Comparison of Land Cover and Land Use Data for Urban Climate Modelling in Southeast Asian Cities – A case study of Johor Bahru

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1. Introduction

Urban climate modelling represents a way of simplifying complex interactions between cities and atmosphere over wide ranges and simulating past, present, and future climatic situations and phenomena. For urban climate modelling, land cover data are an important input, since available energy and water largely depends on the land surface composition. The impact of land cover data quality on climate simulations was studied for different regions and models (e.g.: Sertel, 2009; Santos-Alamillos et al., 2015). However, production of land cover data may be time and resource consuming. This is particularly true for tropical regions where high incidence of cloud cover complicates the process. Application of climate models in studies on urban environment requires accurate and up to date data, which represent the actual situation on the ground.

As an alternative to land cover data, the use of land use data for urban areas in tropical regions may be possible. Land use data are provided by urban planning authorities or other institutions and represent current or future utilization of land. Particularly for the assessment of future urban development, as proposed by city development plans or master plans, the utilization of land use data is crucial. Although the utilization of land use data may be well suitable for urban climate models, there are some aspects that should be considered. Many Southeast Asian cities experience rapid urbanization associated with urban sprawl. This often leads to changes in land surfaces where abandoned open spaces and green areas occur in different areas of the city. These open spaces may not be well represented by land use data and thus have an impact on urban climate modelling. Moreover, the quality of land use data may not always be sufficient enough to represent the situation on the ground accurately.

This study compares the application of land cover and land use data for the simulation of urban climate in one major city in Southeast Asia. Johor Bahru is the capital of the Malaysian state Johor and lies in the southern-most tip of Peninsular Malaysia. The findings of this study shall provide some understanding of how land use and land cover data could be used in urban climate modelling and emphasis the importance of quality of land use data for future research.

2. Methodology

This study was conducted using the Weather Research and Forecasting (WRF) model (version 3.6.1) with integrated Advanced Research WRF (ARW) dynamics solver (Skamarock et al., 2008). The grid cell resolution was chosen as 0.5 km. The vertical resolution comprised of 30 layers which extended to 50 hPa. For modelling purpose, four computational domains (domain 1-4) with resolutions of 13.5 km, 4.5 km, 1.5 km, and 0.5 km were set up. The initial and lateral boundary conditions were defined using data from National Centers for Environmental Prediction (NCEP). The NCEP FNL (Final) data were utilized as Four-dimensional Data Assimilation (FDDA) in all four domains. Figure 1 depicts further model configuration and parameterization.

WRF model requires climate and land cover data as input data for modelling processes. The observational climate data were obtained from weather stations in Johor Bahru and Singapore. The geographic location of the weather stations is shown in figure 2. The climate data for all weather stations except at NUS were provided by the National Climate Data Center of the National Oceanic and Atmospheric Administration (NOAA).

Apart from default land cover data (GLCC data), which were utilized for domain 1 and 2, this study also utilized land cover data provided by the Global Land Cover by National Mapping Organizations (GLCNMO; version 1)(see Tateishi, Uriyangqai, et al., 2011) for domain 3. For domain 4, land cover data produced by using Landsat-8 images and supervised classification method were utilized. The production of land cover data was based on the spatial and spectral information retrieved from two Landsat-8 images acquired on 18 June, 2013 (scene 1) and 27

June, 2013 (scene 2). Due to high incidence of clouds, the land cover data were complemented with data from images acquired on 22 February, 2013 and 24 April, 2013.

	Domain 1	Domain 2	Domain 3	Domain 4
Resolution	13.5 km	4.5 km	1.5 km	0.5 km
Domain Size	204×204×30	204×204×30	198×198×30	204×204×30
WRF Version	WRF ARW v. 3.6.1			
Land use/cover Data	GLCC	GLCC	GLCNMO	Landsat 8
Initial Boundary Condition	GRIB1 NCEP FNL			
Longwave Radiation	RRTM Scheme			
Shortwave Radiation	Dudhia Scheme			
Surface Layer	Monin-Obukhov Similarity Scheme			
Land-Surface	Noah LSM			
Center Point	103.749997°E 1.527785°N			
PBL Type	YSU Scheme			
Microphysics	WRF SM 3-class Scheme			
Cumulus Scheme	Kain-Fritsch Scheme			
Period for Simulation Validation	00:00 UTC 12 to 00:00 UTC 18 June 2013			

Figure 1: WRF model configuration for domain 1 to 4

The land use data were provided by urban planning authority of Johor Bahru and represent the land development in the city up to the year 2012. The data cover the administrative area of the city. It is worth mentioning that the provided land use data do not cover the entire area of domain 4. Therefore, land use data were complemented with land cover data.

