GIS ASSISTED LAND USE STRUCTURE CHANGE ANALYSIS IN THE COLOMBO DISTRICT, SRI LANKA

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ABSTRACT

Rapid urban growth has led to massive urban agglomerations that threaten sustainable development. Ultimately, this high urban concentration gradually expands outwards, in either a haphazardous or a planned manner. The process occurred in a general pattern but the implications were so extensive that continuous changes occurred in urban areas. These spatial changes were happen due to physical processes, which occurred over a long duration showing continuous spatial changes in a temporal manner. Urban growth can be considered as a spatial-temporal process. In many instances, this growth is uncontrolled and dispersed and this is likely to impede sustainable development. Hence, urban land use structure is so complex and analysis of this landscape structure is significant for urban planning. A quantitative and qualitative analysis of the landscape structure is needed to understand the patterns of land use change. Landscape metrics or spatial metrics is one of the reliable methods for this purpose. Spatial metrics is based on the geometric properties of the landscape, and it is generally used to measure different aspects of landscape structure, spatial pattern, and their spatio-temporal variances. Colombo is the most urbanized district in Sri Lanka and its land use gradually face changes. Hence, this research aims to identify land use structure change pattern in the Colombo district using GIS based landscape matrices. Results contribute to the discovery of significant facts about interpretation of urban land use using selected spatial matrices.

KEY WORDS: Urban Growth, Spatial Metrics, Lands Structure, Spatial Changes

1. INTRODUCTION

Urbanisation and urban growth are common phenomena throughout the Western and the Eastern worlds. In 2018, 4.2 billion people, 55 percent of the world's population, lived in cities. By 2050, the urban population is expected to reach 6.5 billion while in the developing countries the figure is around 52%. This indicates that currently more than half of the world's population is urbanised (United Nations, 2018) and the current decade shows higher urban densities in the mega cities of the world compared to previous decades. Instead of that, rapid economic growth of cities created fresh employment opportunities and that attracted an additional commuting population to the city. The development of road networks and public transport facilities encouraged the influx into the city of a commuting population that was accommodated in the urban fringe areas. This process created new demand for housing and other services in the fringe and the fringe responded by increasing the supply of land by the simple expedient of converting agricultural land to non-agricultural uses without proper planning. This continuous growth process creates an uneven growth pattern haphazardly change land use pattern from rural to urban uses. Measurement of this dispersed urban land use changing pattern is a challenging task. In many instances, this growth is uncontrolled and dispersed and this is likely to impede sustainable development (Bhatta, et.al.,2010).]. Landscape metrics or spatial metrics is one of the reliable methods for this purpose. Spatial metrics is based on the geometric properties of the landscape, and it is generally used to measure different aspects of landscape structure, spatial pattern, and their spatio-temporal variances (Ramachandra et.al.2012;Herold et.al.,2003; Weerakoon ,2017).

Spatial metrics are based on landscape patches and the patches are defined as homogenous regions indicating a specific landscape property of interest. Spatial matrices were used to quantify the transformation occurring among different land use categories and the major "sources" and "destinations" of new and disappearing land [Liu et.al.,2010]. In addition, they provide more spatially consistent and detailed information about urban structures with the temporal changes, while facilitating improved representation to provide a better understanding of the homogeneous and heterogeneous characteristics of urban areas. Most scholars use a number of spatial indices to analyse and classify urban form (Ramachandra et.al.2012; Parker et.al.,2001). Those who computed using patch based indices like size, edge length, patch density, and fractal dimension have endorsed the usefulness of spatial metrics for urban modelling [Parker et.al.,2001; Weerakoon,2017]. In fact, several scholars have applied spatial metrics with time series data to analyse urban growth (Nong & Du, 2011); (Ramachandra & Athul.2012);Angel et al. (2007). Hence, suitable adaptation of appropriate metrics could prove effective for showing complex urban spatial variations using available data. This technique appears capable of yielding significant results. This research aimed to measure, land use structure change in the Colombo district using a selected case study area.

