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Kuala Lumpur City Growth Study through Remote Sensing and GIS

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The city of Kuala Lumpur has become one of the most vital cities in Asia. It has booming economy and the vitality of expanding cities. During the last three decades growth in population, industry and economic activities has been strongly concentrated in Kuala Lumpur metropolitan area. Urban growth is characterized by significant gains in urban/built-up areas at the expense of green or open spaces. In this study, the urban/built-up land-cover class is defined as areas dominated by buildings, asphalt, and concrete, including residential, commercial, industrial, and transportation space [1]. Other types of urban land-use, such as golf courses and urban green parks, are not included in the urban/built-up class. Urbanization studies are useful to planners who seek to avoid the irreversible and cumulative effects of urban growth and to optimize the allocation of urban services [2,3]. Furthermore, such information is indispensable for the assessment and evaluation of sustainable urban and environmental planning strategies [4,5]. Land use planning is an integral part of the viability and live ability of a metropolitan area because it affects decisions about where and how we live. Over the last few decades, government agencies and local councils in different countries have been continually developing and adopting land use planning strategies to contain and manage urban growth [6]. Such as 'Smart Growth' in the United States, and the 'compact city' and 'intensification' in Europe, were devised and adopted to regulate and contain urban sprawl. A 'paradigm shift' in urban policy development can be seen as indicated by drastic changes in policy that has favored counter-urbanization over suburbanization, in Australia. There are few other studies such as [7] who focused his attention on Al-Ain in the United Arab Emirates. In another study, [8] used available maps, aerial photographs, and satellite images covering the period between 1950 and 2003 to study the city of Muscat in Oman.

In the past few years, significant research has been carried out on the use of satellite data and GIS for measuring city growth and sprawl development patterns. [9,10] conducted a comprehensive study on urban land cover dynamics using remote sensing data for the development of spatial (landscape) metrics that were analyzed and interpreted in conjunction with results from the spatial modeling of urban growth. Remote sensing provides spatially consistent data sets that cover large areas with both high spatial detail and high temporal frequency. Dating back to 1960, remote sensing can also provide consistent historical time series data. The importance of remote sensing was emphasized as a "unique view" of the spatial and temporal dynamics of the processes in urban growth and land use change [10,11]. Satellite remote sensing (first Landsat mission 1972) techniques have, therefore, been widely used in detecting and monitoring land cover change at various scales with useful results [12-14]. Recently, remote sensing has been used in combination with Geographical Information Systems (GIS) and Global Positioning Systems to assess land cover change more effectively than by remote sensing data only [14,15]. It has already proved useful in mapping urban areas, and as data source for the analysis and modeling of urban growth and land use/land cover change [16-18].

Post-classification refinement was used to improve the accuracy of the classification. In addition, because the urban surface is heterogeneous with a complex combination of features (buildings, roads, grass, trees, soil, water), mixed pixels and the salt and-pepper effect are common problems when using medium spatial resolution data, such as Landsat [19]. In this step, a 3 * 3 majority filter was applied to all the classified land covers [19].

This research is focused on urban built-up and urban vegetation coverage measurement and their interactions. Grassland is considered to be both non-urban vegetation and forest area. Furthermore, water bodies have very limited coverage and, along with bare land cover, are not discussed further in the results and concluding sections. The maps produced are presented in (Figure 1).

After classification multi-buffer rings are created for every 1 km distance from 1 to 50 km from city center to outside. Then the intersection with classified maps for all three dates is performed. Later on all classes' area are measured for 1 to 50 km distance and derive density according to following formula:

$$\text{Urban density} = \frac{\text{Sattlement area / ring}}{\text{Total ring area}}$$

There are several major trends evident in the changes of land-cover that are consistent over the period 1989 - 2014. The urban/built-up area increased rapidly, and there was a mark able decrease in other classes. The final 4 categories in the land-cover maps were forest, urban/built-up, agriculture, and water (Figure 1). Some interesting patterns in the distribution of city across different buffer zones can be noted in Figure 1. As expected, the density in Kuala Lumpur tends to decline outward from the city center. According to the land use/cover maps produced, the total built-up area for 1989 was 456.99 km^2. This increased to 1098.48 km^2 by 2001, and finally reached 1663.23 km^2 in 2014. The urban/built-up area has expanded by factor four over the past 3 decades, increasing from 51.81% of the study area in 1989 to 60.22% in 2001 and finally 64.36% in 2014, while the area of agriculture land decreased from 39.16% in 1989 to 28.53% in 2001 and 27.06% in 2014. The area of forest has first increased from 7.99% to 10.35% from 1989 to 2001 and later on has been reduced 8.13% in 2014. In contrast, the area of water was 1.04% in 1989, 0.91% in 2001, and 0.45% in 2014.

