GIS INTEGRATED URBAN AGGLOMERATION AND SPATIAL PATTERN ANALYSIS IN THE COLOMBO DISTRICT, SRI LANKA

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ABSTRACT: With a fast growing population in this century, an undesirable urban growth has occurred all over the world, but in the developing countries, this situation is aggravated and it requires to be addressed seriously. The present urban population in the developing countries is more than half of the population lives in urban areas. All developing countries are responsible for accommodating this surge of population in liveable areas, which they are unable to do in the right way. Cities play a significant role in our lives, providing a place for fulfilling social, economic, and physical needs for more than half of the population in the entire world. The city is a dynamic entity with complex activities and it faces gradual physical changes or urban growth. Urban growth occurs in a planned or unplanned way. Unplanned urban growth or urban sprawl aggravated huge urban problems in cities and the fringe. Identification of urban growth pattern is significant and measuring and predicting the urban growth in a methodical way is an essential for the decision making process. Urban agglomeration are high end in the Colombo urban area, Sri Lanka and measurement of urban agglomeration and growth pattern is important in the Sri Lankan context and this study attempted to measure urban growth pattern in the Sri Lankan urban area Measuring the urban growth pattern is essential and ArcGIS 10 provides an impressive analytical tool for geographic pattern analysis that helps to understand the geographical phenomenon using spatial autocorrelation. Spatial autocorrelation can be applied to detect the pattern of urban areas at a specific time. It also analyses the degree of dependency among observation in a space. Global Moran I [2, 4], is a measure of spatial autocorrelation, which is not only based on feature locations or attribute values itself, but uses both feature locations and feature values simultaneously. This study used those tools to analyse spatial pattern in the Sri Lankan urban area. Results show type of spatial pattern of the area.

1. INTRODUCTION

With a fast growing population in this century, an undesirable urban growth has occurred all over the world, but in the developing countries, this situation is aggravated and it requires to be addressed seriously. The present urban population in the developing countries is more than half of the population lives in urban areas. All developing countries are responsible for accommodating this surge of population in liveable areas, which they are unable to do in the right way. Therefore urban studies are very important for countries to identify their spatial urban pattern. A vast amount of literature has been published on studies of urban growth in its various aspects during the past two decades, such as urban growth system theories and methods (Cheng & Masser, n.d; Batty, 2001.; Sliuzas et al., 2010), and analysis of urban growth (Herold et al., 2003; Sudhira et al., 2004; Bhatta, 2010). Some of the studies were devoted to analysing the pattern of urban growth (Nong et.al.,2014; Liu et al., 2014), monitoring urban growth (Fan &

Fan, 2014; Kaya & Curran, 2006) and modelling and predicting the spatio-temporal pattern of urban growth (Ramachandran et al., 2012, Thapa et al., 2011; Jat et al., 2008;). Those studies have made valuable contributions to the analysis of urban growth and its consequences (Aljoufle, 2012).

Although several studies have been conducted on the urban growth phenomenon, a thorough analysis of the mutual interactions among the three urban sub-systems (physical, socio-economic and environmental) has not yet been done. In 2003, Cheng addressed certain complexities that arose during an urban development project but his study was concerned only with certain urban growth areas (developing areas) and not with planned urban development. In 2012, Aljoufle explored urban growth and transport interactions. Although there are many driving factors behind urban growth that tend to influence economic, social, and environmental subsystems, most scholarly works only considered the socio-economic factors (Han et al., 2009) while some researchers considered only the environmental factors. Therefore, the majority of scholarly works have only discussed the separate effect of each driver rather than their combined effect and the interactions between those drivers (Ju et al., 2016). In the developing countries, only a few researchers have focused on urban growth drivers connected to all three sub-systems. This research will offer a new perspective in researching the interactions between a large number of growth drivers related to the socio-economic, physical and environmental sub-systems and therefore points the way forward by incorporating the diverse sub-systems with the main system in urban growth studies.

Urban growth is a continuous process that keeps changing the spatial structure of cities. Some scholars have considered it as a static phenomenon, whereas some have analysed it as a dynamic phenomenon; however, most researchers have accepted both as spatial-temporal processes. In 2010, Andrienko et al. mentioned that everything in the physical world is purely spatial and temporal; everything is a process. Change must be seen as a combination of processes that occur along the time scale in the space concerned. Cheng (2003) mentioned that a process is a sequence of changes occurring in space and time, initially as a spatial process and the latter as a temporal process. Measurement of urban growth pattern is important in the Sri Lankan context and this study attempted to measure urban growth pattern in the Sri Lankan urban area. **W**hich are very closed to City of Colombo and it consist of urban as well as completely rural features.

