LAND USE SEGREGATION IN MEASURING URBAN SPRAWL USING REMOTE SENSING AND GIS

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ABSTRACT: The terms urban sprawl has decades-long history in academic discourse and yet there is surprisingly no commonly agreed upon definite of what exactly constitute urban sprawl. Characterizing urban sprawl using spatial measures requires a concise definition of what constitutes sprawling urban spatial patterns. This research tend to study the measurement of defining sprawl by using Land Use Segregation Index through remote sensing and GIS approach. The IKONOS pan-sharpened and Spot-5 with 1 and 2.5 meter resolution were used and combined with GIS database to analyze the geospatial indicators using the land use segregation index. In this research, Kuantan city has been selected as a study area to examine the Land Use Segregation development based on land use pattern for year 2012. The findings shows Kuantan has identified as non-sprawling cities with result from characterization in Land Use segregation that has been tested. However, the gap between sprawl and non-sprawling was very low. It is anticipated this research will provide a new direction in sprawl nationally that address finding of sprawl at the atomic level and present a robust analytical approach for characterizing urban development in city scale at once promoting a city via GIS& Remote Sensing technology respectively.

Keywords: *Sprawl Measurement, Land Use Segregation, Geospatial Indicators, Remote Sensing, GIS, Urban Sprawl*

1.0 INTRODUCTION

Urban sprawl which has become an issue for many rapidly developing areas refers to the uncontrolled growth of an urban area resulting from poorly or totally unplanned urbanization. A variety of definition of urban sprawl has been derived from different author to describe sprawl and as a specific form of urban development with low density, disperse, auto-dependent, environmentally and socially-impacting characteristic [1][2][3][4][5][6][7][12][19]. The rapid urbanization of wildlife habitat, watershed land, farm land and open spaces cause many unforeseen consequences including loss of prime farmland, loss of natural resources, increased environmental pollution, traffic congestion and many other physical, social and economy effect [2][3][8][17[18].

Ways to measure urban sprawl has been a hot issue of research. Remote sensing and GIS can be separately or in combination for application in studies of urban sprawl. Geographical information system (GIS) and Remote sensing data can supply physical, social and economic data for simulation [14]. There are some researches that using remote sensing and GIS to monitor and measure urban

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sprawl [9][10][11][13][16][20][21][22]. There is a strong need for better defining the term sprawl by measuring it, in order to focus specifically on the undesirable and problematic characteristic of development that many stakeholders arguing about.

In this research, an attempt has been made to find a good way measure urban sprawl by using one of the spatial factors which is land use segregation. The IKONOS Pan-Sharpened Images has been use together with the spatial factor formula for land use segregation in order to detect sprawl in the selected area. The calculation carried out based on GIS, the final results of analysis were visualized as maps. On the basis of the calculated result, researchers will be able to identify an empirical metric for distinguishing urban sprawl from non-sprawl urban development using remote sensing and GIS data, measure sprawl development between temporal using land use segregation spatial factors as well as identify the characteristic and qualities of urban sprawl in Malaysia.

Segregated land use consist of single used zoning in which large area of land are strictly confined to only one type of land use, such as residential or commercial [8]. The segregated land use index measure the degree to which land use is mixed at a pedestrian scale. It is a measure of the number of different types of land uses that are within reasonable walking distance to a housing unit. Nelessen (1993)[15] suggest that 1,500 feet (the distance that an average pedestrian will walk in 10 minutes) constitutes reasonable walking distance. The index was calculated by counting the number of different land use types within 1,500 feet of each housing unit as delineated in a land use map. The housing unit values were then averaged across the development tract. Tract of new urban growth with little or no alternate land uses within the pedestrian distance are considered sprawling whereas tract with variety of neighbouring land use are considered less sprawling or smart growth. Among these types, segregated land use seems to have a similar potential occurring on the land use development in Malaysia. This scenario can be seen in the development of a new town with central one type of land use especially in Pahang state. Therefore, this research is aimed to examine the problems of urban sprawl with measurement of geospatial indicators or segregated land use development using remote sensing and GIS techniques.

2.0 RESEARCH METHODOLOGY

2.1 Study Area

The study area is located in Kuantan district (03°52N, 103°17E and 03°45N,103°23E), Malaysia, covers an administrative area spreads over an area of 296,000 hectares. Majority of the land use pattern consist of built-up areas (residential, industrial, commercial, institution, recreation area, road, infrastructure and utilities) and un-build (agriculture, forest, bare land and water bodies). Population of Kuantan was 401,358 in the year 2003, and it is projected to be 241,197 in 2015, as per the present growth rate (Kuantan Local Plan, 2010-2015). For a better planning of future urban development and infrastructure planning, municipal authorities need to know sprawl phenomenon of Kuantan, its types, distribution, factors and in what way it likely to move in the years to come.

