relatively high. This is the transition period from Northeast Monsoon to South West. Monsoon. Therefore northeast monsoon effects can still be seen. Thus vehicle emission lingers in the city area.

6. Conclusions

The findings of this study can be summarized as follows:

1. Colombo fort and Thimbirigasyaya areas have been identified as the most vulnerable areas in terms of concentration of No_2.

2. Level of concentration of No_2 in the city area is well above than that of the National Pollution control level.

3. There is a Locational advantage of the city of Colombo to lessen the degraded the quality of air

4. Level of the concentration of the No_2 depends on the factors such as rainfall seasons. The Northwest Monsoon period is the most vulnerable period of the city in terms of concentration of No_2

5. Traffic density is the most influencing socio-economic factor for the depleting of the air quality of the city of Colombo.

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