2. DATA AND METHOD

Aerial photographs, digital maps, IKONOS images were used to prepare 4 land use maps for 1972, 1984, 2004 and 2014. Aerial photographs, IKONOS images, and digital maps scales and sources are shown in Table 1.

Table 1 Preliminary Data

Data & Year	Scale	Coverage	Map Source
Aerial Photographs (1972)	1: 20000	100%	Survey department
Aerial Photographs (1992)	1: 20000	100%	Survey department
IKONOS Images (2003, 2005)	1 meter resolution	100%	Internet
Land use map 2002	1: 2000 GIS file (shp)	100%	UDA
Land use map 2013	1: 2000 GIS file (shp)	100%	UDA
CMR Structure plan 1996-2020	1: 50000	100%	UDA
Sub District boundary	1: 2000	100%	Survey department

Herold et al., (2005) conducted a study that attempted to analyze urban change in Santa Barbara using remote sensing images and spatial matrices. The study used values of six different matrices with a series of land use data collected at different times. Furthermore, two spatial matrices were used to analyse spatio-temporal growth in the case study area at four different periods; namely, urban patch density and Area Weighted Mean Patch Fractal Dimension (AWMPFD). Figure 5.11 shows the results obtained with these spatial matrices with total urban area, number of individual urban patches and percentage of large urban area in largest urban patch. These spatial matrices were calculated from urban areas extracted from aerial photographs, IKONOS images and spatial data.

3. STUDY AREA

Sri Lanka is positioned in the Indian Ocean, located very close to the Southern strip of the Indian subcontinent, lying between Northern Latitudes 5°55’ and 9°50’ and Eastern Longitudes 79°42’ and 81°52’. The land area of Sri Lanka is 65,610 sq. km., with an overall length of 432 km, width of 224 km. Sri Lanka is divided into nine regions (or provinces) for administrative purposes, and the Western Region is the most urbanised of them which comprises 5.6% of the total land area of the country. The Western Region consists of 3 districts, namely, Colombo, Kalutara, and Gampaha. Colombo is the most urbanised district in Sri Lanka and consist of high urban growth. It contains 77.5% urban population in the country.. Out of 13 local authorities in the Colombo District, one local authority area (located in the urban fringe) called Kaduwela Municipal Council (KMC) was selected as the study area for land use structure change analysis.

Kaduwela is the only Municipal Council located in the urban fringe. This administrative unit was newly established as a Municipal Council in 2012, and it used to be a local council (Pradeshiya Sabha) prior to that. Two thirds of the area show urban-rural mixed land use. It recorded a population growth rate of 2.01% per annum during the period 2001-2012 (census and Statistics 2012). Kaduwela Municipal Council (KMC) shows multiple land use patterns among their 3 sub-units One shows predominantly urban features and others shows predominantly rural features. Last decade many development activities implemented this area and land use highly change due to high urban demand. Three major town centres are established in this area and commercial and trade activities taking place, with other start-ups clustered around in a concentric pattern. As a result, the signs of a rapid conversion of a rural environment into an urban environment are visible in the whole area. The topography of the Colombo urban fringe has a gradual slope and in KMC the slope is at a high elevation in the South and a low elevation in the North. The Kelani River flows from East to West along the Northern boundary of the KMC. The lowest elevation is the bed level of Kelani River, which is about 6m below Mean Sea Level (MSL). The bank level is about 6m above MSL and the highest elevation is about 150m above MSL (Environmental Improvement Master Plan, 2002).

