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Density Indexes in Determining an Urban Sprawl using Remote Sensing and GIS Techniques.

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Abstract

Urban density represents the amount of land occupied by a number of residents and an important factor in understanding how cities function. It is one of the essential components in measuring urban sprawl. The urban density index provides a measure of how much land is consumed per capita for a patch of new development. It is commonly asserted that higher density cities are more sustainable than low density cities because it consumes more land for each resident leaving less of the landscape able to function in other capacities. While some researcher argue that low-density urban area contributed to sprawl, others have counter that higher density results in more negative impact. Characterizing urban sprawl by using density index requires suitable and proper technique. This research attempts to study the measurement of sprawl by using density index with Remote Sensing and Geo-information System (GIS) approach. The SPOT-5 images with 2.5 meters resolution were used and combined with GIS database to analyse the growth of sprawl in Kuala Lumpur metropolitan due to its high-density development. To achieve a better urban development and infrastructure planning in the future, it is crucial for the City Hall to know sprawl phenomenon in Kuala Lumpur, its types, distribution, factors, and the way it is likely to move in the years to come. By using Remote Sensing and GIS, high density area and low density area in Kuala Lumpur can be analysed and compared. The findings show that Kuala Lumpur is a sprawling city. Suitable measures can be adopted by responsible authority to overcome urban sprawl issues in Kuala Lumpur. It is anticipated that this research will provide a new direction in urban sprawl studies and represent a robust analytic approach for characterizing urban development in the city scale at once as well as promoting a city via Remote Sensing and GIS technology.

Keywords: *Urban sprawl measurement, urban density index, Remote sensing and GIS*

1.0 INTRODUCTION

Accurate definition of urban sprawl although is debated, a general consensus is that urban sprawl is characterized by unplanned and uneven pattern of growth, driver by multitude of processes and leading to inefficient resource utilization (Mohd Noor et al,2013;Bhatta, 2010). Urban sprawl refers to the outgrowth of urban areas caused by uncontrolled, uncoordinated and unplanned growth. The inability to visualize such growth during planning, policies and decision making process has resulted in sprawl that is both unsustainable and inefficient. In other word, urban sprawl usually occurs when urban planning is not well managed, turns open spaces into built spaces, and, as a long term consequence, leads to negative effects on the environment, in particular soil sealing and pollution. For over the past three decades, urban sprawl and its impacts have attracted increasing attention from planners and policy makers (Frenkel and Ashkenazi, 2008; Frenkel and Orenstein, 2012), resulting in heated discussions on its definition, measurement, causes and negative consequences.

The methods to measure urban sprawl have been a hot issue of research. Many scholars tend to focus on using indicators to measure urban sprawl by establishing multi-dimensional indicators by GIS analysis or descriptive statistical analysis (Galster et al 2001; Barnes et al 2001; Ewing 1997). Sprawl can be measure in relative and absolute scales (Bhatta et al , 2010). Absolute measurements are capable to create a black and white distinction between a sprawled city and compact city. Relatives' measures in contrast, quantify several attributes of urban growth that can be compared among cities, among different zones within a city, or among different time of city. Many approaches have been used to quantify the sprawl and one of method has been suggested by Heargreaves (2014) in his article which concludes main components in calculating a sprawl was the density of houses and jobs. Density is considered as one of the essential components of measuring sprawl. Since density is a very complex concept and its measures vary in several ways, it is important to clarify certain points. Torrens and Alberti (2000) pointed out that the density level at which a city might be regarded as sprawling, the scale at which density should be measured, and the extent of space over which density should be clarified in determining how the relationship between density and sprawl should be evaluated.

The urban density index provides a measure of how much land is consumed per capita for a patch of new development. Low-density urban growth consumes more land for each resident added to a landscape thereby leaving less of the landscape able to function in other capacities. The density index is a function of new development patch size and number of residents. Density represents the amount of land occupied by a given number of residents. For the purposes of analysis the amount of land utilized for a new housing unit is utilized as a proxy for per capita development density. Lower density is indicative of more sprawling growth whereas higher density signifies less sprawling growth.

