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Modelling Expansion and Densification in Peri-urban Areas: The Case of Goba Ward, Dar es Salaam, Tanzania

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Abstract

Modelling expansion and densification of peri-urban areas may potentially help local authorities and planners to develop intervention strategies for addressing urban planning challenges. This paper employs satellite images information extracted between 2005 and 2020 to predict future expansion and densification trends in Goba ward (Dar es Salaam). 231 grids were established to allow the extraction of data. Each grid was examined from 2005 to 2020 for four periods of five-year intervals. Multiple regression modelling was applied to develop two models (expansion and densification) targeting built-up area and the number of buildings. The results suggest that an increase in the number of buildings will lead to the expansion of a built-up area. High building density in Goba ward has been observed in some areas where economic activities take place (around main centres and main roads). Predictions for expansion and densification show that areas in main centres like Kinzudi, Tegeta A and Goba; and areas around main roads will experience more expansion and densification by 2035. These results inform town planers, decision- and policy-makers to understand the past, current and future situations of expansion and densification; and take proper decisions for enhancing sustainable urban development.

Keywords: *expansion, densification, peri-urban areas, multiple regression modelling*

1. Introduction

Achieving sustainable development in cities remains one of the most important goals for many developing countries. Cities are becoming denser and overcrowded due rapid population growth that is accelerated by rural-urban migration and increasing fertility rate (Cobbinah et al., 2015). This situation triggers the growth of peri-urban areas as people are forced to reside in peri-urban areas in the search for bigger and vacant lands for settlement development (Kombe, 2005).

Nuhu, (2018) noted that peri-urban areas expand and even densify when urban residents search for prime and low-cost land for residential and commercial purposes due to existing pressure of land in urban centres. Many cities have weak capacities and lack resources—both financial and human—which leads

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to unguided peri-urban expansion and densification (Mkalawa & Haixiao, 2014; Hill et al., 2010). Uncontrolled trends of expansion and densification pose a challenge to the sustainability of peri-urban areas, in that, they exert pressure on social, economic and environment aspects (Martellozzo et al., 2018; Xu et al., 2019). This situation threatens the attainment of sustainable development goals, particularly Goal 11 that emphasizes safe, inclusive, resilient and sustainable settlements (Smith, 2020).

Moreover, there is an increasing concern that peri-urban expansion brings more challenges, particularly on the environment, such as the destruction and decline of ecosystem services, loss of green cover and open spaces, and increased pressure on natural resources such as water and land (Nduwayezu et al., 2021; Basse, 2014). Shao (2021) added that, peri-urban expansion has led to negative impacts such as diminished agricultural productivity due to loss of land, lack of hygiene and sanitation infrastructure, industrial effluence, air pollution, greenhouse emission, noise pollution, inadequate provision of basic services and infrastructure, and accumulated solid waste. On the other hand, peri-urban expansion has made positive contribution in changing the economic status and employment structure (Puplampu & Boafo, 2021). Mushi (2008) pointed out that population growth in cities contributes much to the growth of peri-urban areas as it influences more building construction that led to an increase in the number of buildings, hence built-up areas and densification.

Planned urban densification is linked with sustainability, resilience, and economic growth of urban areas, as it reduce costs of service delivery and facilitate infrastructure provision (Roch et al., 2020; Amer, 2017; Dunnning, 2020). However, unguided densification is associated with the eruption of informal settlements with poor social services and amenities; and are responsible for generating environmental pollution, poor sanitation, housing congestion and high rates of social crimes (Nkwanyana, 2015).

A number of studies have examined urban expansion and densification in different perspectives using different methods and techniques. For instance, some have focused on urban expansion and form (Chai & Li, 2018; Seto et al., 2011; Zeng et al., 2017; Liu & Wang 2016; Xu et al. 2019); urban sprawl and its impact on sustainable urban development (Shao et al., 2020); urban expansion and its implication on cultivation (d'Amrou et al., 2016); dynamics of peri-urban densification (Wang et al., 2019); urban expansion and application of remote sensing imagery (Ramachandra et al., 2012), etc. The specified studies employed different methods and techniques to quantify peri-urban expansion and densification such as spatial modelling in geographical information system (GIS) and cellular automata (Basse et al., 2014; Cosentino et al., 2018); auto logistic regression simulation and GIS (Hill & Lindner (2010; Tang, 2020); spatial logistic regression Martellozzo (2018), and grid-cell-based analysis (Bagan &

Yamagata, 2012; Hou et al., 2016). On their part, Zhang and Su (2016) employed multivariable linear logistic regression to look at the determinants of urban expansion and their importance, while Cheng and Masser (2003) used logistic regression for the same purpose. Moreover, some studies have concentrated on land use/land cover change (Cobbinah & Aboagye, 2017; Coulter et al., 2016; Kleemann et al., 2017); and urban land use change and geographical regression modelling (Sharifu et al., 2010). Of the above, only a few studies—such as (Lupala, 2015) on the determinants of peri-urban expansion—have touched on peri-urban expansion and densification.

In Tanzania, Dar es Salaam is the fastest growing city beleaguered with insufficient planned and serviced land (Gwaleba, 2018; Kombe, 2005). Due to this situation, most people tend to buy and build in cheap land in peri-urban areas, hence leading to unguided city growth, expansion and densification (Gwaleba, 2018; Kombe, 2005). Peri-urban areas in Dar es Salaam city includes areas like Mbezi, Kinyerezi, Bunju, Goba, Chanika, Mbagala Rangi Tatu, Nyantira, Kigamboni and Pugu, which are currently experiencing intense expansion and densification due to a large influx of population from the city centre.