Figure 1 Location of Case Study Area

.Important physical characteristic of the area is the depth of the water table. Generally, the water table depth was very shallow, lying between 0 and 1 meter below the ground surface over more than 60% of the total area. It causes to considerable area prone of floods in the rainy season. Paddy fields, water bodies, and marshy areas account for a considerable extent of the shallow water table in the entire KMC. Within the municipal limits, 30% of the total area has a water table depth between 1m and 5m below ground level and 10% of the area has a water table depth of more than 5m below ground level. In the 1970s and earlier, Most of the low-lying areas were used for mining earth for making bricks. Later however, with the commencement of new development projects, urban expansion began in earnest as accommodation and living facilities had to be provided for the influx of people into this area.

3.1 Spatial Variations of Population

The census figures of 2001 and 2012 were used to analyze population variations in the study area. In 2012, the total population in KMC was 252,100, showing an average annual growth rate of 2.01% from 2001. There were some variations within the small administrative units during the two different periods and these can be seen clearly in the population density surfaces created, which meaningfully illustrate the density variations (Figure 2). This map shows the population growth direction of Kaduwela MC and it indicate growth direction moves from the West to the East.

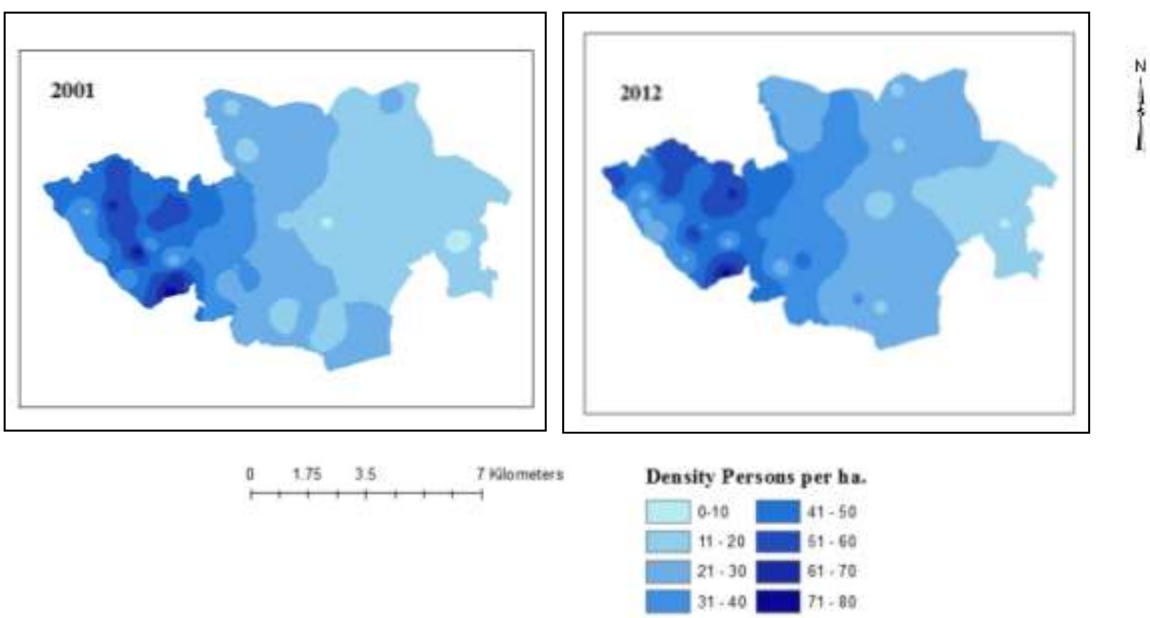


Figure 2 Population Density Variations

3.2 Spatial Variations of Land Use Pattern (1972 to 2014)

The land use maps of 1972, 1984, 2004 and 2014 were considered for analysis. The 1972 land use map was prepared using aerial photographs of 1972. The land use maps of 1984, 2004 and 2014 were developed by the Urban Development Authority via the aid of spot images and considerable fieldwork. Hence, the best possible accuracy has been achieved in this research. The case study area map consist of 27 distinct types of land uses. For analysis purpose the land use was classified into six categories, namely urban built-up, low residential, agricultural, green areas, water bodies and other uses.. Classification of Urban built up category is more complex and changes show in the images were compared physically in the field observations, Interviews and secondary data. . The classified land use maps are shown in Figure 3

