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Research paper

Seasonal Particulate Matter (PM_{10}) Concentration in Klang Valley, Malaysia

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Abstract

This paper presents a study on Seasonal Particulate Matter (PM_{10}) concentration at selected region in Klang Valley for two years database (2002-2004). The study aimed to analyse on how the distribution of PM_{10} concentration has changed over monsoonal. Kriging method was employed for interpolating PM_{10} concentration over limited dataset from seven monitoring stations in Klang Valley. Results found that higher PM_{10} concentration was recorded during Southwest monsoon (65.92µg/m^{-3}) followed by both inter-monsoon (62.17µg/m^{-3}) and (59.13µg/m^{-3}) respectively. Meanwhile, the lowest concentration (36.67µg/m^{-3}) was recorded during northeast monsoon. From the distribution, Klang station has recorded the highest PM_{10} concentration throughout the season, followed by Kuala Selangor (59.33µg/m^{-3}). Hulu Langat and Gombak stations have shown the lowest concentration of $PM_{10,}$ (40.92µg/m^{-3}) and (36.67µg/m^{-3}) respectively. The spatial distribution map indicated that the PM_{10} concentration level is not only determining by seasonal but also depends on location of monitoring station itself. The concentration may increase if the station is closer to the proximity of urban and industrial pollution sources.

Keywords: *GIS ; Kriging ; MODIS ; PM_{10} concentration ; Seasonal*

1. Introduction

Air pollution is often estimated from sparse fixed monitoring sites or from air quality models that provide estimates at a coarse spatial resolution [1]. Spatial analysis provides insight into air pollution monitoring information that retrieved based on limited observation point station into a wider area surrounding the station [2,3]. This allows to appropriately optimize the air quality assessment especially when the monitoring station needs to cover large areas [3]. Air pollution monitoring stations in Malaysia only measured the pollutants in three kilometers radius. Therefore, it is limited to portray the spatially particulate matter (PM_{10}) distribution from based on monitoring stations. This provides additional information on pollutant levels that outside the range [2].

Numerous studies enlightens the use of spatial interpolation analysis on air quality studies [4,5]. The ability of GIS by integrating the digital capture, management, analysis and visualization geographically referenced data spatially. Better interpretation, trends and relationship between air pollutant, demographic, environment, space and time [5]. Study by [6] detected the spatial of rural background monitoring stations for PM2.5 and O3 in Italy. Rahman [7] explored the spatial trend of ambient air pollution (i.e. PM_{10}, CO, NO, No2 and O3 within the eight selected Malaysia air monitoring station in Klang Valley over five years (from 2007-2011) using geographical information system (GIS) and the Principal Component Analysis (PCA). An inverse distance weighted interpolation is used to analyse spatial distribution pattern of air pollutant (TSM, CO, NO_2 and SO_2) in Tehran [8].

Atmospheric circulations can affect air pollutant distributions [7,9,10]. Meteorological factors through complex interactions between various processes such as transport and transformation of chemicals releases affected air quality [11]. Meteorology is important factor in determining in the distribution of ambient air pollution. In fact, there is a strong seasonal meteorological variable that modulate the level of air quality [12]. Therefore, the air quality not only depends on emission sources, but weather elements such as temperature, humidity and wind plays a significant role.

Malaysia is located near to the equator with a hot and humid climate throughout the year. Exhibited two types of monsoon to the country which are the north-east monsoon and the south-west monsoon [18]. There are two transition periods between these two monsoons, i.e. in April and October. During the north-east monsoon, the precipitation of rain will carry the pollutants to the earth; hence, reducing the level of pollutants in the atmosphere [4,13]. During the south-west monsoon, the warmer air near the surface area rises to higher latitude, which causes the pollutants to become unstable; thus, resulting in a high level of pollutants in the [15]. Study on the diurnal and seasonal variations of NO_2, O_3, CO, non-methane hydrocarbon (NMHC) and SO_2 also have been conducted at two cities at Kuwait [16].

