EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/EA
EnvironmentAsia 3(special issue) (2010) 117-123

The Effects of Improved Land Use on the Meteorological Modeling in Klang Valley Region Malaysia

Loi Kok Chng, Ahmad Makmom Abdullah, Wan Nor Azmin Sulaiman and Mohammad Firuz Ramli

Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Abstract

It has been widely known that changes of the land surface from vegetation area to urban area can substantially affect the surrounding meteorological condition. Meteorological model was used to assess meteorological condition for air quality modeling and forecasting. Inputs used in this study for the meteorological and air quality model were land use and land cover of the terrain. This study tends to examine the sensitivity of land use and land cover on the predicted meteorological conditions. A meteorological simulation using fifth generation mesoscale model (MM5) by Penn State/NCAR was used to compare the effects of land use from two different years on meteorological condition. The predicted meteorological conditions were then compared with the respective monitoring station onsite. Results showed there is an improved of surface wind speed and temperature simulated using improved land use map. Findings suggest land use map should be taking into consideration in historical meteorological fields to access future air quality if the area of study expects large changes in land use pattern.

Keywords: meteorological modeling; land use; MM5; urban.

1. Introduction

Urbanization of an area could lead to changes of meteorological parameters such as boundary layer depth, vertical diffusivity and wind stability class. These meteorological parameters played an important role in most of the air quality models which predicts the concentration at each grid. According to Jacobson (2002), one of the factors that affect air pollution is the local wind which resulting from some variables such as uneven ground heating and variable topography. In another word, different land use type may lead to uneven ground heating, because land cover affects ground temperature, which affects pollutant concentration eventually (Jacobson, 2002). Meteorological and air quality models require land use type and surface characteristic that differ by their land use and land cover patterns (Civerolo *et al*., 2000). Study carried out by Jazcilevich *et al.* (2002) pointed up that changes of the land use type could affect its surrounding meteorological condition and dispersion of air pollutant. Much of the current understanding of the urban climate and meteorological condition in Malaysia resulted from the research focused on Kuala Lumpur and Petaling Jaya of Selangor area begins from 1970s (Sham, 1973a; 1973b; 1979a; 1979b; 1987). These researches have focused on the description of the climatology and meteorological aspect such as wind and temperature parameters associated with urban heat island. The meteorological aspects of the Kuala Lumpur and the surrounding cities may change attributed to the alteration of land use and land cover by urbanization and development of the city. However, no study has been done so far to access the meteorological condition of Klang Valley region with current land use and land cover.

The meteorological model used in this study was the Fifth Generation Mesoscale Model (MM5) from PSU/NCAR (Grell *et al*., 1994). In this model the land use type was simulated from the global vegetation dataset from United States Geological Survey (USGS) which were available at 1 degree, 30 min, 10 min, 5 min, and 30 sec resolution. However, the data were derived from satellite observations over a period 1992-3 and the vegetation categories were out of date and not relevant to the focused study area. The objective of the study is to determine to the effects of the land use and land cover changes on the meteorological modeling system. Land use map of the year 2000 obtained from the Town and Country Planning Department (JPBD) will be used to improve 1992-3 USGS land use dataset.

2. Materials and Methods

2.1. The Modeling System

The MM5 model is non-hydrostatic with terrain following coordinates, multi-scale, capable of interface with actual weather forecast models (Global Circulation Model), contains explicit cloud schemes and soil parameterization. MM5 is widely used by the meteorological community and its output could be coupled together with the Sparse Matrix Operation Kernel Emission (SMOKE) model and Community Multiscale Air Quality (CMAQ) model to simulate the dispersion of the air pollutants that take into considerations of the meteorological fields and emission sources. MRF Planetary Boundary Layer (PBL) parameterization scheme and NCEP FNL (Final) Operational Global Analysis data was selected in this study. For inputs of data, land use datasets from USGS will be used as the default land use in base case, and land use map from Town and Country Planning Department (JPBD) as improved land use in case study simulation.

2.2. Domain Setup

Four domains were used as shown in Fig. 1 for this study. The mother domain with the resolution 27 km covers the most of the Peninsular Malaysia; second domain with the 9km resolution covers Selangor state; third domain with 3km resolution covers the center and southern region of Selangor; finest domain with 1km resolution will covers the study area of Klang Valley.