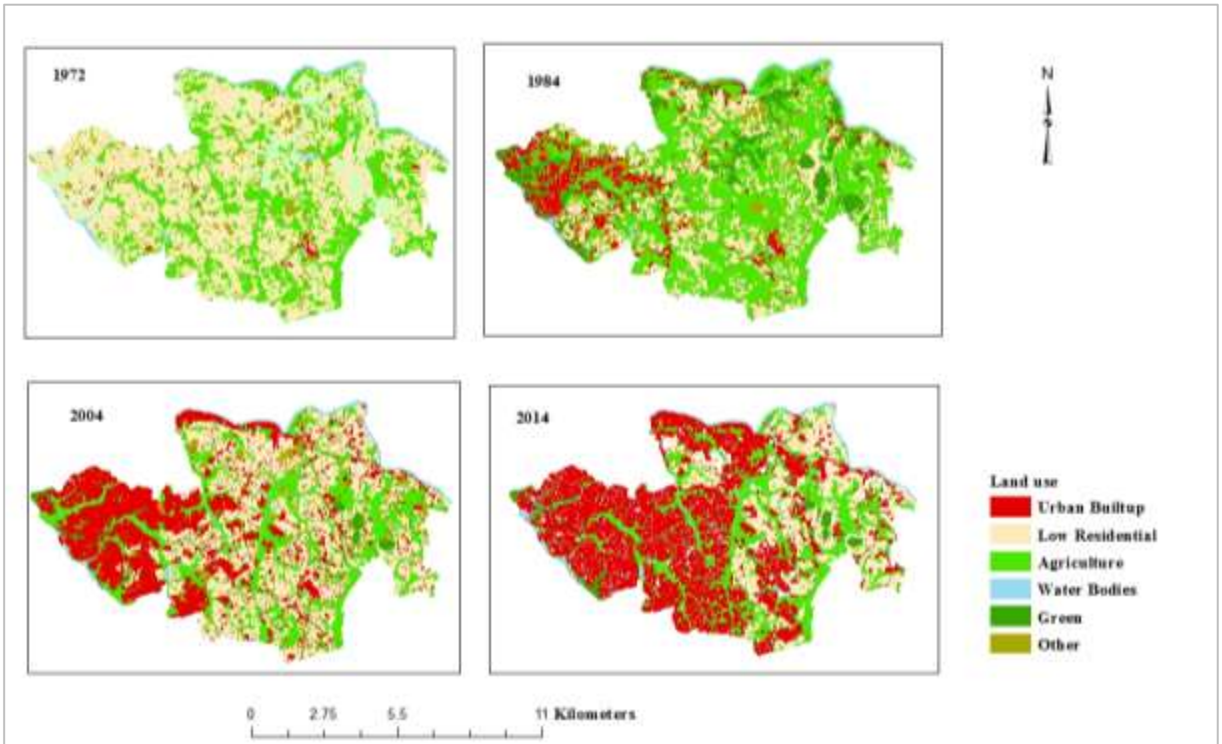


Figure 3 Land use Kaduwela from 1972 - 2014

On the basis of population density, housing density and field observations, urban built-up areas were identified. In addition to that IKONOS images and google images were used to verify the urban built-up areas on the ground. All images and digital maps were geo-referenced in the SL95 local coordinate system and superimposed. For visual interpretation of maps, an on-screen digitising method was used in an ArcGIS 10.2 environment. A careful scrutiny of the maps will show three types of growth patterns such as ribbon development, urban nodes and infill growth. The extents of land use and the land use change Indices for the six classified land use categories are given in Table 2 and Table 3, respectively.