Furthermore, there are studies have explored the spatial distribution of air pollution levels in relation to land use [1,17]. Study by Bozyazi [17] analysed air quality parameters of Sulphur Dioxide (SO) and Total Suspended Paniculate matter (TSP) which associated with land use in Istanbul during winter season. Spatial correlation among 17 monitoring stations was investigated using vario-

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gram analysis. The study indicated that air pollution levels in the city were strongly related to land use type. Therefore, this study aimed to determine the seasonal spatial pattern of PM_{10} concentration using interpolation Ordinary Kriging (OK) technique at selected region in Klang Valley.

2. Methodology

2.1. Study Site

The study area is located in Klang Valley, Malaysia comprises of Kuala Lumpur and its suburbs and adjoining cities and towns in the state of Selangor. It is geographically delineated by Titiwangsa Mountains to the north and east and the Straits of Malacca to the west with 6.9 million populationsin Klang valley (in 2013). Klang Valley is the mainstream economic region in Malaysia with extensive physical development of the infrastructure, industrialisation, and urbanisation which have considerably deteriorated the air quality [4].

Malaysia Department of Environment, 2006 have reported that air quality in Klang valley is polluted with varies of toxic and non-toxic air pollutants especially PM_{10}. The level of pollutants concentration in most area is not always at acceptable levels in accordance with the Malaysia Air Pollution Index (MAPI), and sometimes reached the unhealthy levels during incidences such as haze. There are five components of index pollutants in measuring the MAPI, in which four of them includes Ozone (O3), Carbon Monoxide (CO), Nitrogen dioxide (NO2) and sulfur dioxide (SO2) are reported in part per million (ppm) but PM_{10} is reported in micro gram per meter cube (µgm-3). The highest API level at most area was found during the haze episodes. In this study, the PM_{10} concentration and meteorological parameters from seven continuous air quality monitoring stations were obtained Malaysian Department of Environment (DOE). The geographical locations of the stations are tabulated in Table 1.

Table 1: Location seven air quality monitoring stations in Klang Valley (*Department of Environment (2010)*)

Stations	District	Coordinates	
		Longitudes	Latitudes
Pejabat Jabatan Bekalan Air Gombak	Gombak	3º15.702'N	101º39.103'E
Sek Men Perempuan Raja Zarina, Klang	Klang	3º00.620'N	101º24.484'E
Sek Rendah Sri Petaling, Petaling Jaya	Petaling Jaya	3º06.612'N	101º42.274'E
Country Heights Kajang	Hulu Langat	2º59.645'N	101º44.417'E
Sek Keb TTDI Jaya	Shah Alam	3º06.636'N	101º33.673'E
Sek Men Sains Kuala Selangor	Kuala Selangor	3º19.592'N	101º15.532'E
Sek Men Keb Seri Permaisuri Cheras	Cheras	3º06.376'N	101º43.072'E

2.2. Data Acquisition

Daily mean PM_{10} and meteorological (wind speed, temperature and humidity) data from 2004 to 2006 at seven monitoring sites in Klang valley were provided by Malaysia Department of Environment (DOE). The three years data has been segregated into four monsoons. There are; Northeast Monsoon (November-February), Spring Intermonsoon (March-April), Southwest Monsoon (May-August) and Autumn Intermonsoon (September-October).

Five percent (<5%) of missing data from overall observation was treated by using neighborhood method in R software. The simplest scheme where the endpoints and the gaps are used to estimate all missing values. This by manipulating the distance for each point and the closest point to it [19]. Daily data were aggregated into seasonal values to provide overall picture of seasonal PM_{10} concentration levels over Klang Valley. A standard kriging technique was used to generate seasonal interpolated map of PM_{10} . These maps were compared with ground measurement. To input into ArcGIS 10.3, Klang valley districts and air quality monitoring stations were digitized as a vector base map. Later, spatial interpolation methods namely Ordinary Kriging (OK) were applied to produce spatial PM_{10} concentration distribution in study area as below:

$$Z(x_0) = \sum_{i=1}^{N} \lambda_i Z(x_i) \quad (1)$$

Where, Z (x_0) is the value of unknown estimated sample, Z (x_i) is the value of the known sample near the unknown one, λi (i=1,2,…,N) is the weight assigned to the i- th known sample and N is the number of known sample [20]. By using the GIS is useful to visualize the dispersion of air pollution. Thus, further analysis in evaluating the association between the high concentration level and potential pollution sources. A deterministic method of spatial interpolation provides the estimated values that could not be measured in real life [4].