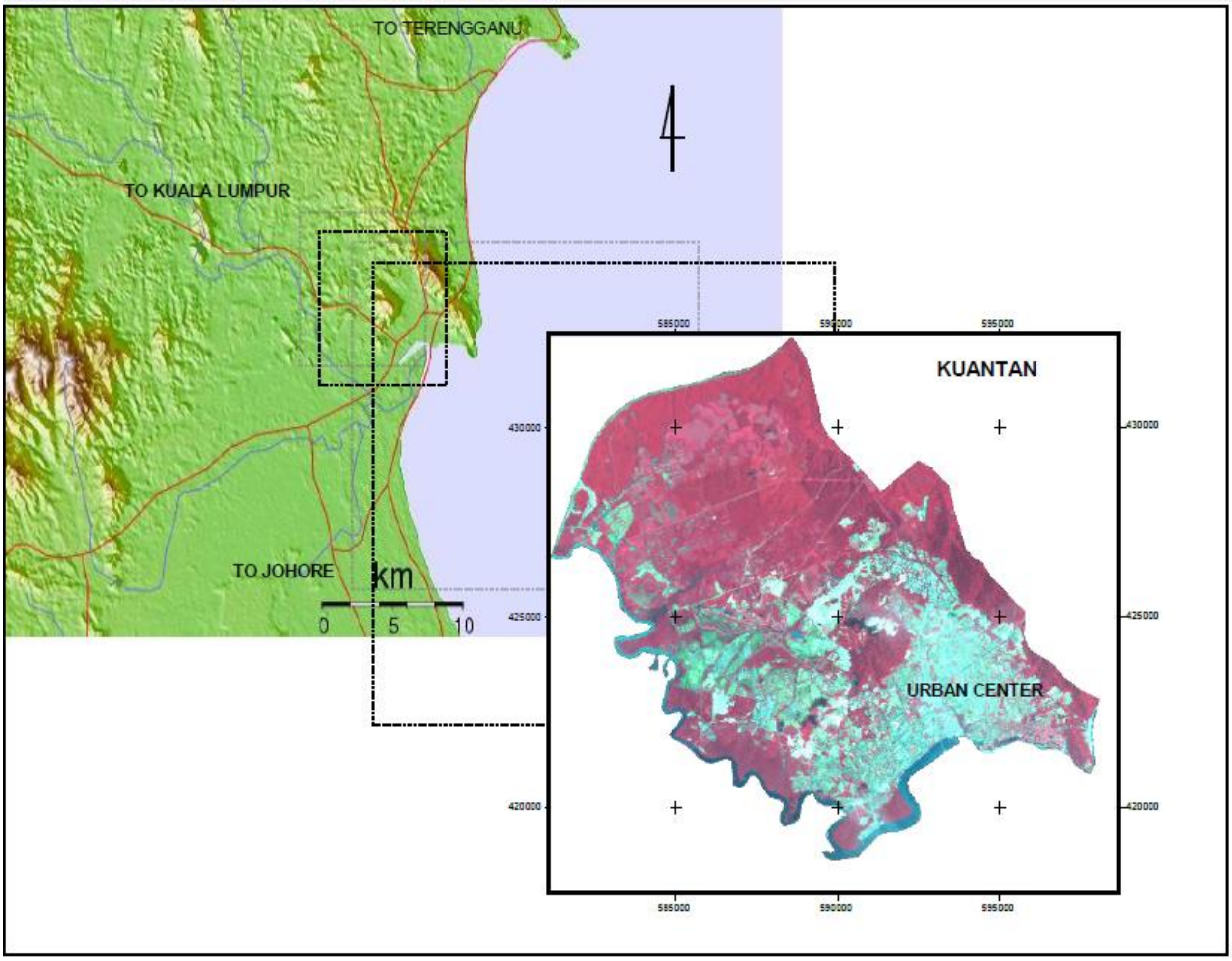

Fig.1. Location of study area – Kuantan District, Malaysia

2.2 Material & Methods

2.2.1 Materials and Software

The primary research will mainly depend on the supply of data from MACRES, Department of survey and mapping Malaysia (JUPEM), and Local Authority (Kuantan Municipal Council). The satellite and ancillary data has been collected from primary and secondary data sources (Table 1). The satellite data collected from primary sources includes IKONOS Pan-Sharpened and Spot-5 images from year 2011. The ancillary data from secondary sources consist of Topographic Maps, Land Use Maps, Road Map, Contour Line, Urban Map and Aerial Photograph. The software that will be used to calculate and analyze raw data and generate finding includes ERDAS, ArcGIS, MAPinfo and SPSS.

