Taming the Sprawl: The Growth of a Peri-urban City and Policy Response

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The concept 'peri-urban' remains elusive and often neglected by urban planners, however, this transitional zone is constantly under pressure by teeming population from the inner city or new entrants from the surrounding rural areas, thereby, resulting to an uncontrolled or unplanned landscape in most developing countries (Iaquinta & Drescher, 2000; Lawanson, Yadua, & Salako, 2012). Even though growth is inevitable and land use changes are imminent with peri-urban expansions of cities, the peri-urban space has a pivotal role in supplying agricultural resources like food and fruits for the survival of the city (Thebo, Drechsel, & Lambin, 2014). Understanding the development patterns, emerging urban forms and their attending impact on the peri-urban requires an understanding of development decisions (Lambin & Geist, 2007), this will help decision makers and urban managers develop appropriate policies to address growth 'edge' cities. This research focuses on the organic growth of Ikorodu, a peri-urban municipality in the outskirt of Lagos that rose from a sleepy farming community with a population of less than 100,000 people in the 1975 to a vibrant city of over a million residents in 2015. The study adopts multi-temporal remote sensing and GIS analysis to detect the urban pattern and emergent form for a 40 year period beginning at 1975 to 2015. An empirical analysis was also carried out by questionnaire survey of 300 land owners in 61 communities to determine the reason for the rapid growth and the response of planners to the city's growth.

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Introduction

Urban growth in developing countries is dynamic and diverse; however, it is also disordered and disturbing. This growth is synonymous with sprawling fractals when compared to compact aggregations seen in the global north. The cost of this sporadic growth in rapidly growing metropolitan regions is enormous, as seen in the consistent depletion and diminution of high quality agricultural land and forests located in the peripheral areas of cities and rural areas by residential and manufacturing activities (Jiang, Deng, & Seto, 2013; Martellozo, et al., 2014). This process known as peri-urbanization largely takes place in the non-contiguous transitional zones between the rural areas and cities (Iaquinta & Drescher, 2000). It has attracted much research focusing on the peri-urban interface, land use change and agricultural economics (Bell & Irwin, 2002; Theobald, 2005; Buxton & Low, 2007; Lawanson, Yadua, & Salako, 2012).

Studies analysing urban forms, spatial patterns and the processes that drives these change can be traced back to early studies of North American and European scholars. Some examples are Burgess' concentric growth of cities inferred from the study of Chicago and Homer Hoyt's 'Sector Theory', which examined the influence of linkages and geographical features on city structure. Other studies include Christaller's 'Central Place Theory', which emphasises spatial equilibrium of urban structure and pattern; Harris and Ullman' 'Multi-Nuclei Theory,' emphasized the polycentricism of cities. However, since the 1990s studies on urban morphology have focussed on fractal geometry of cities (Batty & Longley, 1994; Frankhauser, 1994; Terzi & Kaya, 2011).

However, there are few studies investigating the morphological processes associated with peri-urbanization (Tannier & Pumain, 2005; Lagarias, 2007; Terzi & Kaya, 2011). These existing studies are attributed to scholars in the global north have not been able to address dissimilarities between the northern and southern countries in the speed, scope and experience of peri-urbanization (Fragkias, et al., 2012). Therefore, there is need for studies on peri-urbanization and morphological processes within an African context; this will close such gap in literature. Furthermore, empirical studies investigating the drivers and policy response of peri-urban growth for African cities are not well documented in literature. The study aims at detecting the urban pattern and emergent form of a non-contiguous peri-urban city in the outskirts of Lagos metropolis for a 40 years period beginning at 1975 to 2015. It also aims at identifying the factors responsible for the land use pattern and the response of land use planners to these emerging forms.