3. Result and Discussion

The mean of meteorological and PM_{10} were summarized in Table 4.1. Wind speed was recorded low at Gombak station with 2.82km/h while Kuala Selangor showed the high mean of wind speed (5.27km/h). For the humidity value, the lower mean of humidity was recorded at Petaling Jaya station with 72.42% while the higher mean of humidity 80.19% at Hulu Langat station. Klang station also recorded high reading for mean temperature with 28.44°c while Gombak the lower mean temperature with 26.60°c.

Furthermore, the analysis PM_{10} concentration will be discussed into the perspective of spatial and seasonal distribution. Meteorological variables, e.g., temperatures, wind speed and humidity are important factors that determined the air pollution levels [21]. Meteorological variables, e.g., temperatures, wind speed and humidity were analyzed in this study among meteorological stations in Klang Valley. The figure shows the spatial concentration of PM_{10} by using Ordinary Kriging (OK) method into different season; northeast monsoon, spring monsoon, southwest monsoon and autumn monsoon as shown in Figure 1.

From the figure, strong wind blowing at the Kuala Selangor and Klang station during autumn inter-monsoon at the speed of (5.1km/h-5.3km/h) and southwest monsoon (5.12km/h-5.22km/h) respectively. The specific topographic condition of Kuala Selangor, which is located near the coastal area facing the straits of Malacc which is much dominated by localized land sea breezes of wind circulation can be a reason [15, 21]. Apparently, high PM_{10} concentration is only can be observed at Klang station and Kuala Selangor station (>60 µg/m-3). High concentration of PM_{10} was recorded at Klang station when the temperature is high (28 degree Celcius) during end of SI and beginning of SW monsoon. Azmi and Latif [21] reported positive significant correlation ($p<0.01$) were established between atmospheric pollutants and meteorological parameters at the same study areas.

Table 2: Seasonal Mean of Meteorological Parameters in Klang Valley, Malaysia during year of 2004-2006

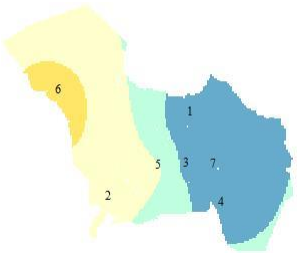
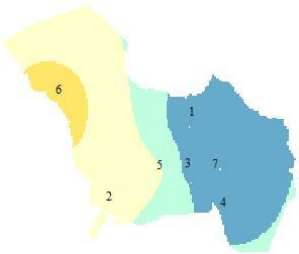
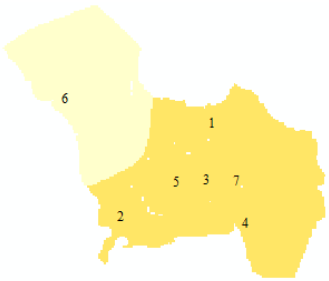
Stations	Parameters	Mean	Median	Std deviation	SE mean	Min	Max
Gombak	- Wind speed	2.827	2.680	0.799	0.024	1.300	10.23
	- Humidity	75.61	76.00	4.898	0.148	57.00	88.00
	- Temperature	26.60	26.53	1.051	0.032	23.60	30.20
Klang	- Wind speed	4.842	4.800	0.849	0.026	2.000	7.770
	- Humidity	75.03	75.00	4.905	0.148	60.61	89.21
	- Temperature	28.44	28.55	1.131	0.034	24.80	31.90
Petaling Jaya	- Wind speed	3.560	3.440	0.862	0.026	1.700	8.420
	- Humidity	72.42	73.00 27.25	1.560	0.047	53.00	85.92
	- Temperature	27.35		5.890	0.178	23.30	31.40
Hulu Langat	- Wind speed	3.363	3.240	0.719	0.022	1.830	8.000
	- Humidity	80.19	80.51	5.250	0.159	57.00	96.00
	- Temperature	26.63	26.70	1.014	0.031	23.90	29.50
Shah Alam	- Wind speed	5.058	5.010	1.182	0.036	2.000	9.780
	- Humidity	75.02	75.00 27.97	5.484	0.036	54.29	91.41
	- Temperature	27.97		1.198	0.166	24.58	31.40
Kuala Selangor	- Wind speed	5.277	5.300	1.219	0.037	1.610	9.200
	- Humidity	74.86	75.08 28.30	4.262	0.129	58.00	88.13
	- Temperature	28.27		0.956	0.029	25.30	31.11
Cheras	- Wind speed	4.006	3.900	0.822	0.025	1.390	6.850
	- Humidity	76.16	76.00	6.553	0.198	53.43	96.05
	- Temperature	27.28	27.27	1.103	0.033	24.32	30.50