City density patterns around the center were also examined to ascertain whether different zones/rings have represented different densities. Figure 2 show 50 buffers from 1 to 50 km. It is argued that the first 20 zones/rings represent the areas that are within walking

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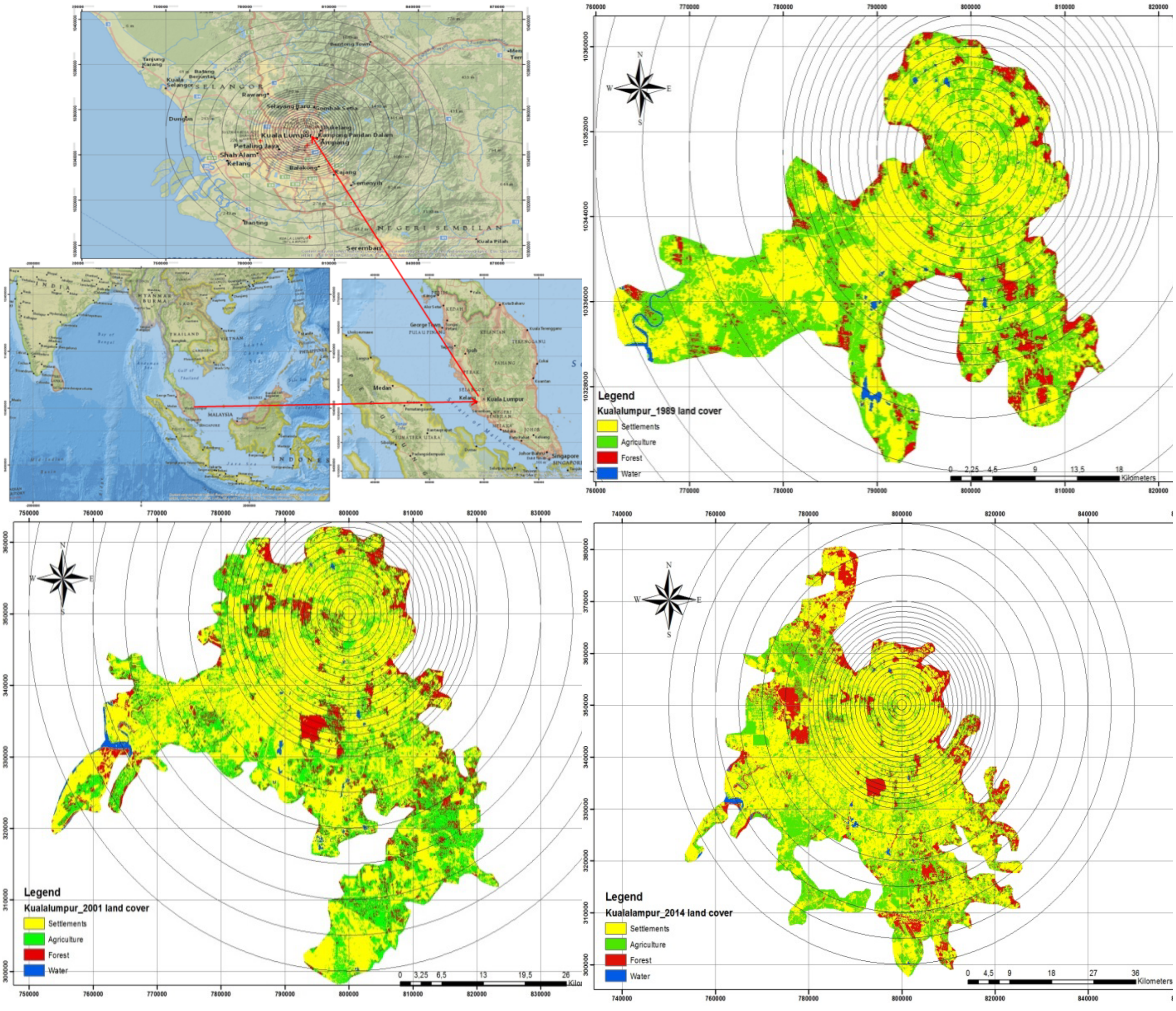

Figure 1: Study area and multi-buffer ring zones around city center of Kuala Lumpur for 1989, 2001 and 2014 map.