Table 2 Land Use Pattern Kaduwela - 1972 to 2012 (extent in hectares)

Year	Urban	Low Residential	Agriculture	Green Area	Water bodies	Other
1972	270.95	2632.81	4163.21	801.92	213.85	326.73
1984	818.01	2331.46	4005.81	729.88	213.85	310.46
2004	2527.21	2173.99	3057.1	136.65	213.85	301.27
2014	4140.44	1389.94	1993.66	183.61	256.25	445.19

This is a significant change compared with the other land uses though it showed a gradual increase. Table 3 shows LUCI, and the LUCI from 1972 to 1984 and 2004 to 2014.

4. DATA ANALYSIS

4.1 Land use change Analysis

Table 3 shows land use structure change index**.** It indicates results in the land use changes in different land uses in the four different periods.

Table 3 Land Use Change Index (%) for Different Land Uses

Year	Urban	Low Residential	Agriculture	Green Area	Water bodies	Other
1972	-	-	-	-	-	-
1984	5.14	-0.99	-0.3	-0.75	-	-0.4
2004	3.22	-0.66	-1.48	-39.46	-	-0.28
2014	3.54	-4.33	-4.8	1.96	1.27	2.93

The land use change index during the period 1984 to 2004 decreased from 5.14 to 3.22. Civil disturbance in the country during this period was one of the reasons for the decrease in the LUCI. However, when compared with the 2004 figure, it had slightly increased to 3.54 in 2014. Low residential use showed a steady decrease from -0.99 to -4.33. During this period agricultural uses had significantly reduced from -0.3 to -4.8 annually. During 2004 -2014 green areas and water bodies had increased in extent, as a consequence of newly introduced recreation and 'green' projects. 'Other uses' also showed an increasing pattern.

4.2 Urban Expansion from 1972 to 2014

The urban built-up area from 1972 to 2014 was extracted from the land use maps depicted in Figure 5.7 and the extracted urban area maps are shown in Figure 4.

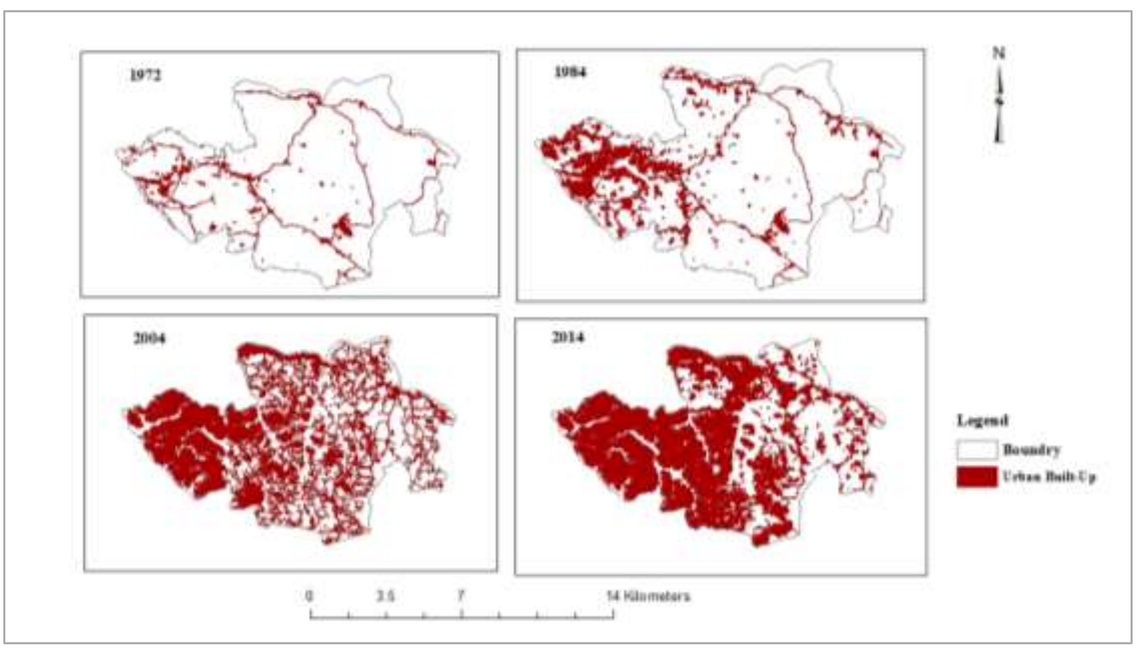


Figure 3 Urban Builtup Changes from 1972 to 2004

The map in Figure 5 shows the urban growth and its direction at various times, but the overall growth has taken place from West to East.

