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Salem, Muhammad
Graduate School of Human-Environment Studies, Kyushu University | Faculty of Urban & Regional Planning

Tsurusaki, Naoki
Graduate School of Human-Environment Studies, Kyushu University

Divigalpitiya, Prasanna
Graduate School of Human-Environment Studies, Kyushu University

https://doi.org/10.15017/1906390

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 3, pp.113-115, 2017-10-19. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University
バージョン：
権利関係：

IEICES

3rd International Exchange and Innovation Conference on Engineering & Sciences
Kyushu University, Fukuoka, Japan
October 19-20, 2017

Fractal Dimension as A Descriptor of Expansion of Peri-Urban Areas in Greater Cairo Region

Muhammad Salem [1], Naoki Tsurusaki [2], Prasanna Divigalpitiya [3]
[1,2&3] Graduate School of Human-Environment Studies, Kyushu University, Japan.
[1] Faculty of Urban & Regional Planning, Cairo University, Egypt.
m.salem@cu.edu.eg

Abstract: *The urban expansion of cities in most developing countries is dynamic, scattered and spatially extensive. This research examines and analyses the urban expansion of peri-urban areas (PUA) in Greater Cairo Region (GCR) for a period of 30 years (1986-2016). Remote sensing, GIS and fractal dimension were used to determine the urban spatial expansion of PUA in GCR. RGB composite raster images were developed from multi-spectral imageries and classified by means of ISODATA algorithm in ArcGIS. The study explains the use of fractal dimension to indicate sprawling and correlate it with the agricultural land loss. Moreover, the study found the average rate of annual loss of agriculture lands in peri-urban areas is between 400 to 500 ha/year.*

Keywords: Urban Expansion; Fractal Dimension; Peri-Urban Areas; Greater Cairo Region.

1. INTRODUCTION

Peri-urban areas are considered a transitional zone between the city and the countryside, where urban and rural activities are juxtaposed and the landscape features are subject to rapid transformations induced by human activities [1, 2]. However, the urban expansion of peri-urban areas remains till now neglected by urban planners and decision makers, especially in developing countries [3]. This expansion led to natural resource depletion and diminution of agricultural and ecological lands [4]. One of the recent global assessment of urban agriculture areas which surrounding cities shows that 1078.7 million hectares (94.1%) of global croplands (i.e., irrigated and rain-fed croplands) are located within 20 km distance range of the urban extents (in peri-urban areas) [5]. Therefore, a need exists for more studies on peri-urban areas to highlight urban expansion influences in these areas, particularly on agricultural lands. This study employs a multi-temporal remote sensing and GIS analysis to detect the urban expansion of peri-urban areas (PUA) in Greater Cairo Region (GCR) form over a 30-year period from 1986 to 2016.

2. THE STUDY AREA

Peri-urban areas (PUA) are represented one of three main parts of Greater Cairo Region (GCR). PUA are situated in north and south of GCR and represent a quarter of the region's population [6, 7] (approx. 5 million inhabitants of 20 million).

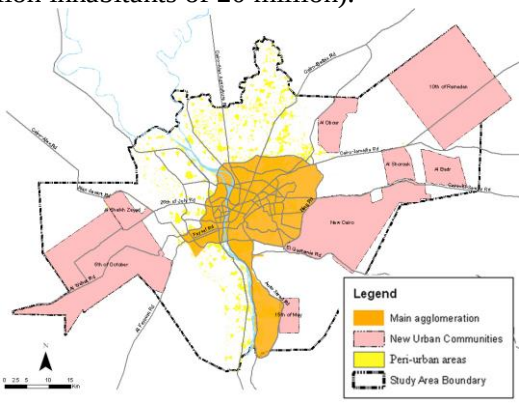

Fig. 1. Peri-urban Areas in Greater Cairo Region

3. METHOD

3.1 Fractal analysis and pattern detection

Fractal analysis has been widely used during the past three decades to highlight the urban pattern of metropolitan cities [8, 9] and they have been helpful for understanding peri-urbanization processes [10, 11].
Highly fragmented built-up areas representing sprawling patterns which have low fractal dimensions, whereas compaction and regularity yield higher figures [12].

3.2 Urban expansions detection using Remote Sensing and GIS

In this research, urban expansions of urban areas were adopted from multi-spectral remote sensing data for available periods (1986, 1996, 2002, 2007, and 2016). RGB composite images were developed from multi-spectral imageries and were further classified by unsupervised algorithm in ArcGIS. Built-up areas were extracted and coded black and other classes of land cover types were coded white. The classified images were subsequently analysed for their fractal dimensions using software known as Fractalyse (version 2.4).