The Study Area

The study area Ikorodu, is a municipality (Local Government Area) in the outskirt of Lagos Metropolis located approximately 36km North East of Lagos between longitude 3.43^{o} W and 3.7^{o}w and latitude 6.68^{o}n and 6.53^{o}n north of the equator. Its area is approximately 396.5 sq. km, with land mass of 368.5 sq.km. Since its creation in 1968 as one of the five administrative divisions of Lagos State, Ikorodu has been known for its extensive farmlands. It houses several hectares of land acquired for farm settlements by the defunct government of Western Region of Nigeria and subsequently, approximately 180 sq. km (49%) of its landmass was zone for agricultural land use in the 1980-2000 Regional plan of Lagos State. While farming, fishing and trading, are basic sources of livelihood of indigenes, the location of the a 1,582.27 hectares industrial estate (the largest in Nigeria) by the Lagos State Government in 1976 has also served as a major pull factor leading to population growth. However, other pull factors include development of a light port terminal at Ipakodo, the expansion of the Lagos-Ikorodu road and the establishment of secondary and tertiary sector activities. The municipality recorded a 186% population increase between the 1991 and 2006 census years (i.e., from 184,674 to 527,917) and its present population is estimated at 1.5 million based on the

United Nations Urbanizations Prospects projection for Lagos State, which is 12.9 million (United Nations, Department of Economic and Social Affiars, Population Division, 2014).

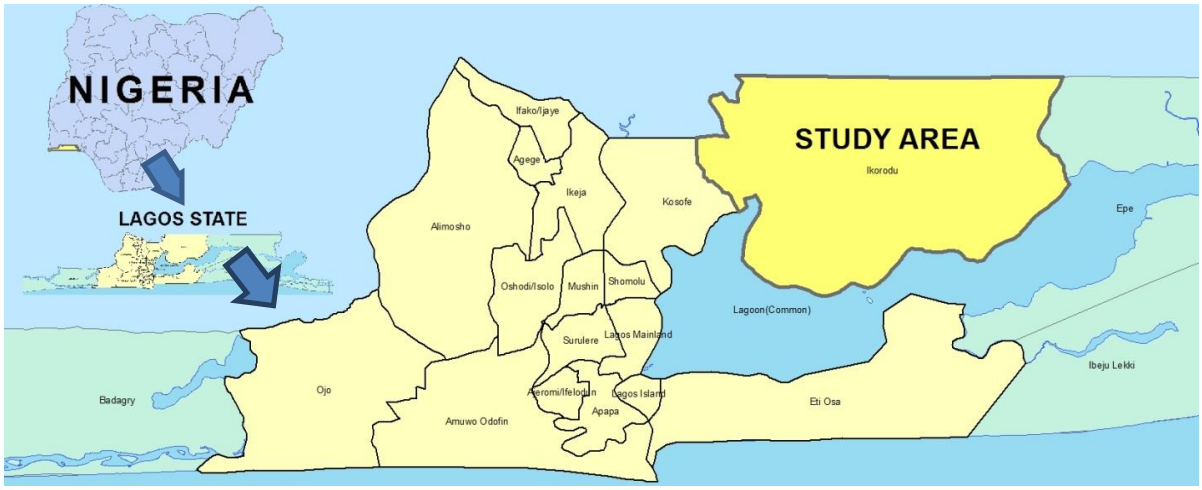

Fig. 1 Map Showing the Study Area within the Lagos Metropolitan Area

Methodology

The use of fractal analysis has been widely used in the past three decades to understand urban patterns and morphologies. Fractals, which connote complexities, hierarchies, self-similarities, across scale and time has been helpful in the study of peri-urbanization processes (Batty & Longley, 1994; Tannier & Pumain, 2005; Thomas, Frankhauser, & De Keersmaecker, 2007; Lifeng, Fang, Zengxiang, & Xiaoli, 2015). Fractal analysis gives the description of the spatial arrangement of built-up areas as well as its quality. Highly fragmented built-up areas representing a sprawling pattern have low fractal dimensions, while compaction and regularity will attract a higher figure. Fractal dimensions may have figures ranging from 1 to 2 for simple geometrical objects and 0 to 2 for urban geometry similar to sierpinski carpets (Tannier & Pumain, 2005).

In this research, we adopted a 5-years interval multi-temporal analysis and data used were multi-spectral remote sense data for available periods (1984, 1990, 2000, 2006, 2011, and 2015). However, Landsat imageries for 1975, 1980, and 1995 were not available, therefore, Land Use/ Land Cover Map of 1976/78 was used to cover for 1975 and 1980. RGB composite rasters were developed from multi-spectral Landsat imageries and were further classified by means of ISODATA unsupervised algorithm.