Information about unplanned settlements in developing cities is often unavailable, due to their rapid development and capacity constraints of planning authorities to keep track. There are still very few tools to assist in the identification of unplanned areas as well as monitoring their development (Kuffer and Barros, 2011). Therefore, there is a clear need for tools such as Geographical Information System (GIS) to be used with spatial databases from remote sensing data. Urban Density indexes seem to have potential to adapt in measuring a sprawl scenario in Malaysia. According to Majid (2011), as different types of sprawl are caused by different factors, different approaches are required to address them. Advocating for more compact development in order to address sprawl phenomenon in Malaysian cities, for example, may not necessarily work without first knowing the type of sprawl the cities are facing.

This paper aims to measure a density indexes in determining urban sprawl. It will examine the pattern of urban sprawl with measurement of geospatial indices on Urban Density using remote sensing and GIS techniques. An attempt has been made to find the best way to measure urban sprawl by using Urban Density spatial factors. The SPOT-5 with 2.5 meter resolution were used and combined with GIS database in order to detect sprawl by this indexes. Based on the calculated results, the researchers were able to identify an empirical metric for distinguishing urban sprawl from non-sprawl urban development using remote sensing and GIS data, to measure sprawl development based on the temporal using urban density indexes, and to identify the characteristics of urban sprawl in Malaysia.

2.0 STUDY AREA

The study area is located in Kuala Lumpur Metropolitan (3°8′51″N 101°41′36″E), Malaysia, which covers an administrative area spread over 24,221.05 hectares (figure 1). Majority of the land use patterns consist of built up areas (residential, industrial, commercial, institution, recreation area, road, infrastructure, and utilities) and un-built areas (agriculture, forest, bare land, and water bodies). Population of Kuala Lumpur was 1,600,000 in 2012 (Kuala Lumpur Local Plan, 2010-2015). To achieve better future urban development and infrastructure planning, it is crucial for the Kuala Lumpur City Hall to recognize sprawl phenomenon happening in Kuala Lumpur including on how to measure and determine urban sprawl factors and patterns in order to control its growth.

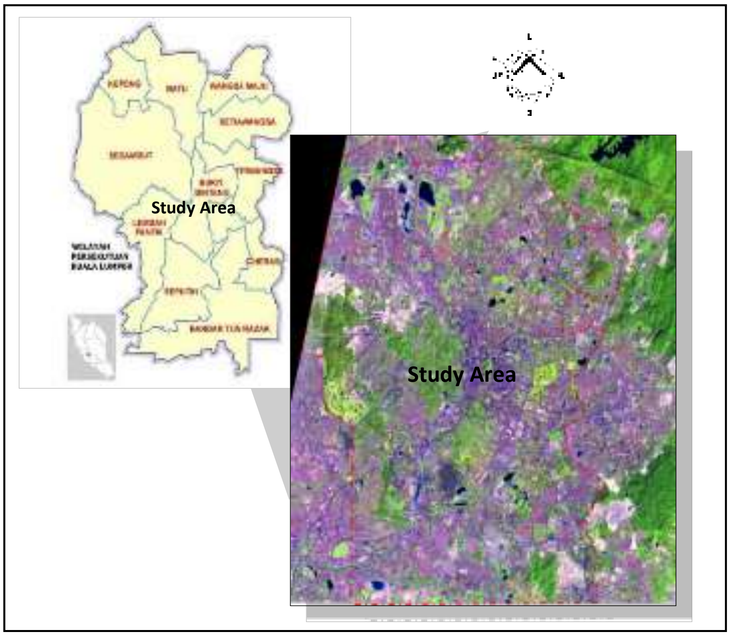

Figure 1: Location of study area – Kuala Lumpur District, Malaysia using vector and SPOT 5 (False color 4,3,2)

3.0 MATERIALS AND METHODS

3.1 Materials and Software

The primary research mainly depended on the data obtained from MACRES, Department of Survey and Mapping Malaysia (JUPEM), and local authority (Kuala Lumpur City Council). The satellite data were the primary sources while the ancillary data were the secondary data (Table 1). The satellite data included SPOT-5 images from 2012. On the other hand, the ancillary data consisted of topographic maps, land use maps, road map, contour line, and urban map. The software used to calculate and analyse the raw data, and to generate the results included ERDAS, ArcGIS, MapInfo, E-cognition and SPSS.