This paper aims at developing a multiple regression models for quantification of past peri-urban expansion and densification based on changes observed in a period that extends from 2005 to 2020. It also predicts future expansion and densification for the next 15 years—up to 2035—of the Goba ward in Dar es Salaam city.

2. Peri-urban Areas, Expansion, Densification: A Theoretical Underpinning

2.1 Peri-urban Areas

Peri-urban areas are defined in different ways. Many scholars provide their own definitions depending on the locality, culture, discipline and purpose of their studies (Nuhu, 2019). Tanzania's Land Act No. 4 of 1999 defines peri-urban land as one that is within a radius of 10km outside the boundaries of an urban or semi-built-up area, or within any large radius that may be prescribed in respect of any particular urban area (URT, 1999). Adamu (2014) defines peri-urban areas as those areas that contain activities, agriculture, and settlements. According to Nuhu (2018), peri-urban areas are areas that are found outside the boundary of a city, and outside the legal jurisdiction of any urban local body. Furthermore, Marshall et al. (2009) define a peri-urban area as a place, concept or process. As a place, it refers to an area located at an urban fringe, and geographically at the edge of a city; as a process it refers to the movement of goods from rural to urban areas; and as a concept it refers to the boundary between rural and urban activities and institutions. Abebe (2013) noted that peri-urban areas are characterized by vacant and farming land with lower population densities, less dynamic processes of land use change, and low rate of daily commuting to urban areas. For Mushi (2008), peri-urban areas are those that are attached to inner urban areas with buildings that are positioned within 200m; and having local shops and services, parks and gardens. Marshall (2009) noted that peri-urban areas are not sustainable as they face problems that exert intense pressures on resources that result to slum formation, the lack of adequate services such as water and sanitation, and poor planning and degradation of farmland due to urban expansion and densification.

2.2 Expansion

Tang (2020) defines expansion as the physical pattern of low density growth of an urban area. This definition is close to that of Zeng et al. (2017) who define urban expansion as a pattern that is not coordinated at a periphery of a city, and is characterized by uncoordinated growth, low density, and poor connectivity. Puplampu and Boafo (2021) define urban expansion as the process of developing a built-up environment in a limited space. Urban expansion takes place in different forms. Zhang and Su (2016) explain that new expansion occurs with the same densities (persons per square kilometre), increased densities, or with reduced densities. Liu et al. (2016) indicate that urban expansion takes place along corridors, which results into a star-shaped, elongated or circular city, particularly in areas closest to city centres. Linear expansion is another type of expansion that follows existing corridors of circulation like highways, railways or transit lines due to easy accessibility offered by these infrastructures (Liu et al., 2016). These peri-urban forms are embraced by the existence of environmental, social, economic and geographical forces that attract people to move in peri-urban areas with those characteristics.

Environmental driving forces for peri-urban expansion include good climate, flat terrain, and the existence of drillable water aquifers (Wu & Zhang, 2012). Economically, peri-urban areas expand depending on household income that enables people to acquire big land for housing, gardening and carrying out other functions. According to Abebe (2013), proximity driving forces—e.g., easy accessibility to services such major roads, economic centres, social services such as health and education, institutions, open spaces, and reliable markets—also influence the expansion into peri-urban areas.

2.3 Densification

Densification refers to the number of buildings per the unit area occupied (Newman, 2014). Erick (2017) describes densification as the proportion of urban land to buildable areas. Delmelle (2014) defines it as infill of open areas left within settlements, or extension of building structures. Marique (2014) perceives densification as an increase of two different forms: population, and built-up area within a defined area. In this paper, densification is perceived as the increase of buildings per unit area.

Nkwanyana et al. (2015) discuss socio-economic factors that influence the densification of peri-urban areas. These include land price, zoning, accessibility to local amenities, and population density. In this paper, the driving force for densification are the number of: buildings per unit area, residential buildings per area, business activities per unit area, road kilometres per unit area, buildings around centres, and of institutions per unit area. These driving forces can be quantified to determine their significance, and predicted using multiple regression modelling. The multiple regression modelling technique is a quantitative tool as it provides mathematical evidences and proper prediction for future decision-making (Thomassen, 2010). This predictive model examines which driving forces are significant for the densification and expansion of peri-urban areas (Hou et al., 2016). Also, the technique assists engineers, planners, and policy-makers with the best solutions in the sustainable development of peri-urban areas. According to Hassan and Lee, (2015) sustainable development is referred to as a dynamic process in social, economic and ecological aspects aimed to meet the needs of current and future generations.

3. Context and Methods

3.1 Study Area

This paper employs data from a study was carried out in Goba ward, Kinondoni, in Dare es Salaam city; 20km from the city centre as shown in Figure 1.