Table 1: Data Sources

Type Of Data Used	Year Of Acquisition/Publication
IKONOS Pan-Sharpened	2010-2011
Spot-5 images (20 sheets)	2006,2010,2011
Topographic Maps	2010
Land Use Maps	2010
Road Map	2010
Contour Line	2010
Urban Map	2010
Aerial Photograph (46 sheets)	1995

2.2.2 Methods

The image pre-processing and data preparation techniques are firstly carried out; these include image rectification and mosaicking. The image- to-map procedures has been applied to the IKONOS image using set of ground control points area appear 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 data sets are then mosaicked producing the entire study area from 1 set of the raw IKONOS data and 20 sets of Spot-5 images as supported data.

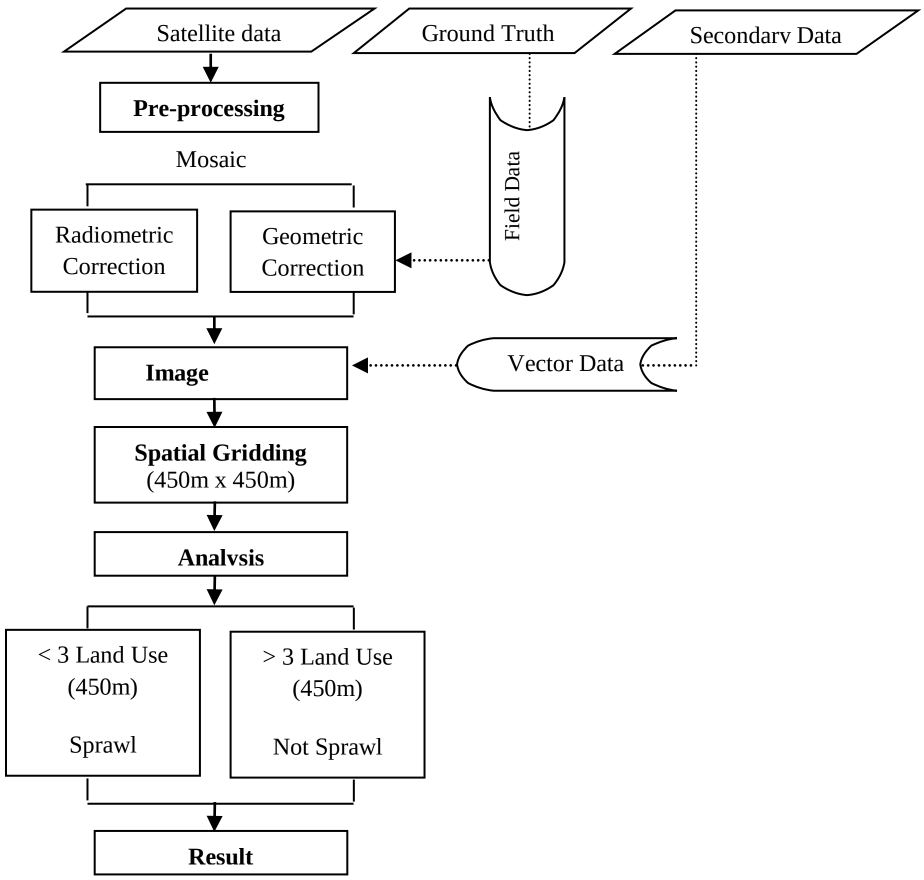

Fig.2. Flowchart of data processing adopted in the study.

Image classification is then applied to the pre-processed image, where the land use classes map of the entire study area is produced. The supervised classifications techniques have been choosen for this study, performed using object-based classifier using eCognition software system, which have enabled all fine details of land cover be classified, later merged accordingly to form the classes in accordance to urban land use classes used in urban planning practice.

In this study the object-based classifier is employed to build optimal training areas and build-up knowledge for each classes of interest prior to classification of the entire image. Initially, the algorithm trains the spectral classes by supervised training process, after collection of parametric and non-parametric signatures (training samples). After completion of the training process, the entire knowledge on the class's occurrence within the IKONOS image is generated. The knowledge is then used to identify all the pixels of in the image into the trained classes with multi-resolution segmentation approach. The classes identified were then re-categorized into two main classes of un-built and build-up, apart from identifying it further into detailed of type of 10 land uses.Then the grid will be set as 450m x 450m or 1500 feet x 1500 feet in the actual area.