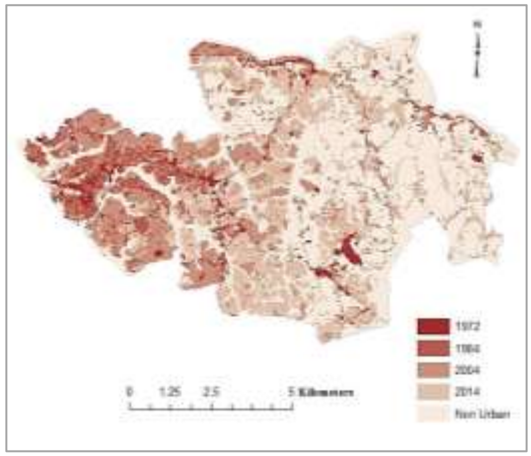
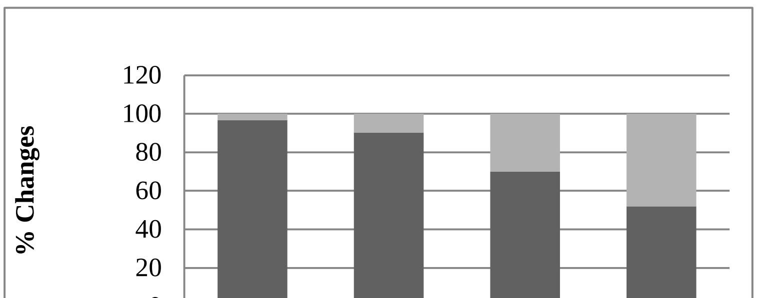


Figure 5 Urban Built-Up Area 1972 to 2014

The nature of expansion in 1972 indicates a linear development and in 1984, urban expansion shows a scattered growth pattern. In 2004, shows a different pattern with the western part of the study area showing infill growth while other parts show a scattered growth. However, in the latest situation illustrated in the 2014 map, 66% of the area shows a high infill growth and the remaining areas shows a scattered growth. Percentage change of urban and non-urban land uses shows in Figure 6.



	1972	1984	2004	2014
Urban	3.22	9.73	30.05	48.09
Non urban	96.78	90.27	69.95	51.91

Figure 6 Urban Expansion

According to that, urban built-up in 1972 was 3.22% and in 2014 it increased to 48.09% which reflects a 16 times increase. Commensurate with that, non-urban uses are decreased.

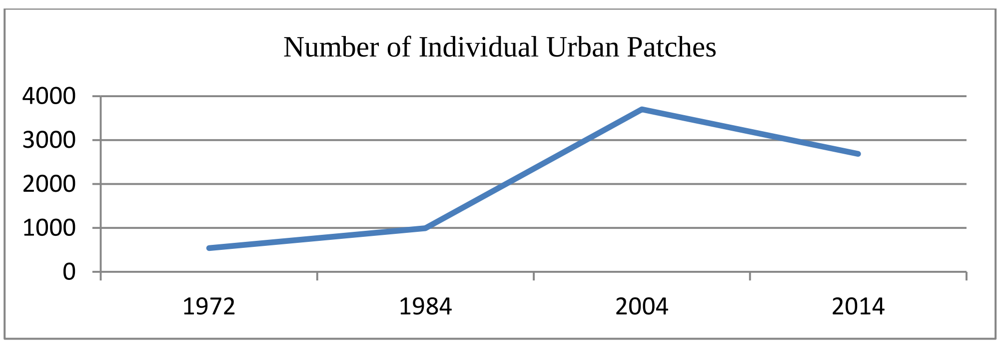
Table 4 presents the exploration of population growth and urban growth According to Table 4, the annual population growth rate for this period was 2.49% and during the same period, the annual urban area growth rate was 2.33%. Hence, the population growth rate was somewhat higher than the urban growth rate. The population density during the same period increased and it included the non-urban areas too. It increased by up to 13 persons per ha. Most people in this area engaged in non-agricultural activities and the employment rate in 2012 was indicated as 92% (Census and Statistics, 2012). They worked in the main city and surrounding towns with fewer people engaged in the agricultural sector. Many were engaged in the brick making and quarry mining occupations.