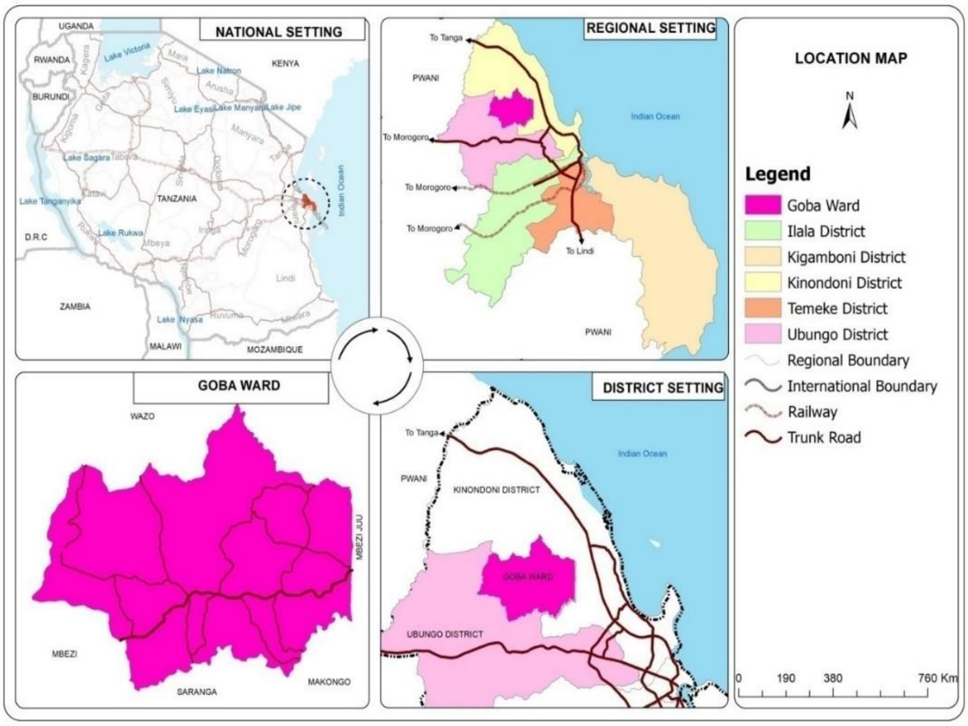

Figure 1: Goba Ward in Kinondoni District in Dar es Salaam

Source: Google Earth (2016)

The ward has a population of 42,667 people, and an area of about 4716.5ha, with a density of 903h/km^2 (URT, 2013). It comprises of 8 sub-wards: Kinzudi, Tegeta A, Kibururu, Matosa, Goba, Muungano, Kulangwa and Goba Kunguru. The ward is located at Latitude 6.732738^0 and Longitude 39.158878^0; and is bordered by Makongo, Mbezi, Saranga, Mbezi-Juu and Wazo wards.

3.2 Data Types and Sources
Spatial variables for model development were selected based on established criteria. The criteria for variable selection were as follows:

a) Variables that have spatial data and can be easily observed in satellite image and toposheets, hence their information can be detected and extracted from the satellite image and toposheets;
b) Variables that show a trend of change from year to year, hence can be used in predictions for future years; and
c) Availability of data from various sources.

A total of six variables were selected, including the number of: buildings, business activities, institutions, road kilometres, buildings from the main centre within 1km, and of buildings from main roads within 250m. Selected spatial variables were observed to be more influential factors in expansion and densification as they were capable of indicating a trend of change from time to time, and provide adequate information in the study. Spatial data were collected from a satellite map, and were verified through field observation 2020.

3.3 Methods
3.3.1 Data Collection
Data collection methods included observation, document review, and extraction of spatial data from satellite images of 2005, 2010, 2015, and 2020 using the Arc Map 10.1 software. Satellite images were obtained from the Department of Survey and Mapping of the Ministry of Lands, Housing and Human Settlement Development, in Tanzania, as standard products. A total of 231 grids were established throughout the entire Goba ward, and each contained 500 × 500m distances within which data were collected. Data were extracted from each grid and recorded in an attribute table to determine possible changes in a period extending from 2005 to 2020. A total of 231 checklists were prepared and filled-in with information extracted from each grid on specified maps (for each year and for every model). Expansion data were obtained through the measurement of a polygon that covered the whole built-up area for each cell; while densification was measured through polygons that covered the concentrations of buildings in each locality for the specified period of time. Observation was employed as a primary method for verifying densification and expansion data from the satellite images.

3.3.2 Expansion and Densification Modelling

Multiple regression analysis (Hou et al., 2016) was employed to develop expansion and densification models. The dependent variables for the models were built-up area, and number of buildings; and the dependent variable for densification was building density (the number of buildings per unit area). The independent variables for the models are shown in Table 1.

Table 1: The Models for Independent Variables

Type of variable	Variables	Abbrev.	Description
Dependent			
	Y – Expansion in terms of built-up area	BUA	Built-up area
	Y – Expansion in terms of number of buildings	NB	Number of buildings
	Y – Densification in terms of number of buildings	BD	Building density (Number of building per area)
Independent	***Expansion in terms of built-up area***		
	X_1	NB	Number of buildings
	X_2	NBA	Number of business activities
	X_3	NI	Number of institutions
	X_4	RK	Road kilometres
	X_5	NBMR	Number of buildings from main roads with 250m buffer zone
	X_6	NBMC	Number of buildings from main centre with 500m buffer zone
	Expansion in terms of the number of buildings		
	X_1	NRB	Number of residential buildings
	X_2	NBA	Number of business activities
	X_3	NI	Number of institutions
	X_4	RK	Road kilometres
	X_5	NBMR	Number of buildings from main roads with 250m buffer zone
	X_6	NBMC	Number of buildings from main centre with 500m buffer zone
	Densification in terms of building density		
	X_1	RBD	Residential building density
	X_2	BAD	Business activities density
	X_3	ID	Institution density
	X_4	RD	Road density
	X_5	MRBD	Main road building density
	X_6	MCBD	Main centre building density

Source: Researcher's illustration, 2020

3.3.3 Expansion and Densification Models Assumptions and Limitations

(a) The number of buildings, built-up area and building density can be used as dependent variables to measure expansion and densification, and can also be used as independent variables with expansion and densification;

(b) The number of buildings, built-up area and building density have been selected as dependent variables due to their convincing power to measure expansion and densification with influencing ability;

(c) All variables have a trend of change over time and can easily be detected and computed using Arc Map 10.1 software;
(d) Selected independent variables were easily observed in satellite imagery, hence easy to extract information;
(e) There was no change of use of any building and all uses have remained the same since 2005 to 2020;
(f) A buffer zone of 1km for main centre, and 250m for main roads, was satisfactory for observing changes as it captures more buildings, which indicate development prevailing in those areas; and
(g) All independent variables seemed to be most influential factors for expansion and densification.