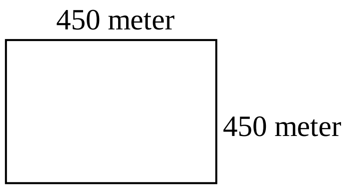

Fig.3. The Size For Gridding Process

The "mixed-use" urban category of the dataset was recorded to a value of 3 considered three different urban land uses. The three different categories of "single unit residential" (rural single unit, single unit low density, and single unit medium density) delineated in the dataset were recorded to a single class labelled "single unit residential" to compensate for the tendency of multiple single-unit categories to skew the results toward a higher land-use mixture than warranted. A neighbourhood variety calculation was performed on the gridded urban land use utilizing a radius of 1,500 feet (450 meters) to represent the pedestrian distance. This produced a grid surface where every cell was enumerated according to the variety or mixture of different urban land use categories within the search radius. The mixed and use surface grid was inverted to a segregated land use value where a higher value represents a greater indication of the non-mixed nature of sprawl. This was accomplished by subtracting the mixed-use grid from a constant grid with a value equal to 1 plus the most mixed grid cell occurrence.

3.0 Analysis and Findings

3 sets of IKONOS and 20 sets of Spot-5 imagery have been successfully geometrically corrected with transformed RSO coordinate with RMSE ±0.5 pixel to ensure accuracy of the sprawl. In fact this RMSE had been widely used a good practice in ensuring good geometric output apart from ensuring sound configuration of ground control point, evenly distributed in the study area. Fill this imagery also subjected to image enhancement respectively.

The image classification carried out in two steps process to produce first level classes of built and un-build areas, and further detailed land use classes within the built-up areas. Final classified image classes were tabulated as in Table 2.

Table 2: Land use classified for year 2010

Land Use Classes	Area (ha)	Percent (%)
Residential	9,795.40	3.31
Commercial	1,104.71	0.37
Industrial	3,056.70	1.03
Institution	3,904.42	1.31
Infrastructure And Utilities	1,636.50	0.55
Open Area And Recreation	2,406.42	0.81
Transportation	9,913.10	3.35
Forest	156,654.13	52.93
Agriculture/Plantation	90875.28	30.71
Vacant Land	11,914.18	4.03
Water Bodies	4,734.1	1.6
TOTAL	**296,000.000**	**100**

3.1 Analysis on Land Use Segregation

The land use was identified specifically in the Housing area [8] to know the urban sprawl pattern in the Kuantan city. If the land use in one grid is more than three, the area was considered as not sprawling while the converse result will be considered as sprawl area. The non-housing area was considered as neutral with no value which consists of Forest, Plantation and Institutional area. The other method is by using built-up area to detect sprawl, all grid in the built up area was selected and the similar method has been applied where the land use that is more than three was considered as non-sprawling area and less than that are sprawls.

Table 3: Percentages of Land Use in the Measurement of Housing and Measurement of Land Use

Location Based	Distribution of land use	Justification	Land use Zoning
Housing	<3	Proposed KuantanSentral	Residential Agriculture
		Kota Sultan Ahmad Shah	Residential Agriculture
		Taman Gelora	Residential Agriculture
	>3	Bandar Kuantan	Residential Commercial Infrastructure and utilities Institution Open Space and Recreational area Industrial
		Bandar InderaMahkota	
		Bukit Setongkol	
		Taman Kampung Padang	
Land Use	<3	Proposed KuantanSentral	Residential Agriculture
		Kota Sultan Ahmad Shah	Residential Agriculture
		UIAM	Institution

		POLISAS	Institution
		Semambu Industrial Area	Industrial Infrastructure
	>3	Taman Kampung Padang Bandar InderaMahkota Bandar Kuantan Bukit Pelindung	Residential Commercial Infrastructure and utilities Institution Open Space and Recreational area Industrial

The distribution of land use based on the measurement of housing shows that the sprawl area (<3 types of land use) mainly focus in the Proposed Kuantan Sentral, Kota Sultan Ahmad Shah and Taman Gelora while the measurement that based on built-up area show more area such as UIAM, POLISAS and Semambu industrial area. The area with more than three types of land use is Bandar Kuantan, Bandar Indera Mahkota, Bukit Setongkol, Bukit Pelindung and Taman Kampung Padang. Table 4 shows the highest number of land use type for both calculation methods are 4 to 5 land uses whole the lowest are 1,7 and 8 types of land uses.