2.3. Processing of Land Use and Land Cover

In the MM5 modeling system, each grid cell was assigned with one land use type based on the dominant category in the grid cell. About 24 categories of vegetation types by USGS were used in classification of land use in MM5 model. Each land use categories consists of six surface parameterization, which includes, albedo, moisture availability, emissivity at 9 m, roughness length, thermal inertia, and surface heat capacity per unit volume. Since Malaysia is a tropical country, summertime values are used in the model setup. Out of 24 land use types in the MM5 model (Guo and Chen, 1994), 14 categories were applied to fully describe the entire domain (Fig. 2), with 22% classified as water bodies, 0.4% as urban area and the largest non water-based category was Irrigated Cropland and Pasture (39%) in domain 3 and as for domain 4, 10% classified as water bodies, 1% as urban area and the largest non water-based category was also categorized as Irrigated Cropland and Pasture (37 %) (Table 1).

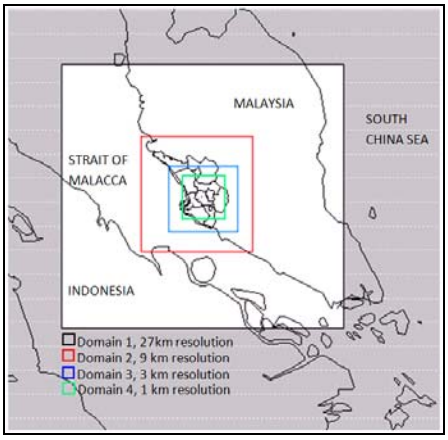

Figure 1. MM5 domain setup.

Since the land use dataset from USGS was generated from the year 1992/3 satellite image, the development of the Klang Valley area for the past 15 years

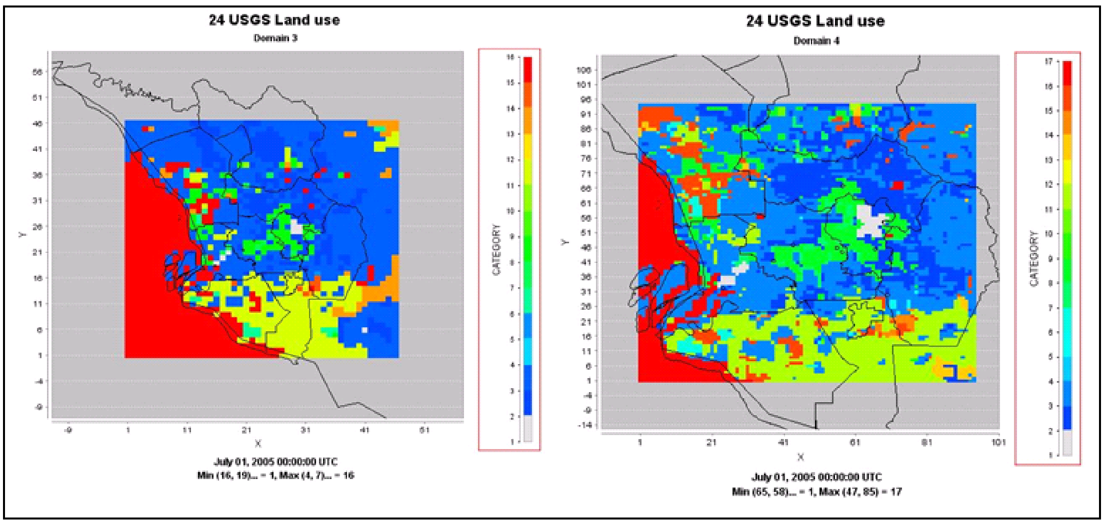

Figure 2. USGS land use dataset domain 3 and domain 4.

Table 1. Percentage of land use category for USGS and JPBD land use Domain 3 and Domain 4.