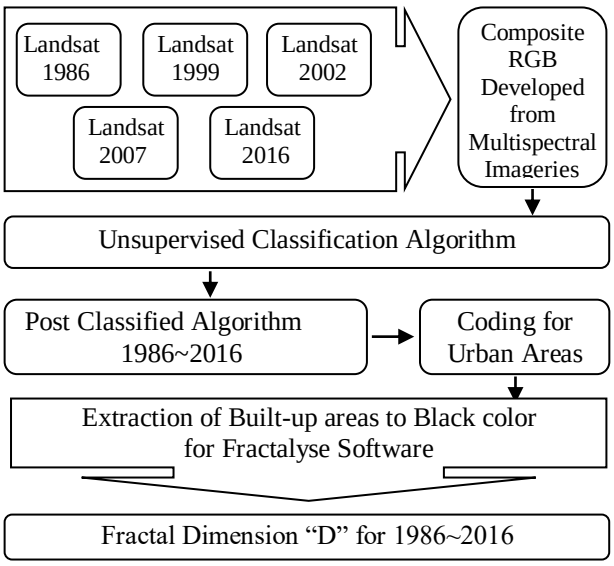

Fig.2 Workflow for Change Pattern Analysis

In this paper, the radial mass measure was employed in Fractalyse Software, which analyses by the iteration principle whereby the total number of built-up pixels are counted within the circle from a specified point (As shown in Figure 3).

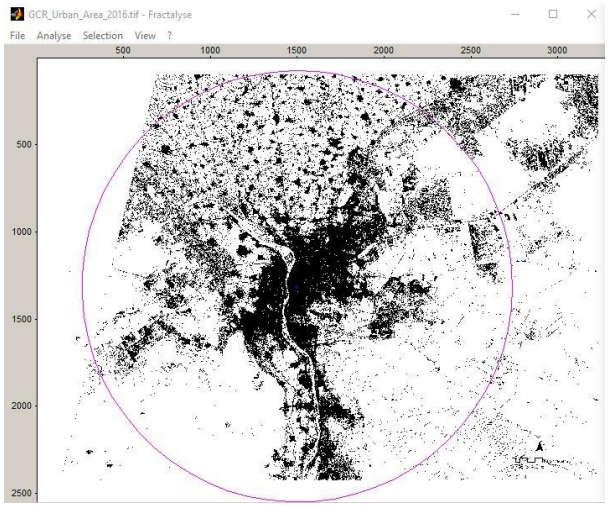

Fig. 3 Screen shot of radial mass method in Fractalyse

At each step, the radius r is gradually increased, and the total number of occupied points N(ε) inside the circle is counted (where ε equals 2.r +1).

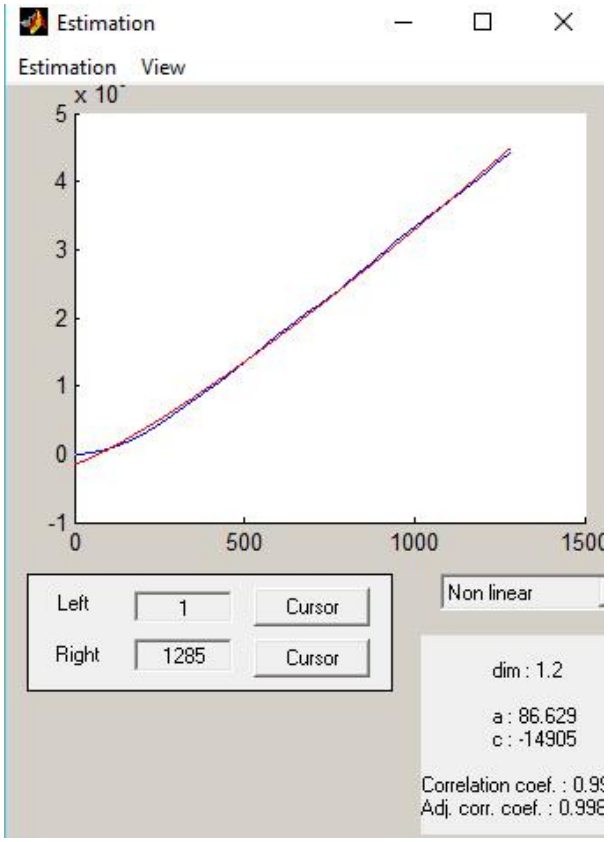

Fig. 4 Screen shot of fractal analysis 'D' estimation in Fractalyse software

4. RESULTS & DISCUSSION

The fractal analysis of the study area based on remotely sensed images from 1986 to 2016 found steady organic growth in which sprawling precedes infilling. The values of the fractal dimension increased steadily from the lowest 0.59 in 1986 to a low 1.2 value in 2016 (see Table 1).