2. METHOD

Identification of the urban pattern is important for the measurement of urban growth. ArcGIS 10 provides an impressive analytical tool for geographic pattern analysis that helps to understand the geographical phenomenon using spatial autocorrelation. Spatial autocorrelation can be applied to detect the pattern of urban areas at a specific time . It also analyses the degree of dependency among observation in a space. Global Moran I [2, 4], is a measure of spatial autocorrelation, which is not only based on feature locations or attribute values itself, but uses both feature locations and feature values simultaneously. It classifies the growth pattern as clustered, dispersed, or random. The tool calculates index value I ranging from +1 to -1 showing clustering and dispersion, as well as a Z value showing the significance of I. The Moran's I statistic is given in the Equation (1) below.

The Morgan's I statistic for spatial autocorrelation is given as;

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2} \quad \text{......} \quad (1)$$

Where z_i is the deviatio ... i
$w_{i,j}$ = spatial weight between feature i and j
n = total number of features
S_0 : the aggregate of the spatial weights which is computed as shown in equation (2)

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} \quad \text{......} \quad (2)$$

The *ZI* -score for t ...)

$$z_I = \frac{I - \mathrm{E}[I]}{\sqrt{\mathrm{V}[I]}} \quad \text{......} \quad (3)$$

Where

$$\mathrm{E}[I] = -1/(n-1) \quad \text{......} \quad (4)$$

$$\mathrm{V}[I] = \mathrm{E}[I^2] - \mathrm{E}[I]^2 \quad \text{......} \quad (5)$$

The Spatial Autocorrelation (Global Moran's I) tool computed the observed Index value and the Expected Index value. The Expected and Observed Index values were then compared. Given the number of features in the dataset and the variance for the data values overall, the tool computed a z-score and p-value indicating whether this difference is statistically significant or not. Index values cannot be interpreted directly; they can only be interpreted within the context of a null hypothesis. In the case of the Spatial Autocorrelation tool, the null hypothesis states, "there is no spatial clustering of the values". When the Z score is large (or small) enough such that it falls outside of the desired significance, the null hypothesis can be rejected. When the null hypothesis is rejected, the next step is to inspect the value of the Moran's I Index. If the value is greater than 0, the set of features exhibit a clustered pattern. If the value is less than 0, the set of features exhibit a dispersed pattern.

3. STUDY AREA

The Kaduwela Municipal Council (KMC) is located at 6°54'N, 79°51'E, 7 m. and it is sited about 11 miles away from the city of Colombo, within the Colombo district of the Western province.

KMC is located in the Wet Zone and it experiences a rainy, humid and hot climate. The topography of KMC is a gradual slope from high elevation in the South to low elevation in the

North.The Kelani River flows from East to West along the Northern boundary of the KMC. Another important factor of physical characteristics of the area is the depth of water table. General picture of water table depth has a shallow ground water table, lying between 0 and 1 meter from the ground surface in more than 60% of the total area. Paddy fields, water bodies, and marshy areas account for a considerable portion of shallow water table in the entire KMC. From an environmental point of view, ground water table depth in 60% of the area is less than 1m. In the 1970s and before people selected this area for housing, people were concerned the water table of the area. Therefore, most of the low-lying areas were used for land mining for making bricks. However, later, urban expansion and new development projects gave incentives for people to in this area.

KMC administratively is divided into three main divisions namely, Battaramulla, Kaduwela and Athurugiriya. Battaramulla area is highly developed and the other two divisions show a rural urban mix. At present, the entire area face rapid land use changes due to new development projects and the entire area functions as a transition zone.

3.1 Population Density

In 2012, the total population in KMC was 252,100 (Development Plan) it shows an average annual growth rate of 2.01, compared with 2001. However, it is lower than the growth rate from 1981 to 2001, which was 2.6%. Thus, an increasing trend of population growth is seen in the KMC Area over the last two decades and this trend continues. It is caused by the natural growth of the population as well as migration mainly due to the availability of developable land. An expanded social infrastructure facility is also an important factor that influenced the higher rate of population growth. KMC administratively divided 3 units and table 1 indicates the population distribution and population density in the three administrative units of the KMC. Overall population density depicts 3 different variations in the different administrative units. The population density when the entire area is taken into consideration, was 23 persons per ha. in 2001 and it increases to 27 persons in 2012.