3.2 Methods

The image pre-processing and data preparation were carried out; these included image rectification and mosaicking. The image-to-map procedures were applied to the Spot 5 images using set of ground control point's area that appeared in the same place, both in the imagery and known locations in corresponding map and urban plan used as ancillary information in the rectification process. The rectified datasets were then mosaicked thus producing the entire study area from Vector Data images as supported data (Figure 2).

Image classification was then applied to the pre-processed image and the land use classes map of the entire study area was produced. Supervised classifications techniques were chosen for this study, which was performed using combination of ERDAS and ArcGIS software system. The system enabled land use to be classified and later merged accordingly to form the classes in accordance to urban land use classes used in urban planning practice. After completion of the training process, the entire knowledge on the class's occurrence within the SPOT-5 image was generated. The knowledge was then used to identify all the pixels in the image into the trained classes with multi-resolution segmentation approach. The classes identified were then recategorized into two main classes namely inbuilt and built up, apart from identifying them further into detailed of type of 11 land uses.

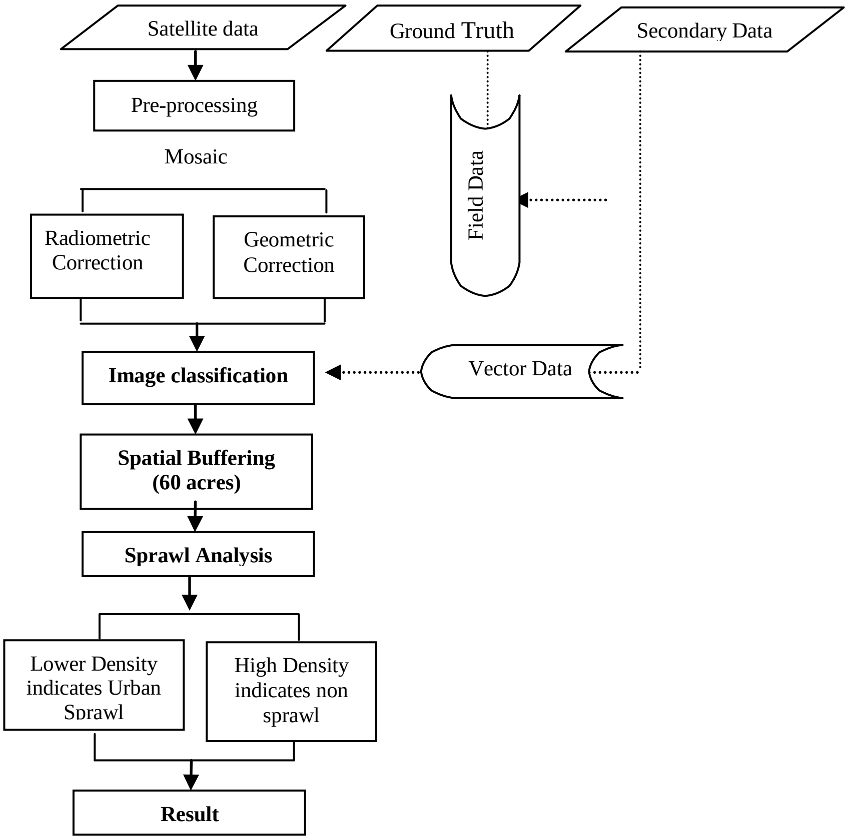

Figure 2: Flowchart of data processing adopted in the study.

The scenario of urban growth that occurred in Kuala Lumpur between year 1990 and 2000 was recognized and extracted from USGS quadrangle map. From each district, a new housing development within an urban growth was selected and parcelled with an area of approximately 60 acres. The area of each parcelled patches represent the density for each housing unit. The housing centroids were also assigned a municipal name field in the same manner. The average municipal housing unit value for urban density (mun UD) was calculated by utilizing the summarize function on the municipal name field of the residential unit table as depicted in Equation 1: (Hasse and Lathrop, 2003).

$$\mathbf{UDmun = (\sum DA_{unit})/N_{unit}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where **UDmun** is the Urban Density index for new urban growth within a municipality, DA_{unit} is the developed area for each new unit, and N_{unit} is the number of new residential units. Higher densities within development patches depict smart growth while lower density indicates sprawling.