Land use code	Land use category	USGS Land use Domain 3 (%)	USGS Land use Domain 4 (%)	JPBD Land use Domain 3 (%)	JPBD Land use Domain 4 (%)
1	Urban and Built -Up Area	0.4	1.0	25.1	40.6
2	Dryland Cropland and Pasture	12.1	17.0	0.0	0.0
3	Irrigated Cropland and Pasture	40.2	37.4	0.0	0.0
4	Mixed Dryland/Irrigated Cropland and Pasture	0.0	0.0	20.4	28.0
5	Cropland/Grassland Mosaic	0.0	0.3	0.0	0.0
6	Cropland/Woodland Mosaic	1.0	1.0	0.0	0.0
7	Grassland	0.7	1.7	0.0	0.0
8	Shrubland	3.7	7.6	0.0	0.0
10	Savanna	0.1	0.2	0.0	0.0
11	Deciduous Broadleaf Forest	13.4	16.5	0.0	0.0
13	Evergreen Broadleaf Forest	2.8	1.1	0.0	0.0
14	Evergreen Needleleaf Forest	0.3	0.5	0.0	0.0
15	Mixed Forest	2.7	5.3	34.4	25.0
16	Water Bodies	22.4	10.3	17.8	6.5

has dramatically changed the land use and land cover of the study area. To improve the land use type, updated land use map from the Town and Country Planning Department was referred in this study. The updated land use map was preprocessed from polygon to gridded land use map based on the classification of the 24 USGS land use categories (Fig. 3). The percen- tage differences of the land use between the default land use and the update land use are shown in (Table 1).

An ASCII type of input file was generated based on the reclassified land use map into specific format. This ASCII file contains column, row, land use type, latitude, longitude, vegetation fraction, and water fraction (Fig. 4).

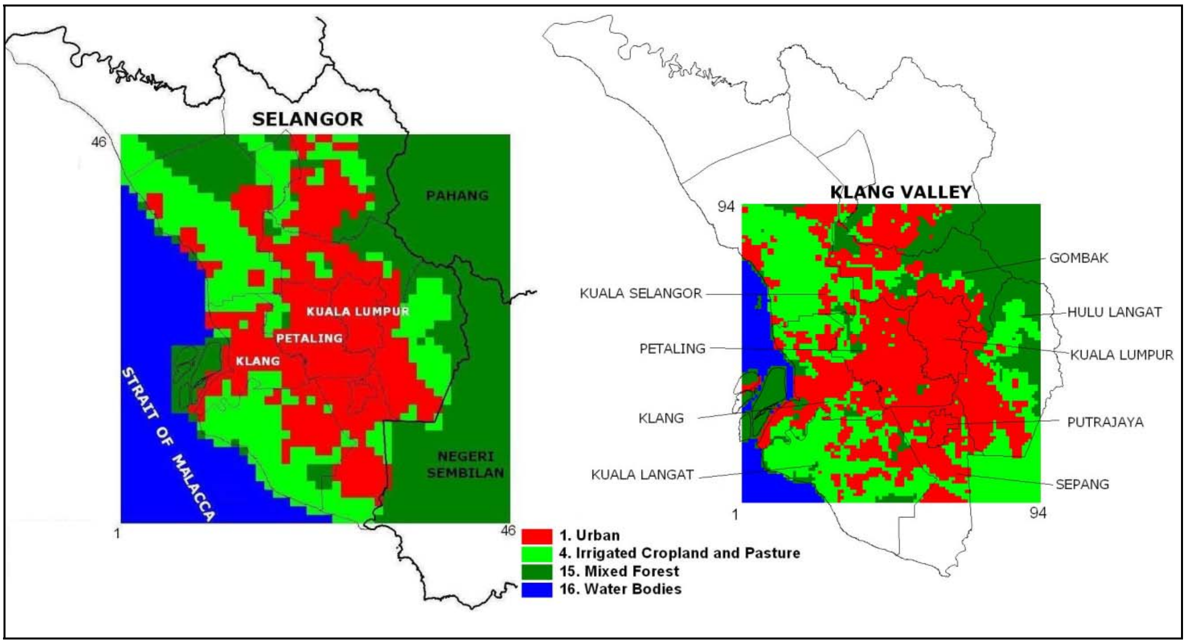

Figure 3. Gridded JPBD land use in 3km and 1km resolution.