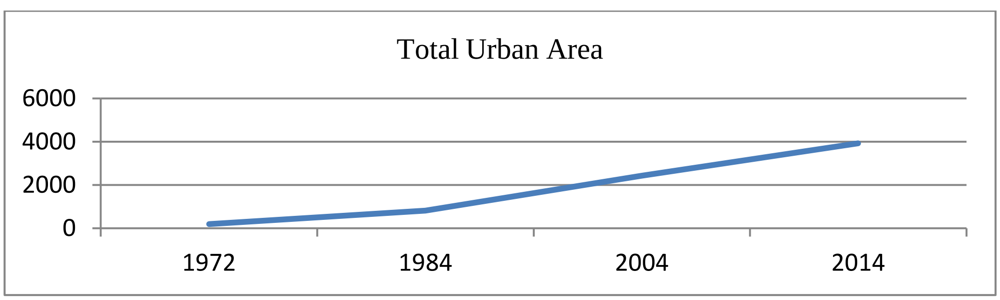
Table 4 Population Growth and Urban Growth 1972 - 2012

Population growth	
Population 1972	126,053
Population 2012	252,100
Net growth	126,047
Change	99.9%
Annual Growth rate	2.49%
Urban Area Growth	
Urban Area 1972 (ha)	270
Urban Area 2012 (ha)	4140
Net growth (ha)	3870
Change	93.5%
Annual Growth Rate	2.33%
Population Vs total Area (persons per ha)	
Population Density 1972	15
Population Density 2012	28
Change (persons per ha)	13

4.3 Analysis of Land use structure change

Changes of land use structure was measured using spatial matrices. It provides a unique insight about how various spatial characteristics of cities change over time. Two spatial matrices were used to analyse land use structure at four different periods; namely, urban patch density and Area Weighted Mean Patch Fractal Dimension (AWMPFD). Figure 7 shows the results obtained with these spatial matrices with total urban area, number of individual urban patches and percentage of large urban area in largest urban patch.