4.0 ANALYSIS AND FINDINGS

A sets of SPOT-5 images were successfully geometrically corrected with transformed RSO coordinate with RMSE ± 0.5 pixels to ensure accuracy of the sprawl. In fact, this RMSE has been widely used as a good practice to ensure good geometric output apart from ensuring sound configuration of ground control point that is evenly distributed in the study area. Fill this imagery is also subject to image enhancement. The image classification was carried out in supervised classification steps process to produce first level classes of built and inbuilt areas, and further detailed land use classes within the built-up areas.

An old settlement area and five new residential areas were selected in each *district* of Kuala Lumpur city. Each area are approximately 60 acres consist of housing units. By using GIS, MapInfo and Remote Sensing applications, new development area was recognized and selected as study area. The calculation method is based on Hasse (2004) where to detect sprawl using Urban Density Index, the area for each new residential will be divided with total housing units. Higher density index result indicates development in the area as smart growth while lower density index indicates sprawling which proved wastage of land area has occurred.

Table 1: Percentages of distance in the measurement of Urban Density development

Housing Development Patches	Area (Acres)	New Housing Units	Density (housing unit/area)	Density Index (John Hasse)
Kampung Baru (Old Settlement)	60.75	291 units	4.79	0.209
Taman Melati	65.04	707 units	10.87	0.092
Sentul Selatan	61.16	226 units	3.69	0.270
Bangsar Baru	63.04	1035 units	16.41	0.061
Bukit Jalil	64.93	388 units	5.98	0.167
Bandar Tun Razak	62.61	843 units	13.46	0.074

The new development areas in this research are Taman Melati, Sentul Selatan, Bangsar Baru, Bukit Jalil and Bandar Tun Razak while the previous settled area was located in Kampung Baru. As compared to Hasse (2004), this research has selected an old residential area (Kampung Baru) and five new residential areas in Kuala Lumpur in order to compare the pattern of sprawl growth based on urban density Spatial Factors.

The result shows that by using geospatial indices on Urban Density development spatial factors in measuring urban sprawl of six housing area in Kuala Lumpur namely Kampung Baru, Taman Melati, Sentul Selatan, Bangsar Baru, Bukit Jalil and Bandar Tun Razak, the sprawl development growth in development area can be detected and measured. Based on Hasse and Lathrop (2003), calculation method to determine either sprawl or non-sprawl was based on housing area. Higher density index result indicates development in the area as smart growth while lower density index indicates sprawling which proved wastage of land area has occurred. The result in this study shows that the development of new housing area in Sentul Selatan is the most sprawl with the lowest urban density index (3.69) followed by Kampung Baru (4.79) and Bukit Jalil (5.98).