Table 1: Data Source

Acquisition Date	Satellite Number	Sensor Type	WRS Path/Row	UTM Zone	Datum	Spatial Resolution (M)	Sources & Year
06/01/2015	Landsat 8	OLI_TIRS	191/55	31N	WGS84	28.5-30	USGS, 2015
03/01/2011	Landsat 7	ETM+	191/55	31 N	WGS84	28.5-30	USGS, 2011
07/12/2006	Landsat 7	ETM+	191/55	31 N	WGS84	28.5-30	USGS, 2006
06/02/2000	Landsat 7	ETM+	191/55	31 N	WGS84	28.5-30	USGS, 2000
27/12/1990	Landsat 4	TM	191/55	31 N	WGS84	28.5-30	USGS, 1990
18/12/1984	Landsat 5	TM	191/55	31 N	WGS84	28.5-30	USGS, 1984
Supporting Spatial Data/Demographic Data							
1976/78	Land Use/Land Cover Map						FORMECU, 1978
1980	The Lagos State Regional Plan (1980-2000)						Doxiadis Associates, 1980
	National Population Census 1963, 1991, 2006						NPC 1991, 2006

Source: Varied

Built-up urban areas were extracted from ISODATA classified rasters by coding built-up pixels black and other classes of land cover types were coded white. The classified imagery were subsequently analysed for their fractal dimensions using software known as *Fractalyse (version 2.3.2)*. The software uses different methods to measure fractal dimension, which include box counting, radius mass, dilation, correlation, etc.

However, for this research, the radial mass measure was adopted in which analysis is done by iteration principle whereby the total number of built-up pixels are counted within the circle from a specific point known as the counting centre (for this research, the urban core area of Ikorodu shown in the 1976/78 land use map is the counting centre).

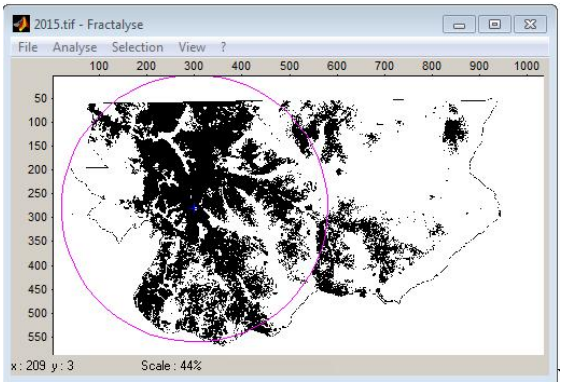

Fig. 2 Screen print of radial mass method in Fractalyse

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). The series of points obtained are represented by a Cartesian graph (fig. 3) with the Y-axis corresponding to the number of counted element (*N)* and the X-axis corresponding the value of the reference element *ε.*

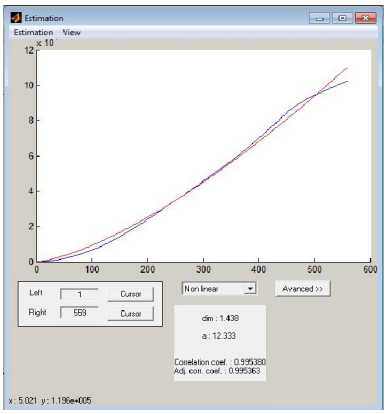

Fig. 3 Screen print of fractal analysis 'D' estimation in Fractalyse

The empirical curve of the plot is then fitted with the estimated curve; a good fit indicate fractality, however, the quality of estimation was verified by correlation coefficient. A non-linear regression derives the value the three parameter *a, D* amd *c*, where *a* is the Pre-shape factor and c is the point of origin on Y-axis (c = 0) (Tannier & Pumain, 2005). Thus, the fractal dimension *D* is determined by the following:

$$N = a\varepsilon^{D} + c \qquad (1)$$

Where

$$\varepsilon = 2.r + 1 \qquad (2)$$

Fractal dimension values close to 2 indicates regularity and orderly development while values close to 1 or 0 as the case may be indicate a sprawling and leapfrog pattern of development. Furthermore, in order to ascertain extent of sprawling development in agricultural land, we extracted the urban extents layer in ArcGIS by intersect geoprocessing with the agricultural land zone of the Regional Plan of Lagos State of 1980. The relationship between fractal dimension and dynamics index of agricultural change was determined by regression analysis. We also calculated the dynamic index (Zhu & Li, 2003) for the change in allocated agricultural land by the following:

$$CDI = \frac{U_a - U_b}{U_a} \times 100\% \qquad (3)$$

Where *CDI* is the change dynamic index for a single land use *U* between initial period *a,* and final period *b*.