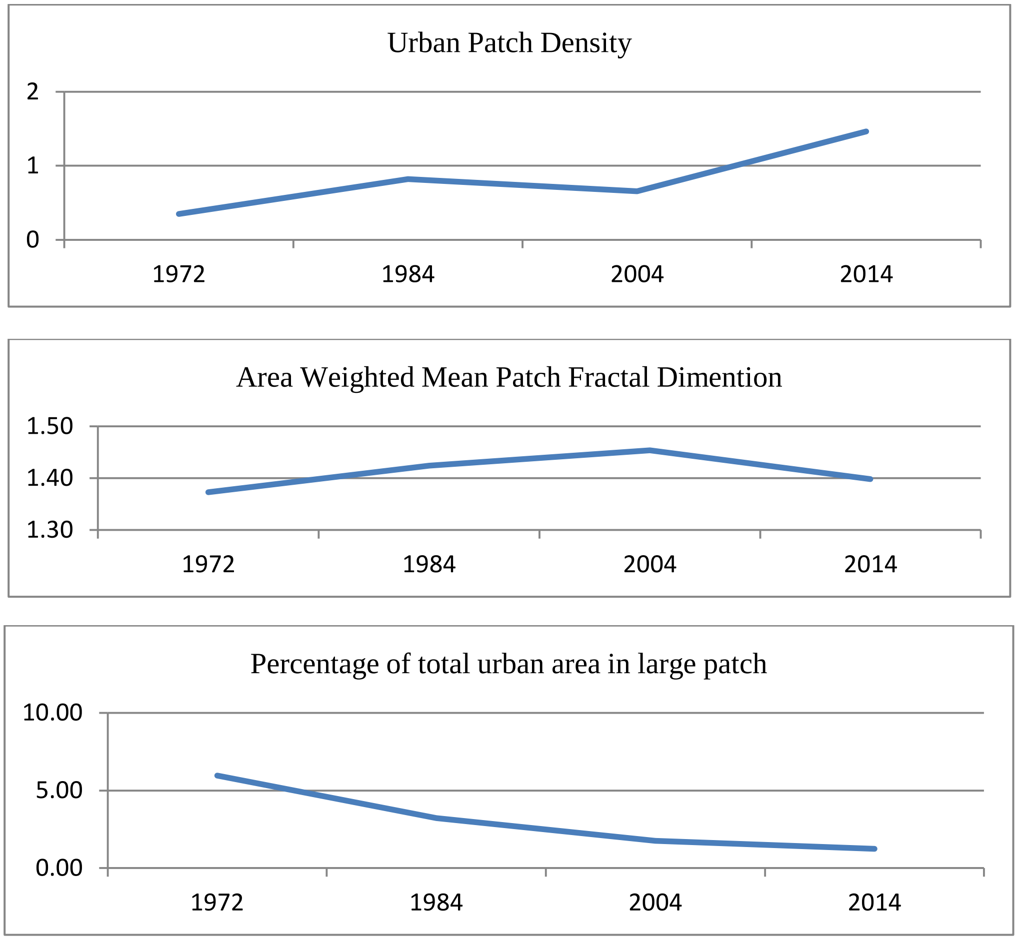


Figure 7 Analysis of Urban Structure Change in the Case Study Area

The above spatial matrices show the periodical expansion of the urban category in the case study area. Accordingly, the urban patches have continuously increased in number from 1972 to 2004 and this shows that the total urban area has increased due to individual development of urban lands as well. However, after 2004 the pattern changed because despite the increase in urban area the number of individual urban patches had decreased due to high infill growth of urban category. However, patch density shows normalisation of individual urban patches compared to total landscape area. Therefore, the figure of patch density shows a clearer picture than individual urban patches. Hence, in 2004, patch density decreased and after that, it again increased. This indicates that though there was a decrease in the number of urban patches after 2004, when compared with the total landscape it had undergone a net increase. AWMPFD shows fragmentation of urban area. It had continuously increased from 1972 to 2004 and then decreased. It means that from 1972 to 2004 many individual urban patches had grown together due to high land fragmentation. The final graph shows percentage of urban area compared with large urban patch and it indicates a decreasing pattern.

5. Conclusion

Land use variations were evaluated using land use change index and the results showed significant variations. In addition, landscape matrices were used to measure the land use structure change. Some of the landscape matrices were measured and the results pinpointed two land use dynamics; one was that land development activities were becoming more diverse and the other was that the land development process caused fragmentation and splitting up of land. It is concluded that large urban patches are not created directly as a result of urban area increases as various other factors also influence that. Much of the available residential lands were fragmented and reduced to small plots. This is a unique feature, quite different from those seen in the other Municipal councils in the District. Further, land use structure changes that occurred in the 1985-2014 period were measured using landscape matrices. Those indices show a 2% annual increase and it indicates that during this period social and economic activities were expanded in terms of spatial structure. An advanced transport network, good road infrastructure, low land values and less pollution are some of the reasons why developers were able to attract people from the core area to this peripheral areas.

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