PM_{10} and meteorological data are interpolated by OK method. These data are placed into attribute tables in different seasons before the interpolation proces is executed. Figure 1 shows the distribution of seasonal PM_{10} concentration at seven monitoring stations in Klang Valley during period of 2004- 2006. Each stations were marked with number as Gombak (1), Klang (2), Petaling Jaya (3), Hulu Langat (4), Shah Alam (5), Kuala Selangor (6) and Cheras (7).

It can be observed that high abundance of PM_{10} concentration distribution increases when low humidity was recorded. Humidity varies are inversely proportional to the temperature [26].During the southwest monsoon, high PM_{10} concentration was (80.71µg/m-3) followed by both inter monsoon (66.78µg/m-3) and (77.6µg/m-3) and decreased in northeast monsoon (33.78µg/m-3). Remarkable seasonal variation with high concentrations of particulate are recorded during the dry season of the summer monsoon [19] and lowest in the wet periods of the year. Similarly study done by [24] has found high concentration of PM_{10} level was estimated from MODIS data especially during Southwest monsoon (79.5578µg/m-3) as compared in the Northeast monsoon (33.78µg/m-3) in Fig.3.

During southwest monsoon, trans-boundary haze pollutant across the Malacca Straits to the southwest of Malaysia Peninsular also can be a plausible caused to contribute to the level of PM_{10} concentration. Forest fire in Sumatra is one of the events that promote the long range transportation of haze to Malaysia [23].

Overall, region which is located in the west area experienced higher PM_{10} as compared with the east and north region in Klang valley. This is because station located in west area i.e., Klang station is located closer to the proximity of port and industrial sources.The combined effects of geographical vicinity of the source area, an unfortunate position in prevailing direction of wind flow and possibly due to trapping of the biomass burning plume might introduce high levels of suspended particles found in Klang valley [22]. The location of Klang station close to a busy port (Port Klang) which has trade connections with over 120 countries and dealings with more than 500 ports around the world, may contributed to high particles in this area [25]. Strategic location as a developed urban area with commercial and industrial activities also contributes to the escalated of PM_{10} concentration. Other factors also contributed to the increasing level of PM_{10} concentration especially during dry season. The land used units such as industrial, residential (high density) and trading centre areas, indicate the highest air pollutant concentration levels. Meteorological conditions (e.g., wind speed, wind direction, temperature,) also affect the spatial distribution of air pollutant levels over Klang valley.