3.4 Definition of Models

3.4.1 Built-up Area and Number of Buildings Expansion

The two models use the same model equation. Built buildings occupy spaces, hence an increase in the number buildings means an increase in built-up area. Similarly, an increase of one building contributes to the increase of the number of buildings.

Equation 1 is a model for built-up area and the number of building expansion:

$$Y = \sum_{0}^{t} (b_0 + b_1 \sum_{1}^{231} X_1 + b_2 \sum_{1}^{231} X_2 + b_3 \sum_{1}^{231} X_3 + b_4 \sum_{1}^{231} X_4) + b_5 \sum_{1}^{231} X_5 + b_6 \sum_{1}^{231} X_6 + C \qquad (1)$$

Whereby: Y = expansion in terms of built-up area, a dependent variable; b_1 to b_n = coefficients of the determination of independent variable X_1, $X_{2,}$ $X_{3,}$ $X_{4,}$ X_5 and X_6; X_1 = number of residential buildings; X_2 = number of business activities; X_3 = number of institutions; X_4 = number of total road kilometres; X_5 = number of buildings in major road of 250m buffer; X = number of buildings in main centre of 1km buffer; C = Y-intercept

Equation 2 define densification model equation:

$$Y = \sum_{0}^{t} (b_0 + b_1 \sum_{1}^{231} \frac{X_1}{A} + b_2 \sum_{1}^{231} \frac{X_2}{A} + b_3 \sum_{1}^{231} \frac{X_3}{A} + b_4 \sum_{1}^{231} \frac{X_4}{A} + b_5 \sum_{1}^{231} \frac{X_5}{A} + b_6 \sum_{1}^{231} \frac{X_6}{A}) + C \qquad (2)$$

Whereby the independent variable are: X_1 = number of residential buildings; X_2 = number of business activities; X_3 = number of institutions; X_4 = number of total road kilometres; X_5 = number of buildings in major road buffer; X_6 = number of buildings in main centre buffer; A = area of a cell/grid; C = Y-intercept; and b_1 to b_n are as defined in equation (1).

4. Results and Discussion

4.1 Expansion Model by the Increase in Built-up Area

It was observed that expansions tend to occur along major roads, main centres, institutional areas, business activity areas and along minor roads. In Figure 2, Map 2010 shows some centres like Kinzudi, Goba-centre and Tegeta A have started to emerge, densify and expand; compared to Map 2005 that had a low rate of expansion and densification.