Table 1 Population distribution

Administrative unit	Extent (ha.)	2001	Density per ha.	2012	Density per ha.
Battaramulla	2191	84,961	39	88,020	40
Kaduwela	3727	63,820	17	77,743	21
Athurugiriya	3258	60,960	19	86,337	27
Total	9176	209,741	23	252,100	27

Furthermore, the three administrative units progressively display increasing population densities. Nevertheless, significant variations of the population density are seen across administrative units of the area. Battaramulla unit indicates the highest population density, but compared to the 2001 density it had only slightly increased compared to the other areas which show an higher rate of increase. Battaramulla unit located very close to the administrate city and most administrative functions concentrated here due to the high demand for land. In the early days, the demand for residential land shifted to other two units due to high land values in Battaramulla. That is one of the reasons to the decrease in population density in 2012. There are some variations among GND units and the population density surface created a meaningful illustration of density variations (figure 1)

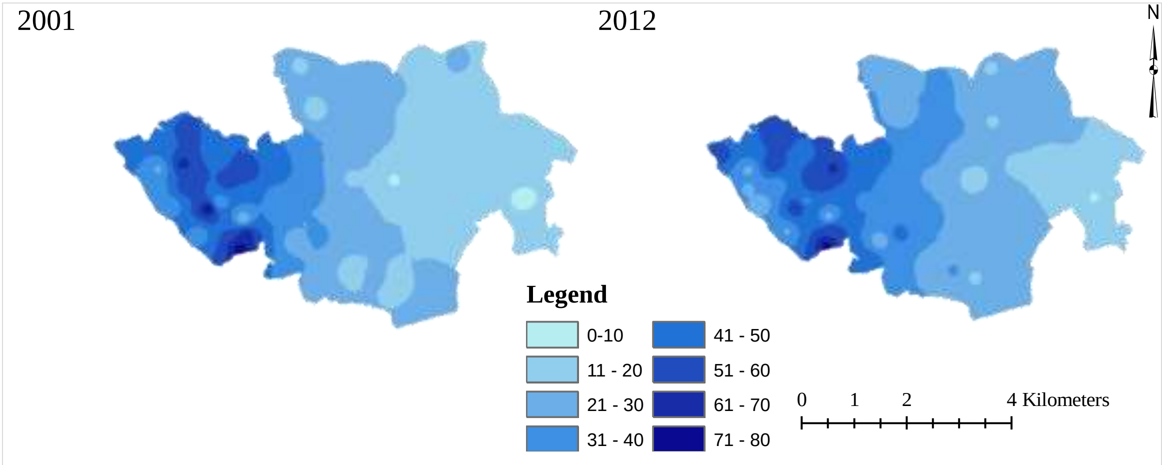


Figure 1 Population Density

3.2 Monitoring urban growth 1972 – 2011 in Kaduwela Municipal Council

Land use Variations from 1972 – 2014

The method used for land use classification was discussed in the chapter five. Accordingly entire land use classified into six categories namely urban built up, low residential, agriculture, green areas, water bodies and other uses. The classified land use map shown in Figure 7.3. It shows land use pattern of the four different years. Map clearly indicates directions of change in different land uses. As well if carefully see the maps it shows ribbon development, urban nodes and infill growth in four different years.

The figures of extent and Land Use Classification Index in classified six land use categories illustrate in table 2 Comparing with all land use figures, the land use category that has significantly changed with time is urban built-up.