Seasonal/ Metrological factor	Wind speed (km/h)	Temperature (˚C)	Humidity (g/m3)
Northeast monsoon			

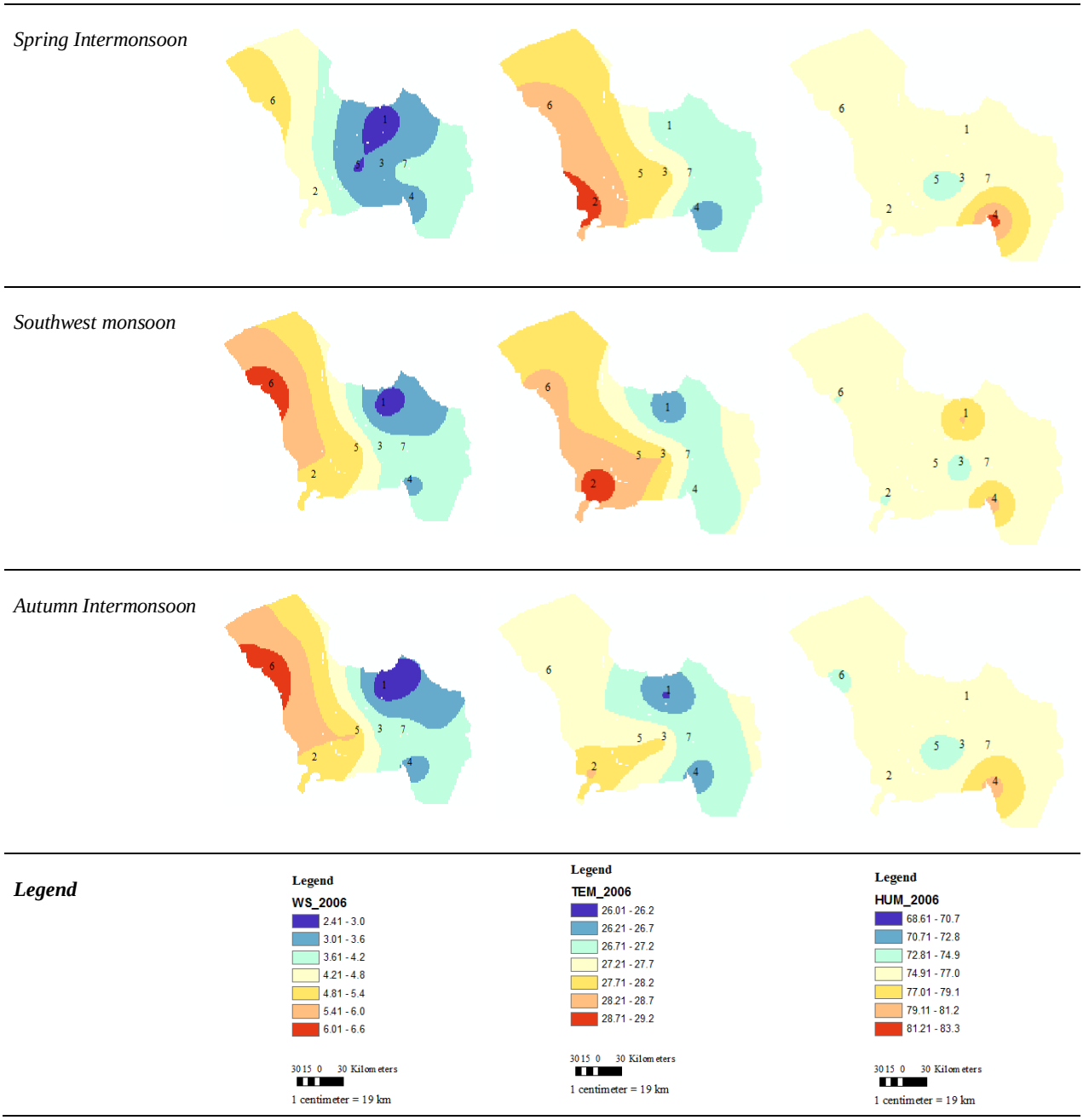
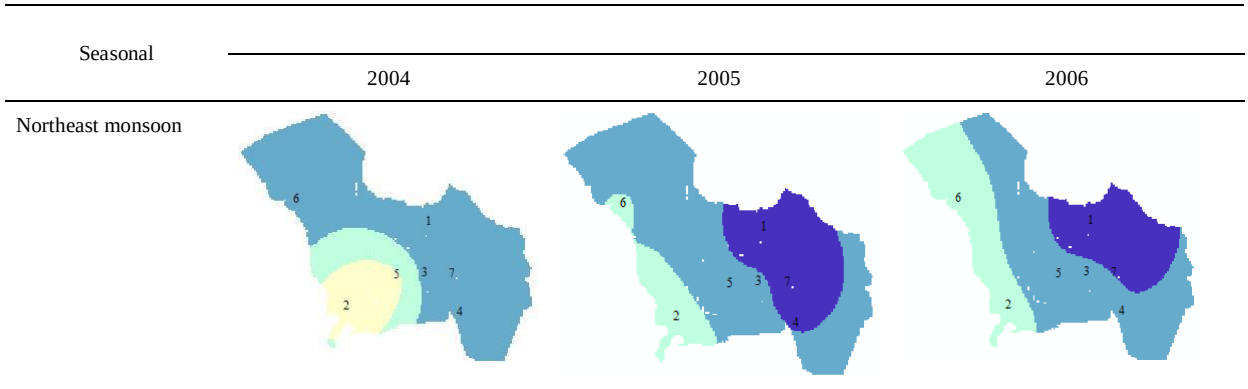