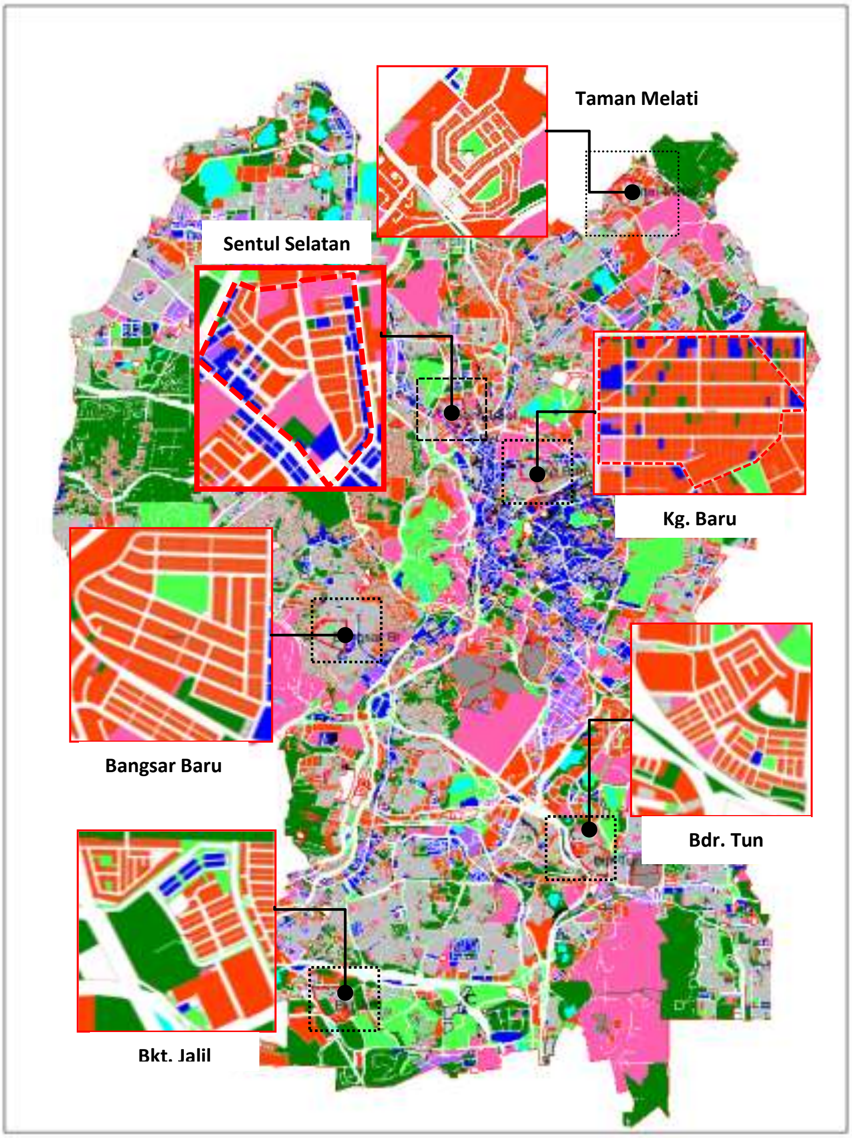

Figure 3: Measurement of sprawl by using Urban Density indexes.

Many factors has contributed to this scenario and the factors that has been recognized are lack of comprehensive planning (Ewing, 1997; Bose, 2011; Berkley, 2005; Striker, 2010;

and Sherman, 2011) which very much related to Kampung Baru and Sentul Selatan area and Consumer Preferences factor (Ewing, 1997; Bose, 2011; Berkley, 2005; Striker, 2010; and Sherman, 2011) where the development spread to the suburbs which the land is much cheaper and in this case, Bukit Jalil. Kampung Baru is one of the oldest settlement area in Kuala Lumpur same goes to Sentul Selatan which is adjacent to Kampung Baru. The old settlement area in Kuala Lumpur has been developed with uncontrolled and unplanned manners due to lack of town planning practice at that time. This situation has cause sprawl development occurred in the centre area of Kuala Lumpur.

While Bukit Jalil has considered as sprawl due to the availability of cheaper land as compared to the city centre. The development has move to the southern parts of Kuala Lumpur where people can have wider land with cheaper price and cause the low density for that area. Taman Melati has been categorized as less sprawl area (10.87) while Bandar Tun Razak (13.46) and Bangsar Baru (16.41) has been considered as Smart Growth due to its compact density index which indicates no wastage of land area. According to the Kuala Lumpur City Council Local Plan 2020, Taman Melati, Bandar Tun Razak and Bangsar Baru are new township which have been properly planned and developed. This scenario has reduced the sprawl growth based on urban density spatial factors. Even though this research has adopted the method by Hasse and Lathrop (2003), it is different by sample of calculation where Hasse and Lathrop (2003) calculate and compare the urban density index for townships in each district of a state. This study tents to focus on one district which is Kuala Lumpur where different area for each District was selected to be compared and analysed.

5.0 CONCLUSION

The complex nature of land use pattern in urban sprawl requires indicators to employ a multiple geospatial indicators. In this paper, researchers examined the most significant indicators related to urban density development city scale using remote sensing imagery data and GIS approaches.

Researchers realize the application of technology in city management is crucially needed since development of cities is moving rapidly in most developing countries. However, there are other possible indicators that have the potential for spatial analysis of urbanization in general and urban sprawl in particular. Urban Density development index provides a significant approach for identifying, comparing, and contrasting sprawl development in a more detailed manner for further investigation of the underlying process at play. As urban patterns for given region change with time, which are reflected in changing sprawl index value and its technological tools, they may give insights into the long term patterns, underlying process, and likely the consequences of spreading development compared to their smart growth analysis.

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