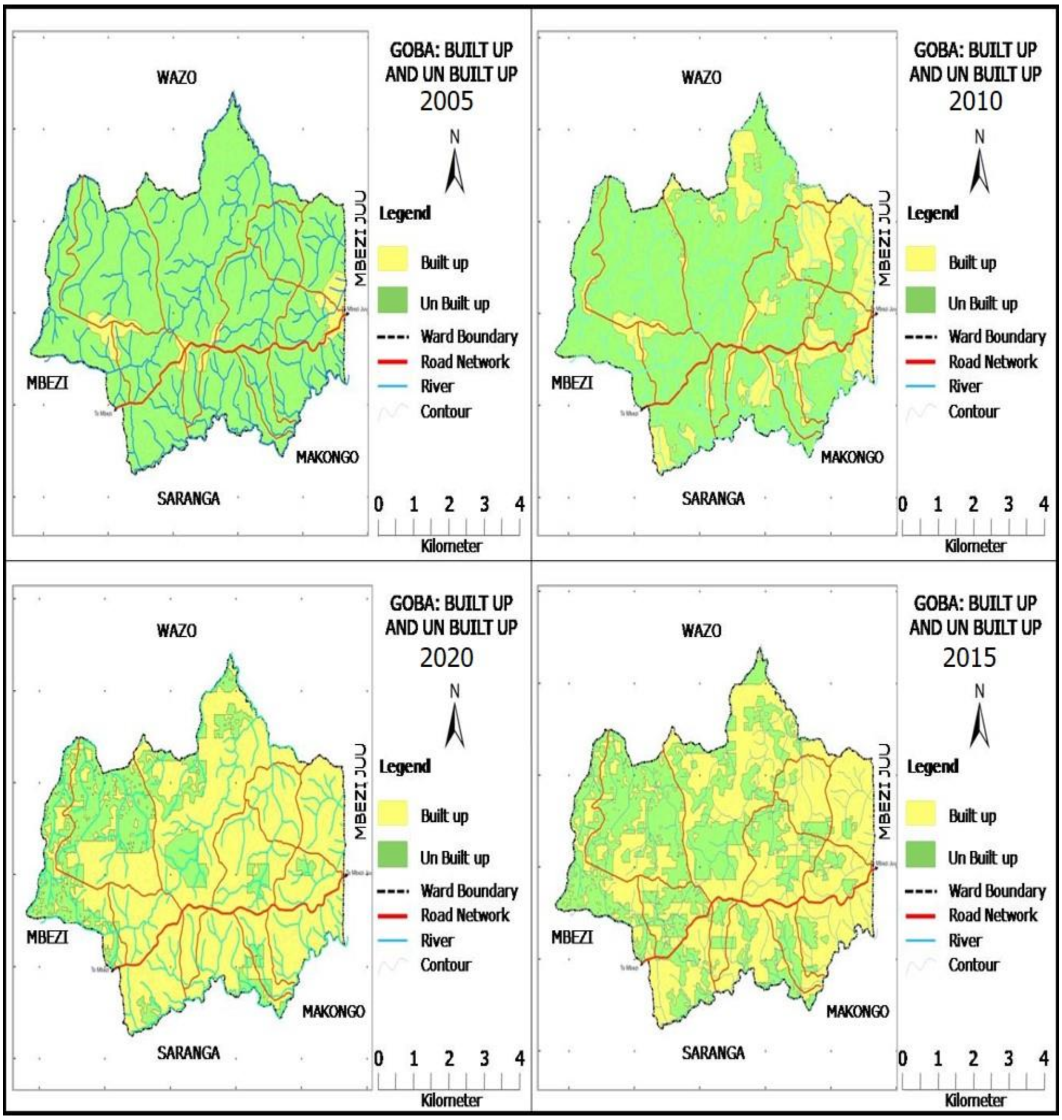

Figure 2. Trend of Built-up Area for Year 2005 to 2020
Source: Researcher illustration, 2020

The built-up area at Goba ward increased to 100ha from 2010–2015, whereby a large part of Kinzudi, Goba centre and Tegeta A sub-wads experienced a high rate of expansion. The current situation in Goba reveals that the ward has changed from open areas to built-up areas, especially along the main roads and main centres. Built-up areas were largest in 2020 (about 1800ha), indicated by increased construction coupled with rapid rate of peri-urbanization.

Similarly, XU et al. (2019) found that built-up areas in all African cities increased by 5 percent per annum during the 1999–2014 period. This is a slight increase compared to the results of this paper, which depicts a rapid increase during the 2010–2015 period. Findings by Fenta et al. (2017) in the evaluation of the dynamics and spatial pattern of the expansion of Mekelle city in Ethiopia for three decades (1984–2014) revealed that the built-up area increased from 531ha in 1984 to 3524ha in 2014. This situation in Africa calls for the need for a planning and surveying land strategy, which will ensures that affordable, planned, surveyed and serviced land is available for housing development.

The model for the prediction of built-up area explain about 96.2% of the increase in building to be influenced by the tested variables as shown by the coefficient of determination of 0.962 (R^2 = 0.962). The model equation was found to be:

$$Y = 503.386 + 0.181344X_1 + 0.131996X_2 + 0.145325X_3 + 1.118189X_4 + 0.166944X_5 + 0.1753924X_6 \quad (3)$$

The prediction in this paper (Figure 3) suggests that built-up areas will continue to expand around main roads, main centres of Goba, Kinzudi, Tegeta A and Matosa; and extend outwards of its surroundings by 2035.

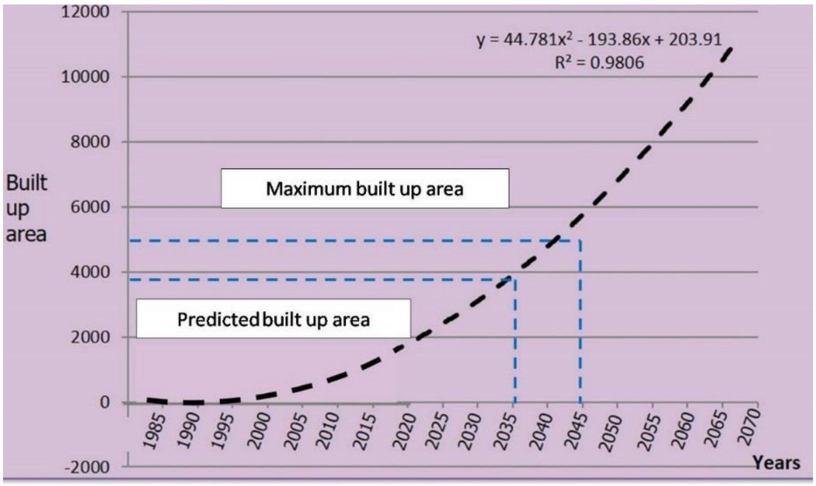

Figure 3: Predicted built-up area in Goba ward by 2035
Source: Field data, 2020

The expansion will be outwards of Goba centre, Kinzudi and Tegeta A centres, and around the main roads. Figure 3 shows the maximum built-up area for Goba will be 4700ha in 2045, with open spaces and landscapes within it, indicating the limits to which all parts of Goba ward will be covered by buildings and roads.

Shariff et al. (2010) applied a simulation to predict the urban growth of Pune city by 2030, and found that the chances of the city's expansion towards the north and east direction could be higher than in the other directions. Sirueri found a substantial increase in the built-up area between 1986 and 2001 by 403,598.3ha (20.8%); later (2008) noting that the built-up area was predicted to expand significantly by 590,274.1ha (37.8%) in 2014. Similarly, Nduwaye (2015) predicted that the Kigali city in Rwanda will expand to double by 2040 if the current trend of expansion rate continues. These findings are in the same trend as those of the Goba ward: implying that expansion in African cities tend to increase over time.