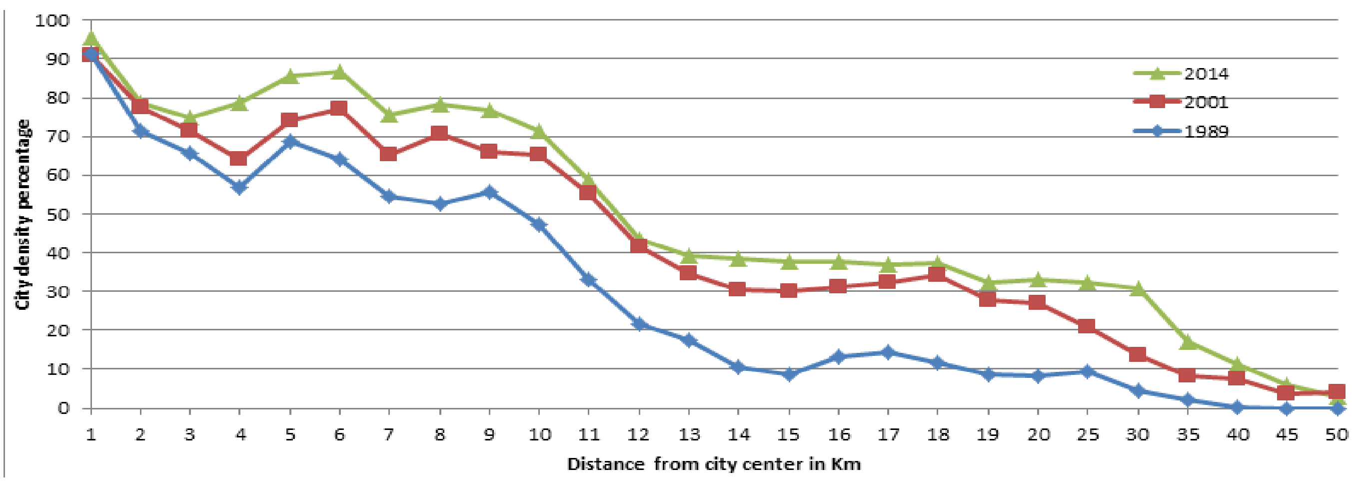

Figure 2: Kuala Lumpur city density from 1 to 50 km distance for 1089, 2001 and 2014.

distance from center. High-density development has been supported by the government to encouraged people to walk to train stations or other destinations such as shopping centers. This policy has in part been pursued to encourage active transport as part of a healthy lifestyle.

Results show that within the city centre urban density was more than 90% for last three decade. In 1989 it has been reduced dramatically on distance of 5 km from city centre around 55% and on 15 km less than 10% and after 40 km it`s 0%. Comparing 1989 and 2014 on distance of 5, 8, 15, 20 and 30 km, the city density has increased by a very high pace. In comparison of 1989 and 2001 on the distance on 8, 15 and 19 km, the city density has been again highly increased. From 2001 to 2014 on the distance of 4 and 30 km density was has continuously increased. On distance of 50 km the city density was found to be 0% in last 3 decades. For the whole 3 decades city density was dramatically reduced on distance of 20 km and later on has been stable (Figure 2).

The census data indicate that the main phase of population growth in Kuala Lumpur occurred between 1989 and 2001. The main causes of this growth were a high birth rate in the early years, rural to city migration, and the merging of nearby villages with the city as it developed. Urban expansion and subsequent landscape changes are governed by geographical and socio-economic factors, such as population growth, policy, and economic development. In most cases, urban expansion and associated land use/cover changes resulted from a combination of these factors. For example, socioeconomic policy can strongly affect urban expansion, and under the changes driven by urban expansion, the land use patterns of the urban outskirts are altered or adjusted in pursuit of high economic returns (orchards or croplands changing to vegetable land). Even though it is difficult to clarify the influence of these factors in these changes, their influence was examined by analyzing the relationships between developed area (including urban and residential area) and socioeconomic factors, such as, population, industrialization, traffic conditions, and infrastructure.

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