47	15	15	3.5870	101.3753	0	0
47	16	04	3.5870	101.3968	0	0
47	17	04	3.5870	101.4183	0	0
47	18	04	3.5870	101.4398	0	0
47	19	15	3.5870	101.4613	0	0
47	20	15	3.5870	101.4828	0	0
47	21	15	3.5870	101.5043	0	0
47	22	01	3.5870	101.5258	0	0
47	23	01	3.5870	101.5473	0	0
47	24	04	3.5870	101.5688	0	0

Figure 4. Example of ASCII format input.

The FORTRAN code named “replace_lulc.f ” was used to replace the land use type, vegetation fraction and water fraction in the TERRAIN_DOMAINx file based on the coordinates of the reclassified grid cells and the respective land use type, and other parameters provided in the ASCII file. The FORTRAN code was compiled using run script çrun.replaceé which also determines the input and output files to process, and parameters to be updated (Fig. 5).

3. Results

3.1. MM5 Simulation Results

MM5 simulation was performed from 1st July 2005 (18:00) to 3rd July 2005 (17:00) with total simulation time of 48 hours using USGS vegetation dataset for 27km, 9km, 3km and 1km domains as base case. The 3km and 1km domain will be compared with the output of MM5 simulation utilizing JPBD land use dataset during for same period. All the physical options used were identical for both simulations. Observation from the Continuous Air Quality Monitoring (CAQM) station from Alam Sekitar Malaysia Sdn. Bhd. (ASMA) and Malaysian Meteorological Department (MMD) were used to validate the MM5 performance from the both USGS and JPBD land use dataset. Three CAQM sites were selected to validate the MM5 performance, which were the monitoring stations based in Klang, Shah Alam and Subang.

The simulations that utilized USGS land use dataset showed overestimation of the wind speed and produces sudden peak at certain hour in the simulation. The improved land use dataset using JPBD land use data reduces the wind speed and frequency of the sudden peak, yet still over estimated the overall wind speed compared to the observation data (Fig. 6). However, the improved land use dataset using JPBD increases the correlations between the observed wind speed and simulated wind speed from all CAQM site (Table 2). The lowered wind speed due to the improved land use data set could lead to an increased of stability and reduced vertical mixing. This could increase the air pollution concentration in certain area.

The temperature profiles simulated by both using USGS and JPBD land use dataset were able to simulate the afternoon temperature near surface when compare with the onsite observation temperature data. However, both USGS and JPBD land use dataset tends to overestimate the temperature near surface during the night (Fig. 7). The correlation between observed temperature and simulated temperature slightly increases when apply JPBD land use dataset in the simulation for the all monitoring site (Table 2).

```
#!/bin/csh -f

ifort -free -convert big_endian readv3.f

set infile   = TERRAIN_DOMAIN3                     # original TERRAIN file
set outfile  = TERRAIN_JPBD_DOMAIN3                # output TERRAIN file name
set datafile = JPBD_DOMAIN3.txt    # LULC data file in ASCII format
set in_ii    = 48                                 # y-direction (IX in mm5)
set in_jj    = 48                                 # x-direction (JX in mm5)
set LU_FLAG     = 'Y'         # 'Y' update lulc, 'N' do not update
set VEG_FLAG    = 'N'         # 'Y' update vegetation fraction, 'N' do not update
set SOIL_FLAG   = 'N'         # 'Y' update soil type, 'N' do not update

./a.out << _EOF
$infile
$outfile
$datafile
$in_ii
$in_jj
$LU_FLAG
$VEG_FLAG
$SOIL_FLAG
_EOF
```

Figure 5. Example of run.replace script.