The predicted amount of built-up area in Goba ward entails negative effects if proper measures are not taken. Chai (2018) explains such problems to include the loss of highly productive agricultural land, destruction of biotopes and habitats, and a decline of ecosystem services. In addition to these, Seto (2017) adds inadequate shelter provision, growth of informal settlements, pressure on urban infrastructure and services, increasing unemployment, poverty and informal sector activities, and the deterioration of urban social services. Similarly, Sirueri (2015) argues that urban expansion involves fragmented buildings, which are associated with more traffic on the roads that increases public costs and cost of infrastructure. These problems might infringe the sustainability of Goba ward in 15 years to come.

4.2 Expansion Model by the Increase in the Number of Buildings

The number of buildings kept increasing from 2005–2020; and were concentrated on the major roads, main centres, institutional areas, business activities, and along other minor roads as shown in Figure 4.

Changes noted from 2010–2020 show that the most increased number of buildings were particularly in large part of Kinzudi, Goba centre and Tegeta A sub-wards. This is the same in areas around 250m from the main roads in the same period due to the ease of accessibility that attracts people to access shops, services and other commercial needs.

The model of the prediction of the number of buildings explain about 97.1% of the increase to be influenced by the tested variables. The model equation is shown by coefficient of determination of 97.1% (R^2 = 0.971).

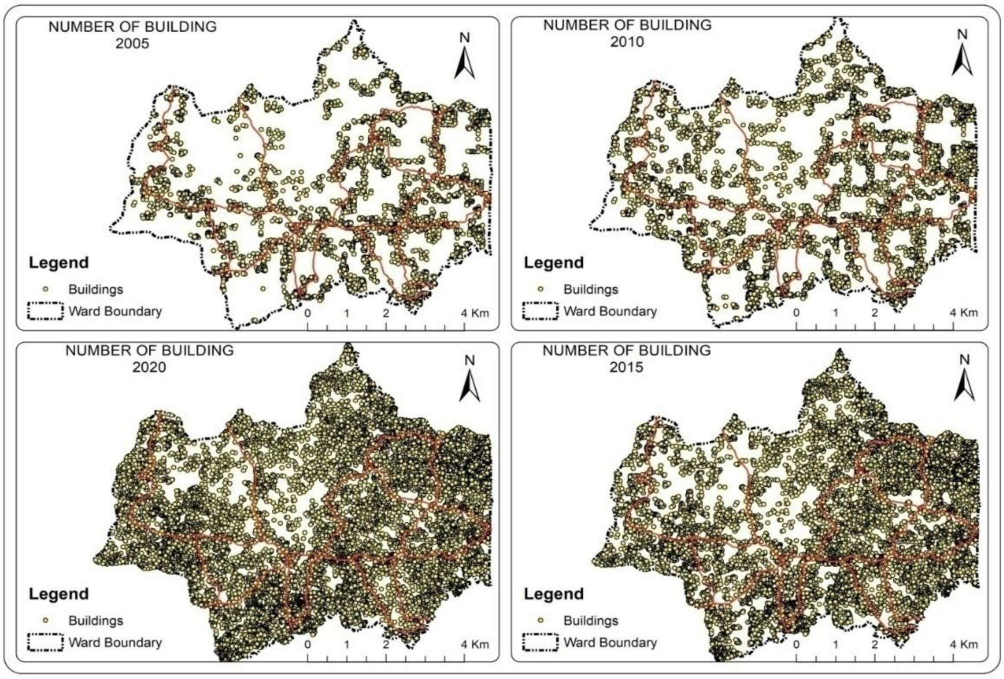

Figure 4: Trend of Number of Buildings from 2005 to 2020
Source: Researcher's illustration, 2020

Here, the model equation was found to be:

$$Y = 503.386 + 0.181344X_1 + 0.131996X_2 + 0.145325X_3 + 1.118189X_4 + 0.166944X_5 + 0.1753924X_6$$

Independent variables in this model include the number of residential buildings (X_1), number of buildings within 250m of main roads (X_5), number of building within 1km from main centres (X_6), number of business activities (X_2), number of road kilometres (X_4), and the number of institutions (X_3). The number of institutions (X_3) had less p-value at significant levels, while the number of business activities (X_2) and the number of road kilometres (X_4) were not significant to the model. The number of residential buildings (X_1) proved to be the most significant variable. A unit increase of residential buildings (X_1) increases the number of buildings by 0.181344 residential units. It was found that areas of 250m from main roads (X_5) experience more buildings than others. Physical observations revealed such places to be occupied by different economic activities like shops, bus stands, cafeterias, etc.

Also, a unit increase of one building causes changes in the total number of buildings by 0.166944 units. The same applied to areas within 1km from main centres (X_6), whereby a unit increase of residential buildings within a centre caused changes in the number of buildings in Goba ward by 0.1753924 residential units. The number of road kilometres (X_4) led to changes of the number of buildings by 0.145325, through a unit increase of one institution building. On the other hand, the number of business activities (X_2) and the number of institutions (X_3) were less significant in bringing more changes in buildings.

Mustafa (2018) found that land-use policy, slope, and distance to roads are the most important determinants of the expansion of cities. These finding differ from those of this paper which identified roads and the number of residential buildings as the foremost determinants of the expansion of peri-urban areas. Nduwaye (2015), on the other hand, finds that expansion tends to occur in areas around local and big centres (CBD), on wetlands, and on low-slope sites. This is in line with the results of this paper: most buildings were concentrated around the centres of Kinzudi, Tegeta A and Goba centre.