Values less than one indicate lack of connectivity among elements in the built-up space, whereas values slightly greater than one indicates sprawl [13].

Table 1. Urban expansion and fractal dimension in PUA

Year	Population of PUA (1000 person)	lose of Agriculture lands in PUA (ha)	Rate of lose (ha/year)	(D)
1986	1661.5	-	-	0.59
1999	2857.5	6556	512	0.81
2002	3412.2	1410	470	0.91
2006	3942.3	1600	400	0.96
2016	5231.4	4850	485	1.2

As seen in Table 1, the highest fractal dimension (D) value in this study is 1.2, which indicates sprawl [10, 12]. The implication of this pattern is loss of valuable agricultural land to urban development, which could have major repercussions on sustainable food production and security [14].

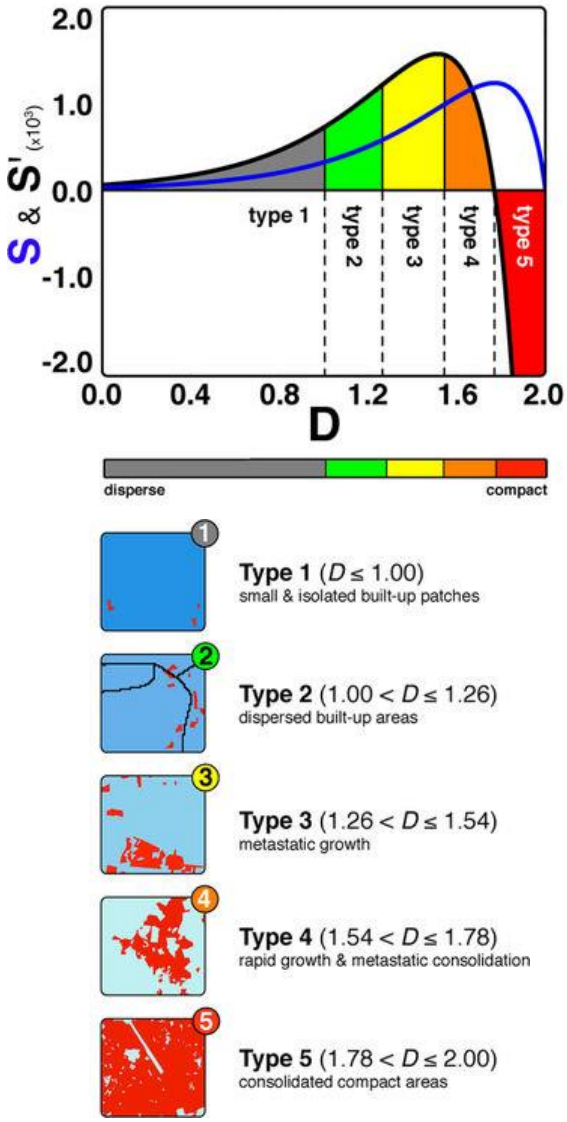

Fig. 4 Types of built-up areas

It is noticeable that the pattern of urban expansion for peri-urban areas, just like scattered urban islands (leap frog pattern) and more visible along or near major roads and railways. The average rate of annual loss of agriculture lands in peri-urban areas is between 400 to 500 ha/year, which considers a big amount of area.

5. CONCLUSION

This study examined the growth and morphology of peri-urban areas of GCR spanning a period of thirty years. The results of its fractal dimension analysis indicate rapid urban changes that correlate with the pace of agricultural land loss.

However, this study attempted to quantify the allocated agricultural land and found that such lands in the study area were reduced by the significant extent of 400 -500 ha/year. If nothing is done to alter that trend, the food security of the Greater Cairo region could be at risk.

Therefore, we recommend that urban and regional planners in developing countries like Egypt incorporate real-time remote sensing data and geospatial technology to monitor urban expansion, particularly in the peri-urban areas, which are presently neglected.

Furthermore, comparative morphological studies of other peri-urban settlements in developing countries should be undertaken to develop theories relevant to these phenomena.

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