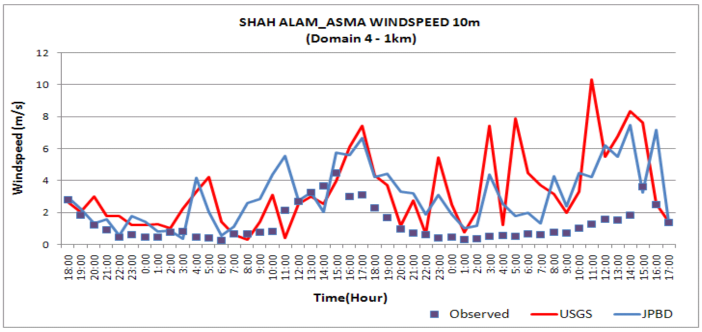

Figure 6. Time series comparison of wind speed at 1km domain for Shah Alam

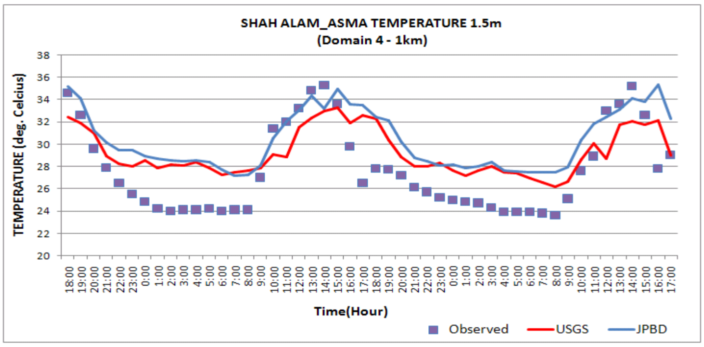

Figure 7. Time series comparison of 1.5m temperature at 1km domain for Shah Alam

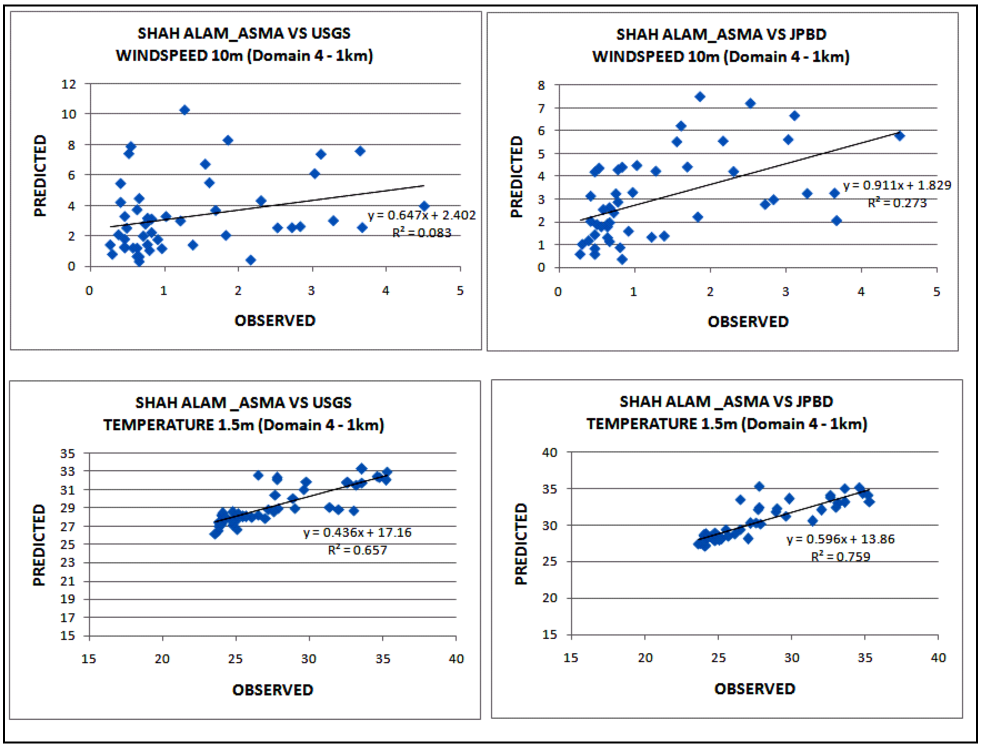

Figure 8. Correlation between observed and predicted data at Shah Alam.

Table 2. Summary of correlation between observed and predicted data for all the location.