The simulation period was chosen from 9 June to 15 June, 2009. This period represents the southwest monsoon season with mean air temperature of 27.46 °C. The prevailing wind direction during this season is south. However, at night, the wind direction significantly changes with wind blowing from the north.

3. Results and Discussion of Urban Climate Modeling

3.1 Model Validation

Accuracy assessment of land cover classification shall provide means to validate the prepared land cover data using supervised classification algorithm. The overall accuracy for scene 1 resulted in 83.33%. In case of scene 2, the over accuracy was 87.40%. Figure 2 depicts the prepared Land Use and Land Cover (LULC) map using produced land cover data and land use data.

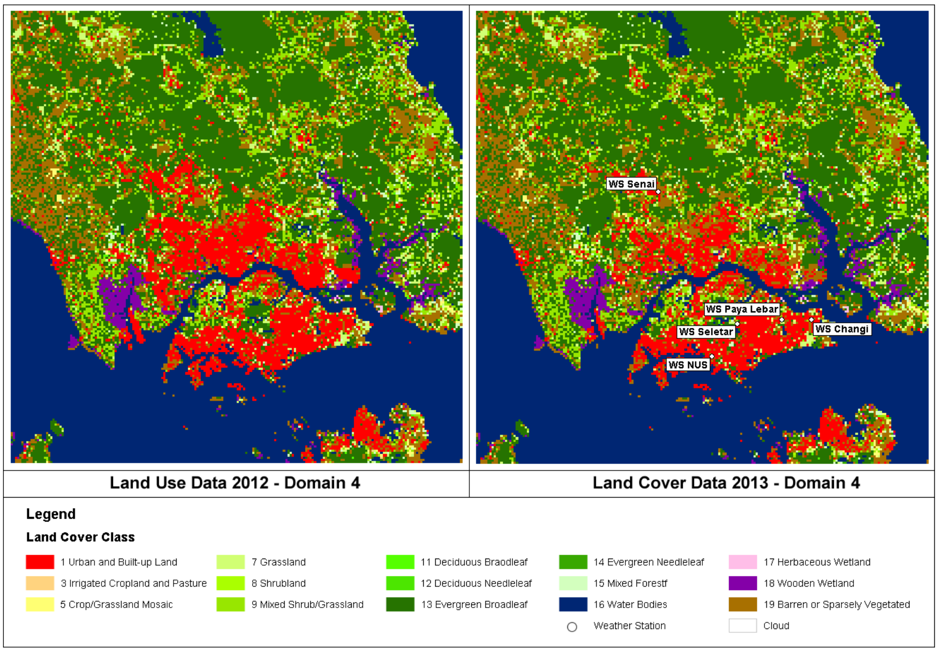

Figure 2: Combination of land use and produced land cover data (left) and produced land cover data only (right)

Validation of WRF model was conducted by using observational data from five weather stations (WSs). The climate data for Singapore were collected at four different WSs distributed all over Singapore Island. The WS at Paya Lebar, Changi, and Seletar are located on the premises of airfields/airports. The fourth WS in Singapore is located on the campus of the National University of Singapore (NUS). In case of JB, only one WS was available which is located at Senai International Airport. The validation was carried out for the period from 08:00 MYT (00:00 UTC) 12 to 08:00 MYT (00:00 UTC) 19 June, 2013. Table 2 summarizes the validation results. The deviation of simulated results from observed data occurs due to application of various schemes and input data that may affect the computational processes during the simulation. The validation results of the WRF model showed that the set of physical schemes and input data is suitable to simulate the climatic conditions in the research area.

Table 1: Validation of WRF model

		Senai	Changi	Seletar	Paya Lebar	NUS
Temperature	R^2	0.892	0.734	0.863	0.821	0.570
	RMSE	1.274	1.143	1.561	3.032	0.599
	Bias	-0.189	-0.324	-0.878	-1.524	0.136
Wind Speed	R^2	0.643	0.483	0.542	0.548	0.540
	RMSE	2.482	1.775	1.731	1.390	1.007
	Bias	1.303	0.824	0.857	0.489	-0.062

3.2 Comparison of Land use and Land Cover Data

The utilization of land use data for representation of urban development in Johor Bahru results in an increase of urban and built-up area of 31.44 %. In contrast to the land cover data, small scale open spaces, constructions sites, and small green areas are not sufficiently represented by land use data. The land use data represent the fragmented pattern of Johor Bahru's land development as a coherent urban pattern. Apart from that, land use data include future land development which is not yet found on the ground. This contributes to an increase of urban and built-up area as compared to land cover data.