Urban morphology cannot be divorced from anthropogenic factors, therefore questionnaires were distributed to 300 house owners across 61 communities in the 6 Local Council Development Areas (LCDAs) of the study area to determine the drivers of the land use change as well as the effectiveness of existing land use planning policies managing or taming the sprawling pattern of development. The total number of house owners identified by the Lagos State Government for Land Use Charge was 89, 609 in 2012 (Lagos State Government, 2013), however, this would have increased. Questions were asked on the motivation for developing in the peri-urban municipality, type of land use, time of property development, and awareness of planning regulations and the development control agencies restraints or approval of their home construction. 270 house owners (i.e. 90%) responded and data was analysed using SPSS and Excel. We adopted factor analysis to determine key drivers of urban morphology, the suitability of our data was examined by the use Kaiser-Meyer-Olkin Measure of Sample Adequacy (KMO) and Bartlett's test of sphericity, in which the KMO result obtained was 0.930 and the Bartlett's significance value is 0. This initial result confirms the suitable of our data for factor analysis (the KMO must be 0.6 minimum and the Bartlett's significance value must be 0.5 or less). Three components with eiginevalues over 1.0 explained 59.9% of the variations in the data; however, using the scree plot and the component matrix, two components have the highest number of loading and explain 54.2%. Therefore, Principal Components Analysis with Direct Oblimin rotation with Kaiser Normalization was applied to extract the highest loading factors from the two components, which were identified as the major driver of morphological changes. Furthermore, descriptive and inferential statistics were used to assess the effect of existing policies in managing sprawl and land use change.

Forming process

The peri-urbanization process in Ikorodu in the past four decades reveals dynamism in urban change as well as a sprawling development pattern. The fractal analysis of the study area based on remote sensed imageries acquired from 1984 to 2015 shows a steady organic growth, in which sprawling precedes infilling. The values of fractal dimension increased steadily form the lowest 0.41 in 1975 to a low 1.44 value in 2015 (see table 2). A value below 1 indicates lack of connectivity of elements in the built-up space, while values slightly above 1 indicates sprawl (Thomas, Frankhauser, & Biernacki, 2008). The highest fractal dimension (D) value in this research is 1.44, which indicates sprawl. The implication of this pattern is the loss of valuable agricultural land to urban development, which has great repercussions on sustainable food production and security.