Table 4: Percentages of Land Use based on Measurement of Housing and Land Use

Number of Land Use	Quantity (Housing)	Percentages (%)	Quantity (Land Use)	Percentages (%)
1	6	2.17	19	5.03
2	33	11.91	76	20.11
3	45	15.89	65	17.20
4	60	21.66	75	19.84
5	69	24.91	76	20.11
6	44	15.89	46	12.17
7	14	5.06	14	3.71
8	6	2.17	7	1.85
TOTAL	**277**	**100**	**378**	**100**

4.0 RESULT AND DISCUSSION

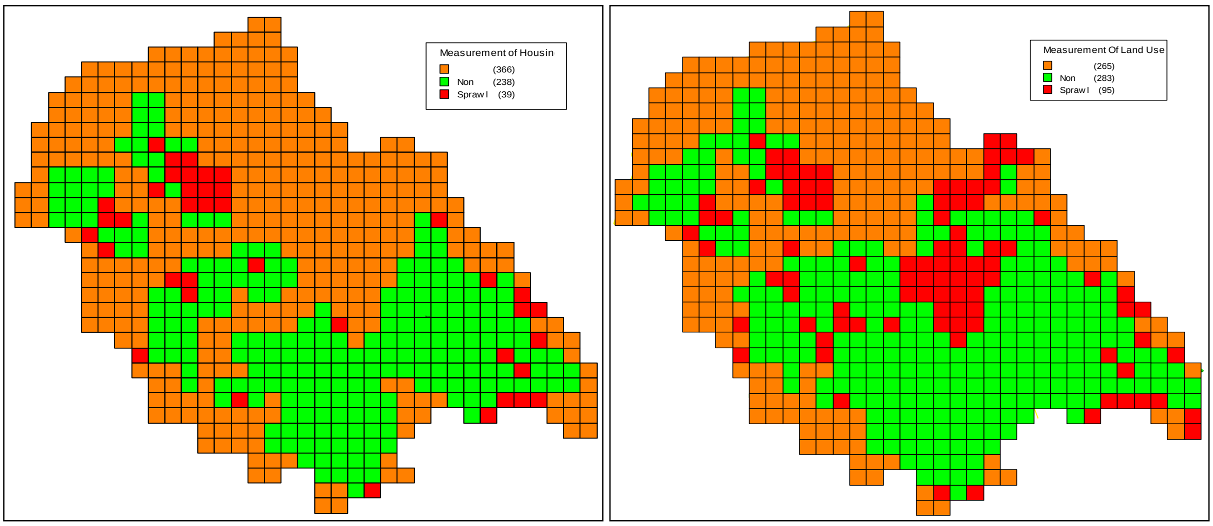

Fig.4. Measurement of sprawl based on (a) Housing; (b) Land use

Based on Hasse and Lathrop (2003)[8] calculation method based on housing area as the starting point, the development in Kuantan city was considered as not sprawling. However, in some area, the pattern of sprawl has started to develop and need to be cater so it will not become worst in the future. In addition, when the area being re-calculated by using built area as point of calculation, by assuming the grid with less than 3 land use are sprawl and the grid with more than 3 land uses are non-sprawl, the result shows an increase area for both sprawl and non-sprawl. This is because the majority of the institutional area consist only one or two type of land uses. The non-sprawling area also increases because there are other area which consist of more than 3 land uses type which are industrial area and commercial area.

Table 5: Measurement of urban sprawl based on a) Housing and b) Land Use.

RESULT		**QUANTITY**	**PERCENTAGES (%)**
Housing Area	Sprawl	39	6.1
	Non-sprawl	238	37.0
Non Housing Area*		366	56.9
TOTAL		**643**	**100**
Built Up Area	Sprawl	95	14.8
	Non-sprawl	283	44.0
Inbuilt Area*		265	41.2
TOTAL		**643**	**100**

** Not counted as area of sprawl*

5.0 CONCLUSION

The complex nature of land use pattern in urban sprawl requires indicators measures to employ a multiple geospatial indicators. In this paper we examine for the most significant indicators related to land use segregation city scale using remote sensing imagery data and GIS approach. We realize the application of technology in city management is crucial needed since cities were moving rapidly in the most developing countries. However, there are other possible measures or variation to the measures employed here that hold potential for spatial analysis of urbanization in general & urban sprawl in specific.

Land use segregation index provide 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, that reflected in changing sprawl index value and its technological tools may itself provide insight into the long term patterns, underlying process, and likely consequences of spreading development compared to its smart growth analysis.

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