Fig. 1: Mean seasonal wind Speed, temperature and humidity data at seven air quality monitoring stations in Klang Valley for year 2006. (1- Gombak; 2- Klang; 3- Petaling Jaya; 4- Kajang; 5- Hulu Langat; 6- Kuala Selangor 7- Cheras)



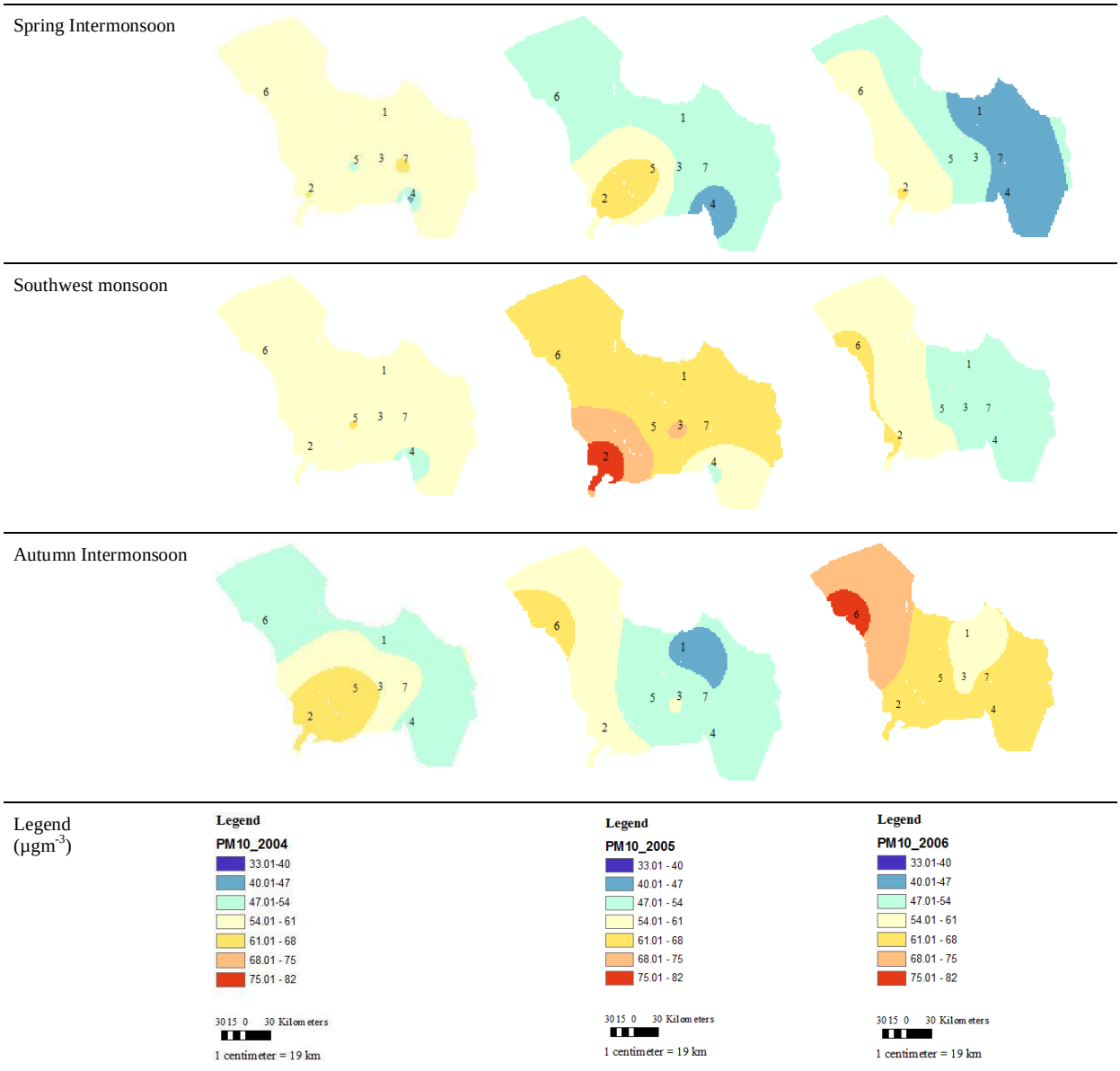
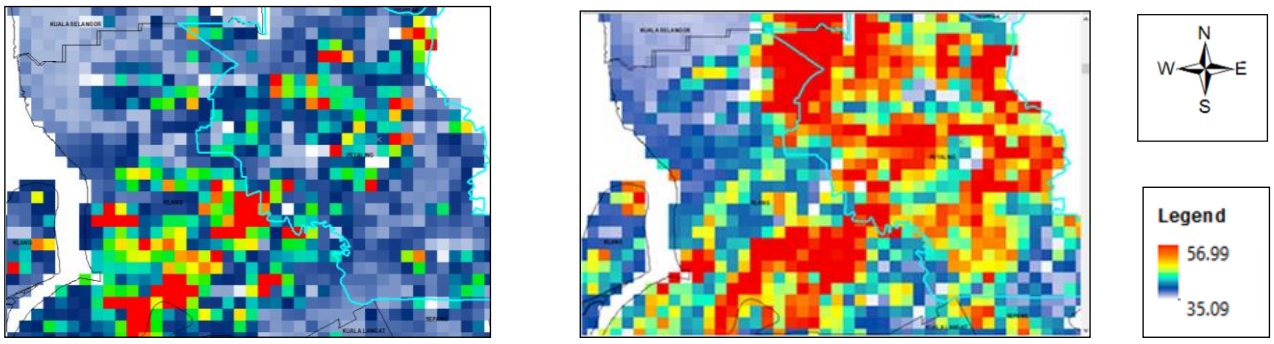


Fig.2: Distribution of seasonal PM_{10} concentration at seven monitoring stations in Klang Valley during period of 2004- 2006. (1- Gombak; 2- Klang; 3- Petaling Jaya; 4- Kajang; 5- Hulu Langat; 6- Kuala Selangor 7- Cheras)



a) Northeast Monsoon b) Southwest monsoon

Fig 3: PM_{10} concentration from MODIS in Klang valley, Malaysia for a) Northeast monsoon b) Southwest monsoon

4. Conclusion

The present study concluded that the concentration of air pollution in Klang valley were seasonally varied, and the spatial pattern of PM_{10} concentration can be associated with the geographical distribution of air pollutant sources surrounding the monitoring station.

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