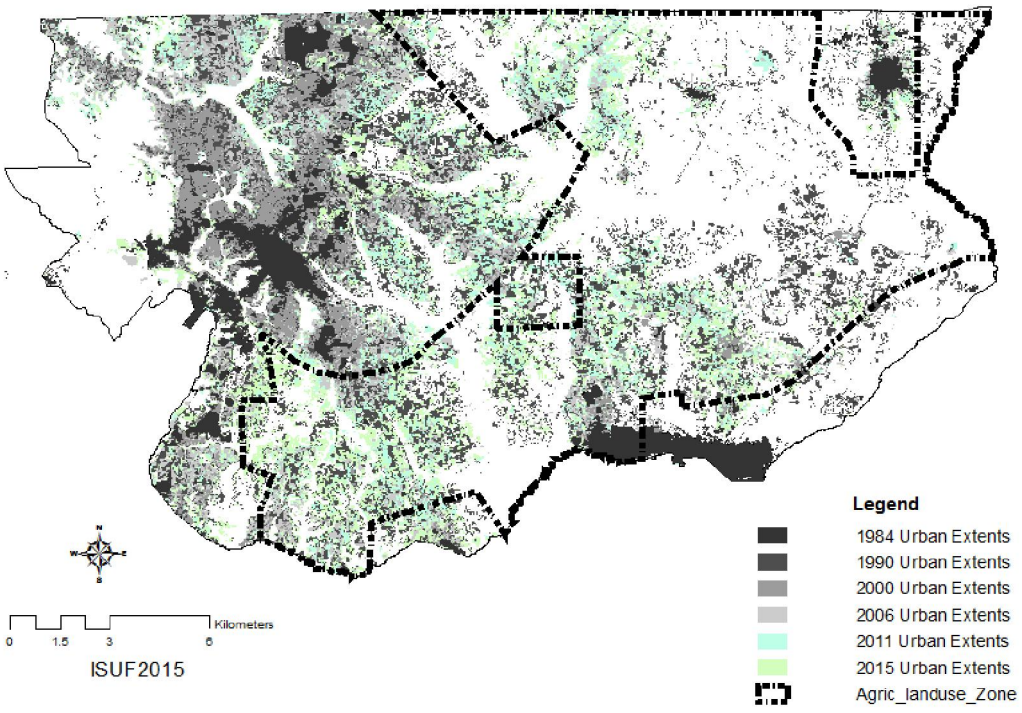

Fig. 4 Map of Ikorodu Showing Urban Growth and Extents in Agricultural Zone (1984-2015)

Table 2: Urban Growth and Fractal Dimensions of Ikorodu

Year	Population	Population Density per sqkm.	Urban Area (Ha)	Annual Urban Change Rate	Allocated Agric. Land Change to Urban (Ha)	Allocated Agric. Land (Ha).	% of Allocated Agric. Land Loss.	Agric. Land Change Dynamic Index	Fractal Dimension. (D)	a	Corr. Coeff.
1975	154377	389	419.00	0.00	0	17903	0.0	0.0	0.411	172.16	0.86
1984	170535	430	2252.05	229.13	274	17629	1.5	1.5	0.788	108	0.98
1990	182654	461	2961.83	118.30	707	17196	3.9	2.5	0.924	66.07	0.99
2000	390620	985	4587.01	162.52	871	17032	4.9	1.0	0.933	109.5	0.98
2006	527917	1331	7506.12	486.52	1425	16478	8.0	3.3	1.194	34.04	0.99
2011	946722	2388	9087.45	316.26	2293	15609	12.8	5.3	1.308	19.15	1.00
2015	1510594	3810	13772.10	1171.16	4615	13288	25.8	14.9	1.438	12.33	1.00

Source: Authors, 2015

The continuous urban expansion in the past four decades as seen in the table 2 above have resulted in non less than 25.8% of the total land area allocated for agriculture and food production in Ikorodu. Moreover, the annual urban growth rate in the study area tripled from 316 Hectares per annum in 2011 to 1171 Hectares per annum in 2015, leaving much for concerns. The regression model applied indicates a strong positive correlation between fractal dimension 'D' and change dynamic index (CDI) for allocated agricultural land (r= 0.78 at 0.04 level of significance). This is because the more the infilling of sprawled spaces, the more the value of the fractal dimension (D) and the more loss of peri-urban agricultural land. Even though this pattern of growth is noticeable in most cities' growth throughout history, in which 'D' increases with time, the pertinent question is how guided is the growth or how conformed is the growth to existing regional plans?