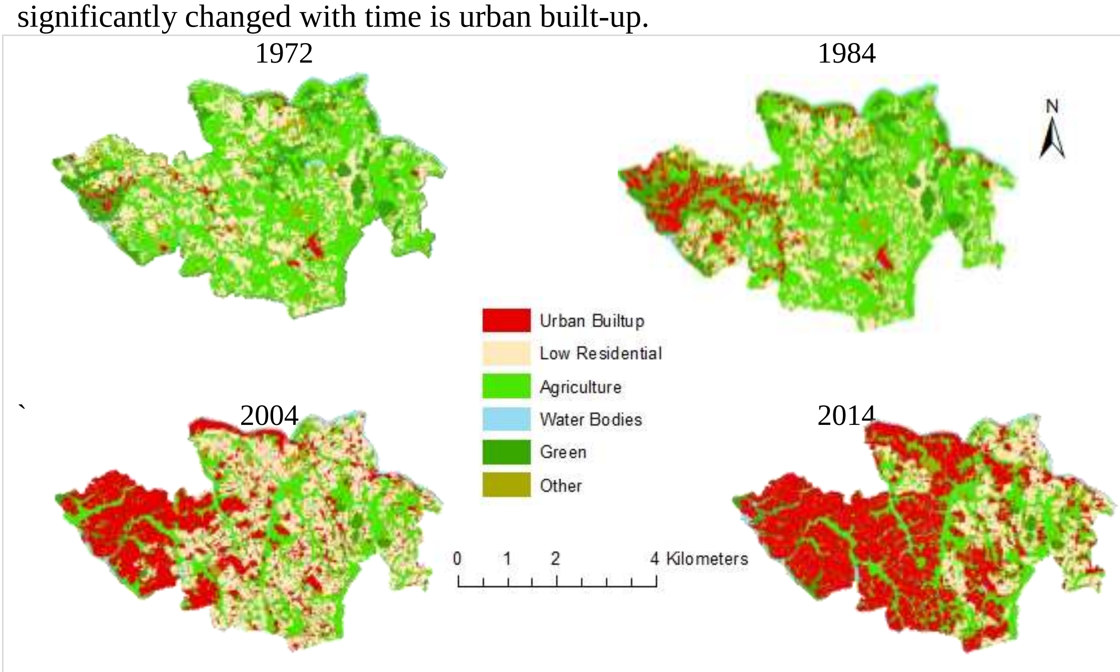


Figure 2 Land use categories

Table 2 shows in extent of different land uses

Table 2 Land use changes from 1972 - 2014

Year	**Urban**	**Low Residential**	**Agriculture**	**Green Area**	**Water bodies**	**Other**
	Extent (ha)	Extent	Extent	Extent (ha)	Extent	Extent
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

Table 3 discusses Land Use Classification Index (LUCI) of the different land uses.

Table 3 Land Use Change Index in different land uses

Year	Urban	Low Residential	Agriculture	Green Area	Water bodies	Other
	LUCI %	LUCI %	LUCI %	LUCI %	LUCI %	LUCI %
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

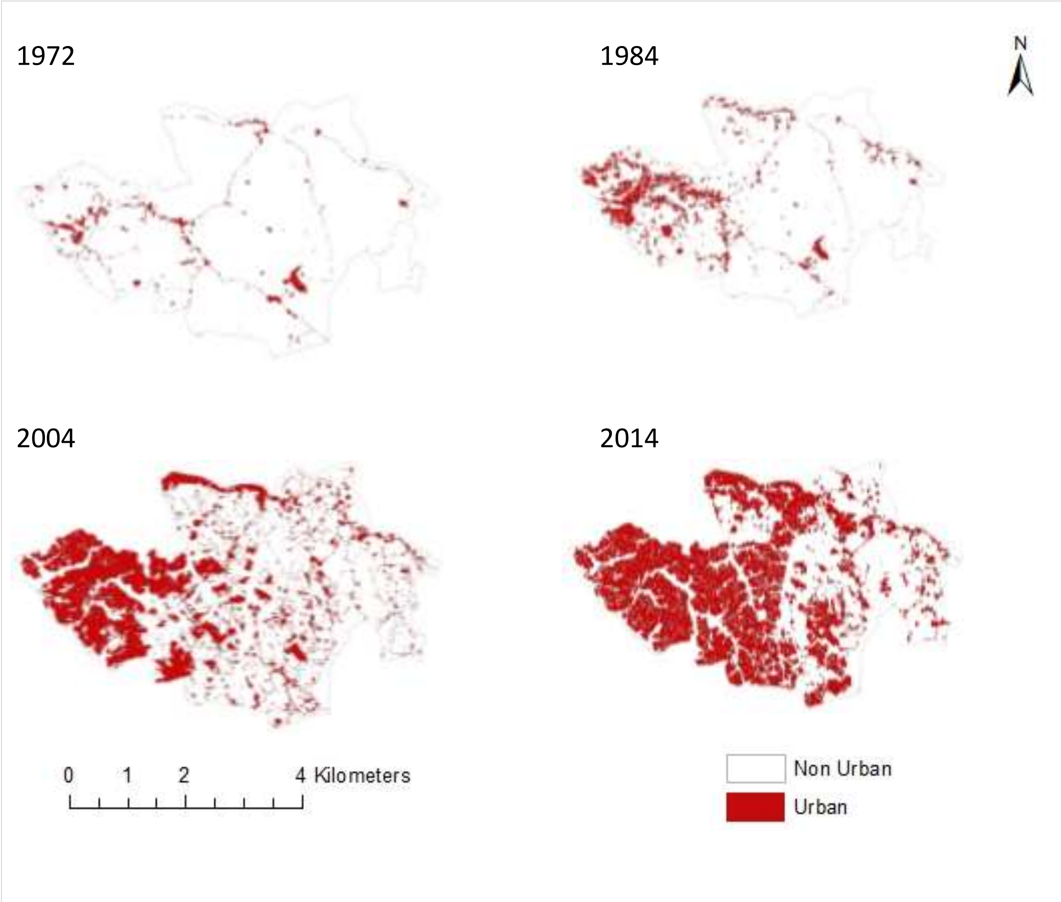
Accordingly table 2, from 1972 to 2014 built up area changed from 270 ha. to 4140 ha. This is a significant change compared with the other land uses and it shows gradual increase. However when it compared with LUCI (table 7.3) from 1972 to 1984, a gradual increase is seen. The land use from 1984 to 2004 increased but LUCI decreased from 5.14 to 3.22.