Parameter	Domain	Monitoring Station		
		Klang, ASMA	Shah Alam, ASMA	Subang, MMD
Wind speed 10m	Domain 3 USGS	0.034	0.082	0.176
	Domain 3 JPBD	0.311	0.318	0.214
	Domain 4 USGS	0.015	0.083	0.169
	Domain 4 JPBD	0.277	0.273	0.254
Temperature 1.5m	Domain 3 USGS	0.673	0.672	0.410
	Domain 3 JPBD	0.774	0.788	0.537
	Domain 4 USGS	0.666	0.657	0.411
	Domain 4 JPBD	0.790	0.759	0.544

The results suggest that modified land use dataset (JPBD) could improve the overall simulation result (Table 2). The changes of the meteorological parameters could affect dispersion of air pollutant, energy demand that could affect anthropogenic emissions. Moreover, the changes of the MM5 output could also affect the calculation of the air pollution modeling software such as CMAQ.

4. Discussion

The land use is just one of many factors that could affect the meteorological modeling system. The results showed improvement of the simulated wind speed and temperature near surface. The performance of the MM5 on simulation could be improved by modifying the MM5 physical options and schemes depending on the resolution and location of the study area. Since the land use and land cover changes affect the near surface meteorological, it should be included as one of the key factors in the air pollution modeling especially future air quality scenarios. The changes of the temperature that lead by land use could increase downwind, and potentially affects the air quality simulation. The changes of the wind speed will also affect the dispersal of air pollutants and mixing in the atmosphere, changes of the air pollutant concentration are expected.

Changes in the land use and land cover patterns due to the urban sprawl, agricultural patterns, forestation and deforestation are expected to affects to landscape. The alteration of landscape will lead to changes in population, energy consumption, anthropogenic and biogenic emissions. The results suggested that land use should be taken into consideration when using air quality forecasting model to predicts and evaluate the air quality.

Acknowledgment

The authors thank the Ministry of Science and Technology (MOSTI) Malaysia for supporting this research, under project no. 04-01-04-SF0674. We also thank Department of Environment (DOE) Malaysia, Malaysian Meteorological Department (MMD) and Town and Planning Department (JPBD) Malaysia for data supplying. The views expressed by the authours do not neccesarily reflect those of the agency.

References

Civerolo KL, Sistla G, Rao ST, Nowak DJ. The effects of land use in meteorological modeling: implications for assessment of future air quality scenarios. Atmospheric Environment 2000; 34: 1615-21.

Grell GA, Dudhia J, Stauffer DR. A description of the fifth-generation Penn State/NCAR Mesoscale Model (MM5). NCAR Technical Note TN-398 + SRT. 1994.

Guo YR, Chen S. Terrain and land use for the fifth-generation Penn State/NCAR mesoscale modeling system (MM5): program TERRAIN. NCAR Technical Note TN-397 + 1A. 1994.

Jacobson MZ. Effects of meteorological on air pollution. In: Atmospheric Pollution: History, Science, and Regulation. Cambridge University Press. New York, USA. 2002; 145-76.

Jazcilevich AD, Garcia AR, Ruiz-Suarez LG. A modeling study of air pollution modulation through land-use change in the Valley of Mexico. Atmospheric Environment 2002; 36: 2297-307.

Sham S. The urban heat island: its concept and application to Kuala Lumpur. Sains Malaysiana 1973a; 2(1): 53-64.

Sham S. Observations on the effect of a city's form and functions on temperature patterns: a case of Kuala Lumpur. Journal Tropical Geography 1973b; 36: 60-65.

Sham S. Aspects of climatology in a tropical city, a case of Kuala Lumpur-Petaling Jaya, Malaysia. Penerbit UKM. Bangi, Malaysia 1979a; 387.
Sham S. The climate of Kuala Lumpur-Petaling Jaya area, Malaysia. Penerbit UKM. Bangi, Malaysia 1979b; 334.
Sham S. Urbanization and the atmospheric environment in low tropics: experiences from the Kelang Valley Region Malaysia. Penerbit UKM. Bangi, Malaysia 1987; 606.

Received 4 June 2009
Accepted 21 August 2009

Correspondence to
Dr. Ahmad Makmom Abdullah
Department of Environmental Sciences,
Faculty of Environmental Studies,
Universiti Putra Malaysia,
43400 UPM Serdang, Selangor,
Malaysia
Tel: (603)8946-6770
Fax: (603)8946-7463
E-mail: amakmom@env.upm.edu.my