3.3 Simulation Results

The temporal variation of mean air temperature for urban and built-up areas, as depicted in figure 3, shows similar pattern for land use data and land cover data. At sunrise (07:00 MYT), the air temperature reaches its minimum value. With the sun rising, the air temperature starts gradually to increase to reach its maximum value between 15:00 MYT and 16:00 MYT. After the daily maximum, the air temperature starts to decrease until its minimum values in the morning hours. The mean air temperature for urban and built-up areas in case of land use data is slightly higher than in case of land cover data (see table 2). When looking at the mean air temperature in the Central Business District (CBD) of Johor Bahru, the difference in mean air temperature is insignificant (29.72 °C vs. 29.70 °C). This is likely due to the fact that the CBD is a densely built up are with only little share of open spaces. The densely built up characteristic of this area is well represented in the land cover data.

Table 2: Mean air temperature for urban and built-up areas

	Land Use Data	Land Cover Data
Mean Air Temperature	29.25 °C	29.05 °C
Mean Air Temperature in CBD	29.72 °C	29.70 °C

As shown in figure 3, the mean air temperature at night is higher when using land use data. This is likely due to the increased urban and built-up areas and decrease of mixed land use including open spaces. The heat flux from buildings is predominant at night hours. The mean air temperature reaches higher maximum values during daytime when using land cover data.

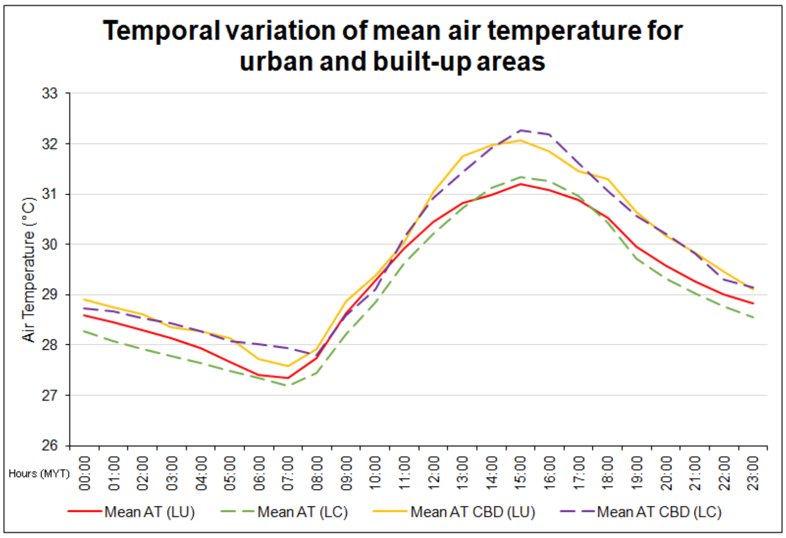

Figure 3: Temporal variation of mean air temperature for land use data and land cover data

The spatial distribution of mean air temperature at 07:00 MYT and 15:00 MYT is depicted in figure 4. With the increased urban and built-up areas, due to the utilization of land use data, the mean air temperature in particular in the northern part of Johor Bahru experiences air temperature increase of up to 2.5 °C. Being mainly dominated by palm oil plantations, this area undergoes major development in the course of the implementation of the

Comprehensive Development Plan for Johor Bahru (KN, 2006). The utilization of land use data affects also areas in the western and eastern part of Johor Bahru, where the air temperature shows an increase of up to 2 °C as compared with land cover data.