Civil disturbances existed in the country during this period was one of the reasons for LUCI decrease. However, when compared with the 2014 figures, it has slightly increased to 3.54. Low residential are shows gradual decrease from – 0.99 to - 4.33. During this period agriculture uses have significantly reduce from -0.3 to -4.8 annually. In 2014 green areas and water bodies depicts increased, the consequence of newly introduced recreation projects. Other uses also showed a decreasing pattern.

3.3 Urban Expansion from 1972 - 2014

Entire urban expansion from 1972 to 2014 show in the figure 4. Urban expansion is a significant factor to measure urban growth and the urban built up category is important in this context. The above figures show the LUCI about urban built up expansion. Figure 7.3 shows urban built up area in these four different years and it shows the urban growth direction has taken place through west to east. Accordingly, the nature of expansion in 1972 indicates a linear development. In 1984, urban expansion shows a scattered growth. In 2004, expansion is shows different pattern with the western part of the study area showing infill growth and other parts show a scattered growth. However, in the present situation illustrated, in the 2014 map, 2/3 of the area shows a high infill growth and rest shows a scattered growth.

Figure 3



Following figure 4 and 5 show the above illustrated four maps in a single map and single figure. In the period from 1972 to 2014, the rate of urban built up area increased dramatically while the non-urban area declined significantly as shown in the above figure. Present development projects and infrastructure development are two reasons for such development. Furthermore, it is also seen that area of urban built-up land has extended from 270 hectare to 4140 hectare and percentages range from 3.22% to 48.09%.

Figure 4

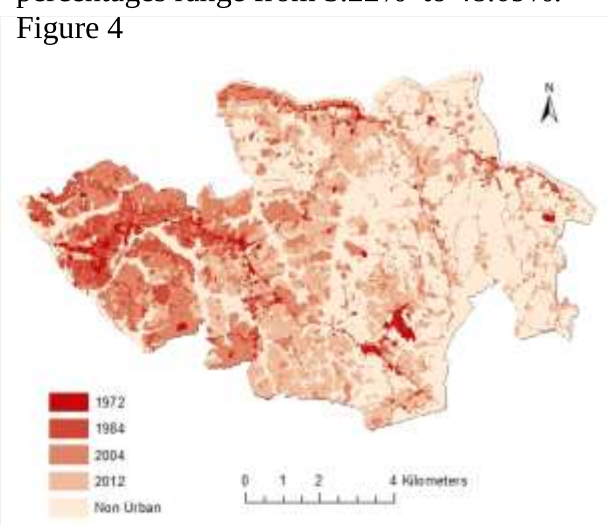
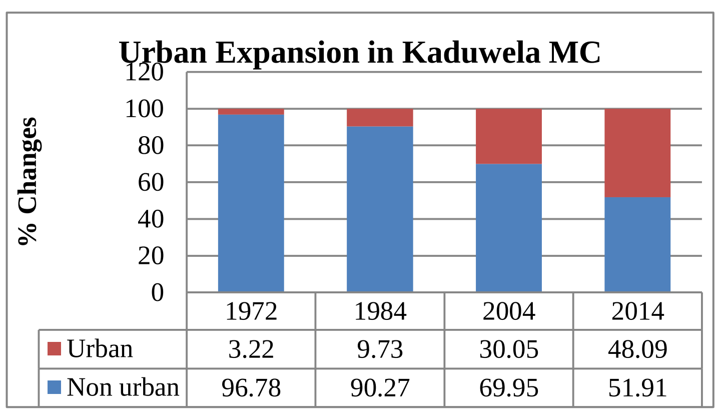


Figure 5



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

Table 4 indicates the relationship between urban growth and population growth. Apart from that, it indicates the population density variations.