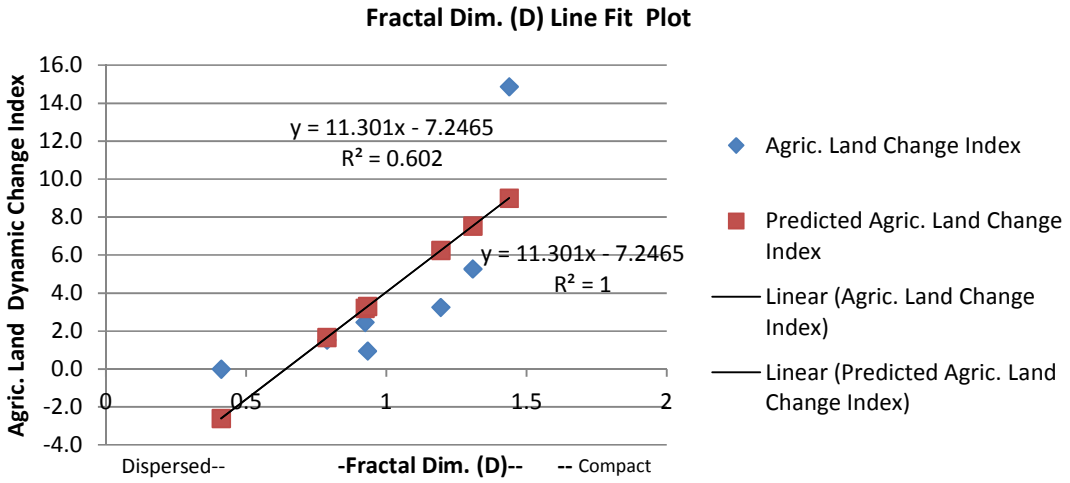

Fig. 5 Map of Ikorodu Showing Urban Growth and Extents in Agricultural Zone (1984-2015)

As seen in figure 4, there has been uncontrolled urban development on allocated agricultural land (about 25%), this implies that urban spatial expansion and densification has not followed the provision of the existing regional plan. Furthermore, the survey shows that only 39% of the respondents have obtained building permit, while any inspector of the development control or planning agencies had never visited the rest 61%. The ineffective development control system is partly responsible for uncontrolled expansion.

The factors responsible for continuous growth were reduced 18 to 10 using Principal Component Analysis as shown in table 3 below; however, three of the highest loading factors (i.e., those above 0.70) were selected as

the main drivers of peri-urban growth in Ikorodu. These includes, less time and money spent on transportation from location (0.899), proximity to work (0.888) and good health and less stress than the city (0.829). Proximity to work and ease of transportation as principal driving factors is corroborated by the survey result shown in table 4 as 50% of the respondent indicated that the location of their workplace is within the Ikorodu municipality. As mention earlier, Ikorodu has the single largest industrial estate in Nigeria and is a home for many secondary and tertiary activities, these serves as attraction for housing and other development.

Table 3: Pattern Matrix[a]

Reasons for residential development		Component	
		1	2
1	Less time and money spent from location	**.899**	
2	Proximity to work	**.888**	
3	Good health and less stress than city	**.829**	
4	Lower cost of living than city	.731	
5	Purchased through cooperative	.725	
6	Closeness to leisure and nature	.711	
7	Land speculation /investment	.673	
8	Affordable land	.582	
9	Proximity to family and friends	.451	.304
10	Obtained by inheritance	.444	
11	Invited to purchase by someone close	.377	
12	Personal achievement of a life time		.766
13	Proximity of site to urban infrastructure		.750
14	Site access to transport infrastructure		.727
15	Security of land tenure		.718
16	Adequate security of life an property		.683
17	Inheritance to leave for children		.494
18	Land free from govt acquisition	.301	.482

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 7 iterations.

Table 4: Location of work place

Location of Workplace		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Ikorodu	135	50.0	50.8	50.8
	Lagos Metropolis	111	41.1	41.7	92.5
	Other Lagos Area	7	2.6	2.6	95.1
	Ogun State	8	3.0	3.0	98.1
	Other Nigerian States	1	.4	.4	98.5
	Not Applicable	4	1.5	1.5	100.0
	Total	266	98.5	100.0	
Missing	System	4	1.5		
Total		270	100.0		

Conclusion

This research paper has been able to examine the growth and morphology of a peri-urban city spanning a period of forty years. The result of its fractal dimension analysis indicates rapid urban change, which also correlates with the speed agricultural land loss. Moreover, ineffective control and lack of policy implementation or enforcement has resulted in sprawling and unguided development in urban fringe areas of the Lagos metropolitan region exemplified by Ikorodu. The implication of this continuous n the absence of archaeological evidence, the confidence that can be placed in inferences is dependent on the uncontrolled expansion is diminution of precious agricultural lands and forested lands. Even though efforts have been made to quantify the peri-urban croplands globally (Thebo, Drechsel, & Lambin, 2014), this research, has also attempted to quantify the allocated agricultural land and shows that such lands in the study area has been reduced by a significant level of 25%, which if nothing is done, may affect food security of the Lagos metropolitan region. We therefore recommend that urban and regional planners in developing countries like Nigeria should incorporate the use of real time remote sensed data and geospatial technology in monitoring urban expansion, especially in the peri-urban areas, which presently seemed neglected. Furthermore, comparative morphological studies of other peri-urban towns in developing countries should be undertaken in order to develop theories endemic to situation in these climes.

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