Figure 5 shows that while the numbers of buildings at Goba ward were 18,000 in 2020, they were predicted to rise up to 38,000 by 2035. The maximum expansion in terms of the number of buildings is predicted to be 55,000 in 2045. The expected increase in the number of buildings brings environmental problems, and threatens the wellbeing of peri-urban areas.

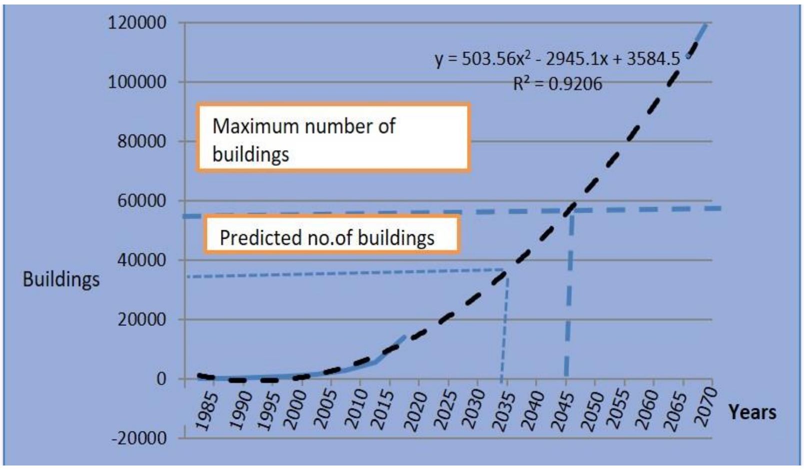

Figure 5: Predicted Number of Buildings by 2035
Source: Researcher's illustration, 2020

5. Densification of Buildings in Goba Ward

A high density was seen to be at the Goba and Kinzudi centres, and a slight density was observed at Tegeta A and Matosa centres. High density was mainly found along the main roads, and slightly dispersed further from the roads. Figure 6 illustrate how Goba was transforming from more vacant spaces to concentrated settlements.

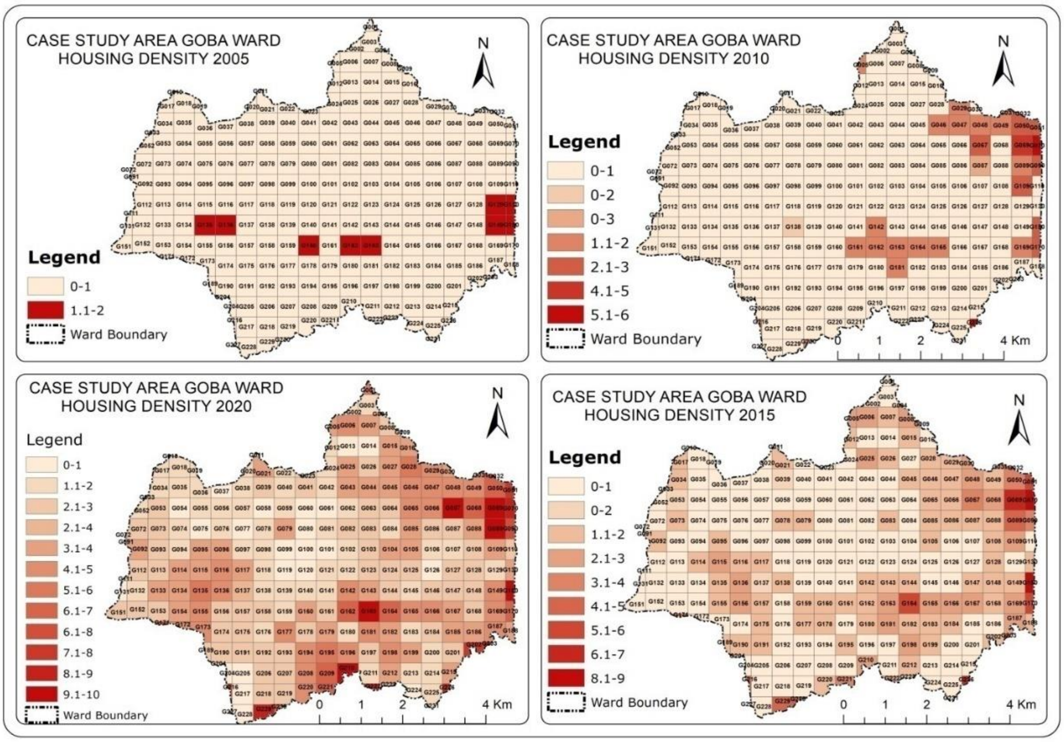

Figure 6: Densification Trend in Terms of Building Density (2005–2020)
Source: Researcher illustration, 2021

The presence of more buildings at centres and around main roads have attracted more people to build and settle in; and as a result the ward building density increased in 2015 compared to 2000. These centres are concentrated with business activities like retail shops, wholesales, *genges*, carpentries, welding, bricks-making, *mama lishe*, cafeterias, and transport services like tricycles and motorcycles.

The final model for building density is the number of buildings per unit area. The model equation explains about 94% of the densification of buildings in Goba ward, as shown by the coefficient of determination of 0.943 ($R^2 = 0.943$).