Table 4 Population growth and urban growth 1972 - 2012	
Population growth	
Population 1972 (thousands)	209,741
Population 2012 (thousands)	252,100
Net growth	42,359
Change	16.6
Annual Growth rate	0.41
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 1981	23
Population Density 2012	28
Change (persons per ha)	5

4 Measurement of the urban growth pattern

Identification of the urban pattern is important for the measurement of urban growth. Spatial autocorrelation can be applied to detect the pattern of urban areas at a specific time. It also analyses the degree of dependency among observation in a space. Global Moran I [2, 4], is used for that. The results of Moran I statistics of 1972 and 2014 are shown in the figure 6 and figure 7 of the study area, respectively.

Moran's Index: 0.385559
z-score: 3.455928
p-value: 0.000548

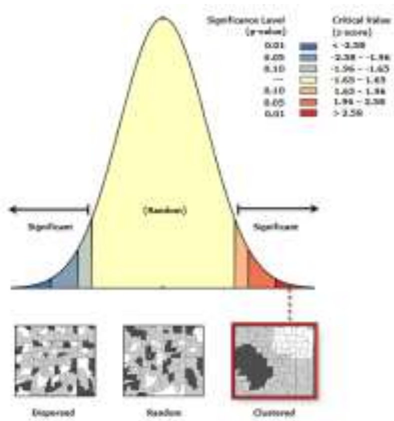


Figure 6 Moran I results of 1972

Moran's I statistical analysis, is shown in figure 7.7, and the Moran's I Index value of 0.385559, which is close to +1.0000, indicates clustering pattern. The statistical result is significant as p-value is 0.000548 ($p < 0.05$). Given the z-score of 3.45, the spatial distribution of urban pattern in 1972 is clustered.

Figure 7indicates the 2014 urban pattern. Accordingly, the Moran's I Index value of 0.44, which is near to +1.0000 indicates a clustering pattern. The statistical result is significant as p-value is

0.000013 ($p < 0.05$). Given the z-score of 4.36, the spatial distribution of urban pattern in 2014 is clustered.

Moran's Index:	0.445693
z-score:	4.364333
p-value:	0.000013

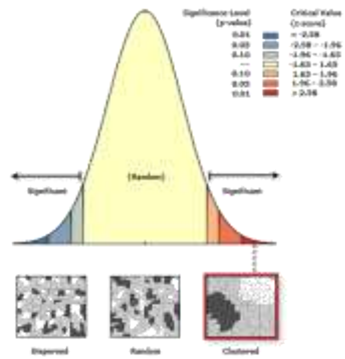


Figure 7 Morgan 1 results of 2012

Accordingly, Moran I statistics show that the urban growth of two years is clustered. This data is compared with the results matrix developed by experts and residents. The outcome of the analysis of their views indicates three types of views regarding the urban growth of the study area.

4. Conclusions

The urban growth pattern in the Colombo District was studied and evaluated using data on the past urban growth pattern, population distribution and land use variations. Accordingly, total population, population density, and land use at different periods were considered as the main factors in the process. Urban agglomeration is common feature of the Colombo district and population density movements show high to low variation from West to East (urban fringe) in the district. In addition, this pattern will be a continuous process moving in parallel to the existing Western Region Megapolis plan which aims to boost urban development in the entire Western Region. This paradigm will help to shift population to the surrounding regions, and the population trend of existing urban areas will show a decreasing pattern. Land use pattern were evaluated using Moran I statistics and it shows the urban growth of two decades is clustered. This data is compared with the results matrix developed by experts and residents. The outcome of the analysis of their views indicates three types of views regarding the urban growth of the study area. The land use pattern presents a different picture and it shows the urban area gradually expanding by spreading out through peripheral areas with the urban fringe functioning as a transition zone. As a result, fringe land keeps getting converted to urban uses on a massive scale. It is important to measure this conversion pattern as well as the conversion type. The existing urban development policies in Sri Lanka provide a pathway for movement of the population to the other two districts in the Western region and outer regions.

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