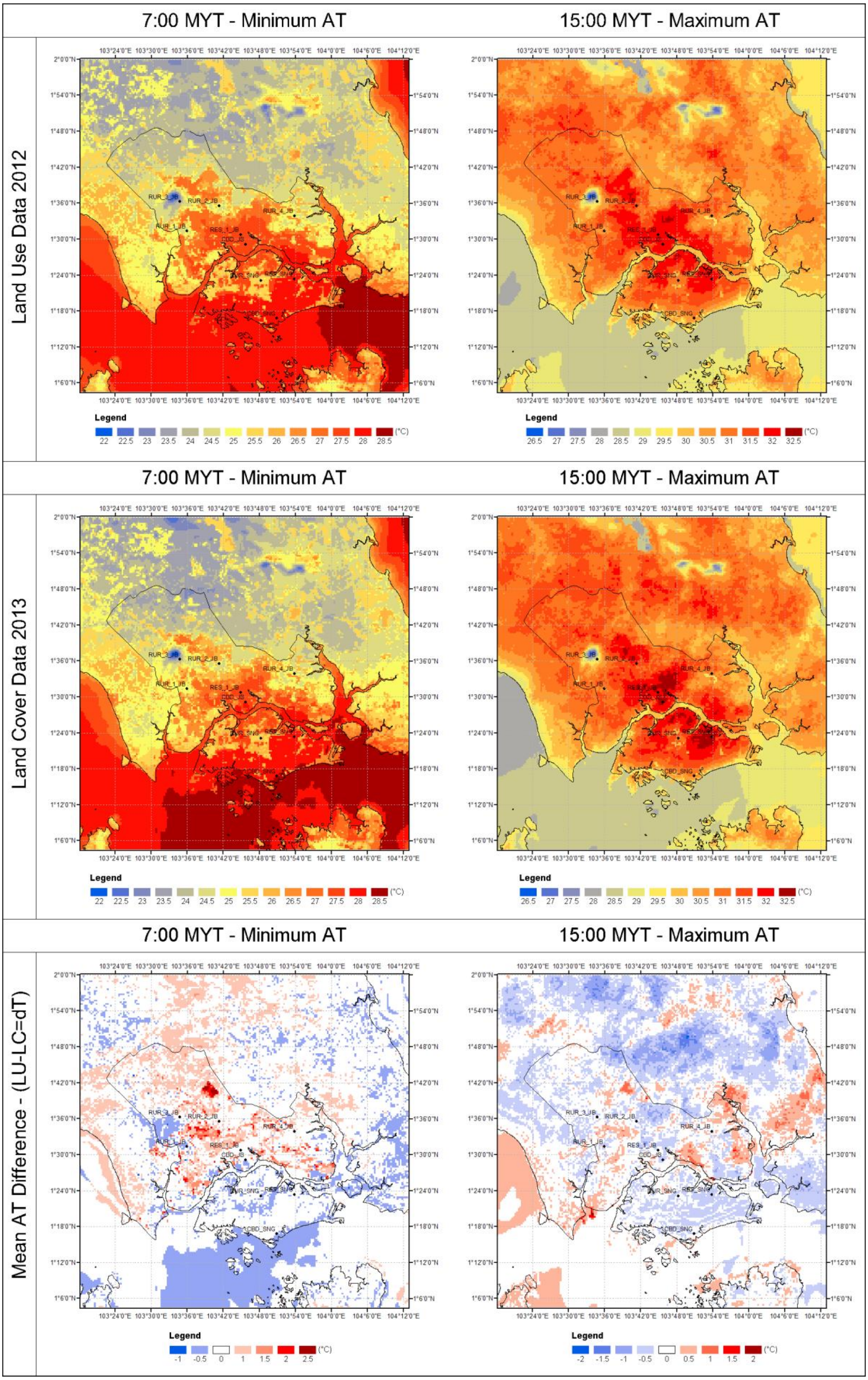

Figure 4: Spatial distribution of mean air temperature at 07:00 MYT and 15:00 MYT

4. Conclusion

Production of land cover data as input data for urban climate models requires a sophisticated approach to achieve high accuracy and thus represent the actual situation on the ground. Particularly in tropical regions where high incidence of clouds contaminated large areas of the scene, the production of land cover data may be time and resource consuming. Utilization of land use data provided by urban planning authorities or other institutions for representation of current land development in a city may provide easily accessible data with high accuracy. This research aimed at comparison of land use data and land cover data for Johor Bahru. The findings showed that the land use data increase the urban and built-up areas by more than 30 %. This resulted in an increase of air temperature in areas where land use data indicated urban areas instead of representing the actual situation on the ground. Despite increased urban and built-up area, the simulation results showed only a slight difference in mean air temperature of 0.20 °C. In the CBD of Johor Bahru, the difference in air temperature is negligible. The utilization of land use data for urban climate modelling represents thus a practical approach to overcome difficulties in producing land cover data. Higher quality of land use data would improve the simulation results and contribute to better simulation of future development.

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