The model equation was found to be as follows:

$$Y = 11.67778 + 0.1983508X_1 + 0.137839X_2 + 0.97594X_3 + 1.029494X_4 + 0.17875X_5 + 0.19432X_6$$

The significant variables were residential density (X_1), road density (X_4), main road building density (X_5), and main centre building density (X_6); while business density (X_2) and institution density (X_3) were not significant to the model.

Residential density (X_1) is one of the most significant variables to cause changes in building density as revealed in the model that a unit increase of one residential density amounts to an increase of building density by 0.1983508 residential densities. Also, a one unit increase of road density (X_4) will amount to an increase of building density by 1.029494. Similarly, a unit increase of building density within 250m from the road, and building density within 1km from a main centre, will increase more building density by 0.17875 and 0.19432, respectively. Building density results plays a significant role in determining densification of Goba ward as it shows the transformation of buildings from low density to high density. These findings imply that road density creates a permeability that eases accessibility to various places, and also influences building constructions along the main roads for easy transportation of goods and services: all of which invite settlements.

Building density of Goba ward depended on the concentration of buildings in localities such as high density areas which contained 63 buildings per unit area/ cell area; medium density had 33 buildings/unit areas; and low density contained 20 buildings/unit area. Figure 7 shows that the density of Goba ward in 2020 was 240 buildings/unit area, but when this was predicted for 15 years the results suggested the rise of the density up to 400 buildings/unit area by 2035.

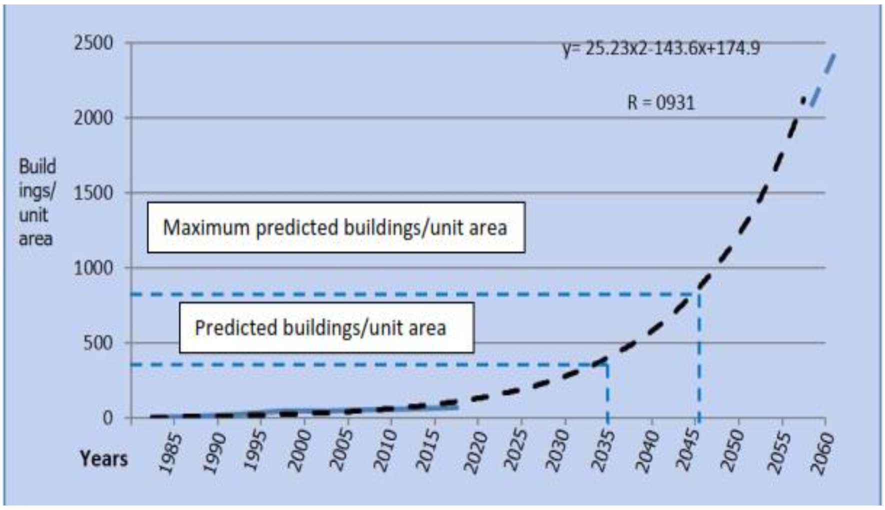

Figure 7: Predicted Buildings/ Unit Area by 2035
Source: Field Data, April 2020

The maximum density for Goba ward is expected to be 800 buildings /unit area by 2045. Kinyua (2010) recommends building density to be 45/buildings per hectare; as such, the projected and expected maximum density will exert pressure on the sustainability of Goba ward; giving rise to more social and environmental problems like pollution, congested buildings, inaccessibility, social crime and insufficient services. Figure 7 indicates that the maximum densification will be 850 buildings/unit areas in the whole Goba ward, particularly in areas around 250m from main roads, and 1km from sub-centres. This is a very high density that might trigger the social and environmental problems mentioned earlier. Dawodieh (2017) reported that unguided density is linked to noise and air pollution in Jordan, Israel; while Lupala and Bayo (2014) found that unguided building density is associated with blocked ventilation, loss of view, loss of privacy, broken skyline, and the creation of unused spaces between buildings.

Building density may also reduce ecosystem and ecological value of land because of housing construction that degrades land. In exploring rural-urban linkages and examining how changes of land-use are influenced in peri-urban areas, Mushi (2008) noted that the increase in density led to diminished fertile land and loss of ecosystem services. Other problems associated with the increase in density include increased surface-run water that leads to flooding, and reduced ecological value of land because of degradation arising from impacts of increased housing (Delmelle, 2014). On the other hand, Nkwanyana (2015) observed the contrary: that densification creates an opportunity for service delivery due to increased demand in densified areas than in scattered areas. However, Kinyua (2010) argues that sustainable peri-urban development can be achieved by controlling the increase of density through various strategies like regularisation and redevelopment strategies. This is supported by Magina et al. (2020) who recommends to undertaking regularisation in areas that indicate unguided densification. The strategy enhances sustainable development of peri-urban areas through offering property rights for security of tenure, and securing land for basic community services and infrastructure to improve the well-being of residents in densified areas. Since the projected maximum density of Goba ward is unhealthy, this paper recommends the adoption of the above strategies to ensure secure sustainable and improved settlement.

6. Conclusion

Peri-urban areas are subjected to sharp increase in built-up areas, number of buildings, and building density due to rapid urbanization. The results show that the rate of peri-urban expansion and densification continues to increase over time, which possess more threats to sustainable development of peri-urban areas and associated natural resources. The paper recommends that the built models be adopted as useful tools for equipping planners, policy- and decision-makers with appropriate instruments in addressing the rapid expansion of built-up areas, increased number of buildings and densification; and ensure sustainable peri-urban development. The uncovered results on the expansion and densification of the Goba ward also calls for planning and regulatory interventions.

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