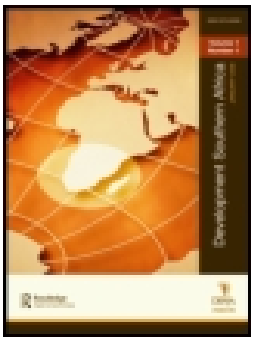

Development Southern Africa

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cdsa20

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To cite this article: Samuel Tumwesigye, Matthias Vanmaercke, Lisa-Marie Hemerijckx, Alfonse Opio, Jean Poesen, Ronald Twongyirwe & Anton Van Rompaey (2021): Spatial patterns of urbanisation in Sub-Saharan Africa: A case study of Uganda, Development Southern Africa, DOI: 10.1080/0376835X.2021.1932426

To link to this article: https://doi.org/10.1080/0376835X.2021.1932426

Published online: 10 Jun 2021.

DEVELOPMENT SOUTHERN AFRICA
https://doi.org/10.1080/0376835X.2021.1932426

Spatial patterns of urbanisation in Sub-Saharan Africa: A case study of Uganda

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ABSTRACT
Sub-Saharan Africa is rapidly urbanising. This urbanisation may contribute to socio-economic development as more people participate in the urban economy. Nevertheless, rapid urbanisation is not always sustainable. Primary cities often grow fast, leaving secondary towns lagging behind with weaker economies. Viable strategies for sustainable urbanisation may therefore also need to focus on developing secondary towns. Nevertheless, very few studies, hitherto, have assessed the (relative) importance of secondary towns in urbanisation process in Sub-Saharan Africa. We aim to address this gap by studying the patterns and explanatory factors of urban population growth in Uganda. Based on a longitudinal analysis of population rank-size distribution, we show that the population distribution gap between secondary towns and the primary city is widening. Nevertheless, statistical analyses further indicate that secondary towns with above 50 000 inhabitants have the highest population growth rates. This indicates that future investments should aim at upgrading socio-economic infrastructures in secondary towns.

KEYWORDS
Sustainable urbanisation; rank-size analysis; secondary towns; Sub-Saharan Africa

1. Introduction

Sub-Saharan Africa (SSA) has been experiencing a progressive economic growth and social improvements over the past decades (Heidhues, 2009; AUC-DEA, 2018). This social and economic progress is closely linked to a demographic transition in the SSA region. In this region, population has been growing by an annual average of 1.3% since 2000, with 40.7% of the total population living in urban areas by 2019 (World Bank, 2019). The urban population is predicted to double by 2050 (UN-DESA/PD, 2018b).

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Conventionally, as national economies grow, there is a tendency of increasing urbanisation (Kuznets, 1968; Bairoch, 1988; Henderson, 2010; Jedwab & Vollrath, 2019). However, urbanisation in SSA is occurring at a much faster pace than countries in developed regions (Jedwab & Vollrath, 2015; UN-DESA/PD, 2018a). By 2018 thirteen SSA countries had attained an urbanisation level of over 30%, despite their annual GDP per capita being only around US $1000 (World Bank, 2019). The rate of this phenomenon also exposes development concerns that may require governments' policies and actions if urbanisation is to effectively contribute to SSA's sustainable social and economic transformation.

In 2018, the urban population of the SSA region increased with 4.1%. This is an annual growth rate that is twice as high as the global rate of 2% (UN-DESA/PD, 2018a). By 2050, six out of ten people in SSA are expected to be urban dwellers (World Bank, 2013). Notably, the average annual urbanisation rate (2000–18) was above the SSA region average of 4% for 19 SSA countries (Figure 1(b)). These countries are not necessarily those that were the least urbanised in 2000. Gabon, for example, which had an urbanisation level of 78% in 2000, has urbanised at an average rate of 5.3% per year over the last 18 years (Figure 1(a)). Countries like Angola, Mali, Tanzania and Uganda are even urbanising at a rate of over 8% per year (Figure 1(b)).

The rapid growth in urban populations is associated with drastic expansion and emergency of urban centres. In 2018, the World Cities Report (UN-DESA/PD, 2018a) highlighted the significant increase in the number of urban centres across Africa. In Uganda, for example, the gazetted urban centres increased from 94 in 2002 to 468 in 2018 (MFPED, 2019a). Today, more than 80% of the urban dwellers in SSA live in secondary towns, rather than in the capital city of each country (Hommann & Lall, 2019; World Bank, 2019). Therefore, a key development question is: which category of urban centres is likely to absorb the largest portion of Africa's growing urban population?

In 2016, 'The World's Cities in 2016 Report' (UN-Habitat, 2016) noted an increasing population growth rate in secondary towns and predicted a sustained growth trend during the next two decades. Depending on their function and population size, urban centres can be classified as either primary or secondary towns or cities. The primary town/city, commonly also the capital city, is typically the main political, social and economic centre at a national level, while smaller towns only play a secondary role at subnational levels. The growth of cities in Africa, normally takes the form of spatial expansion into their peri-urban spaces and eventually converge and agglomerate with their neighbouring other towns. Related to population size, growth is a function of natural population increase and in-migration (UN-DESA/PD, 2018b).

In most SSA countries, there is a significant gap in the level of growth and development in capital cities and secondary towns (UN-DESA/PD, 2018b). Historically, development efforts and public investments have disproportionately focused on the capital cities, leaving secondary towns with weaker urban economies and institutional bases (UN-Habitat, 2016). Most countries lack an integrated urban development strategy (Cohen, 2006; Cobbinah & Darkwah, 2017), making secondary towns lag behind. This disparity may significantly affect the capacity of secondary towns to contribute to (sub-)national social and economic development. Furthermore, the lack of functional urban planning and management structures (Satterthwaite, 2017) exacerbate the negative effects of urban sprawl already observed in most SSA countries (Nagendra et al., 2018)

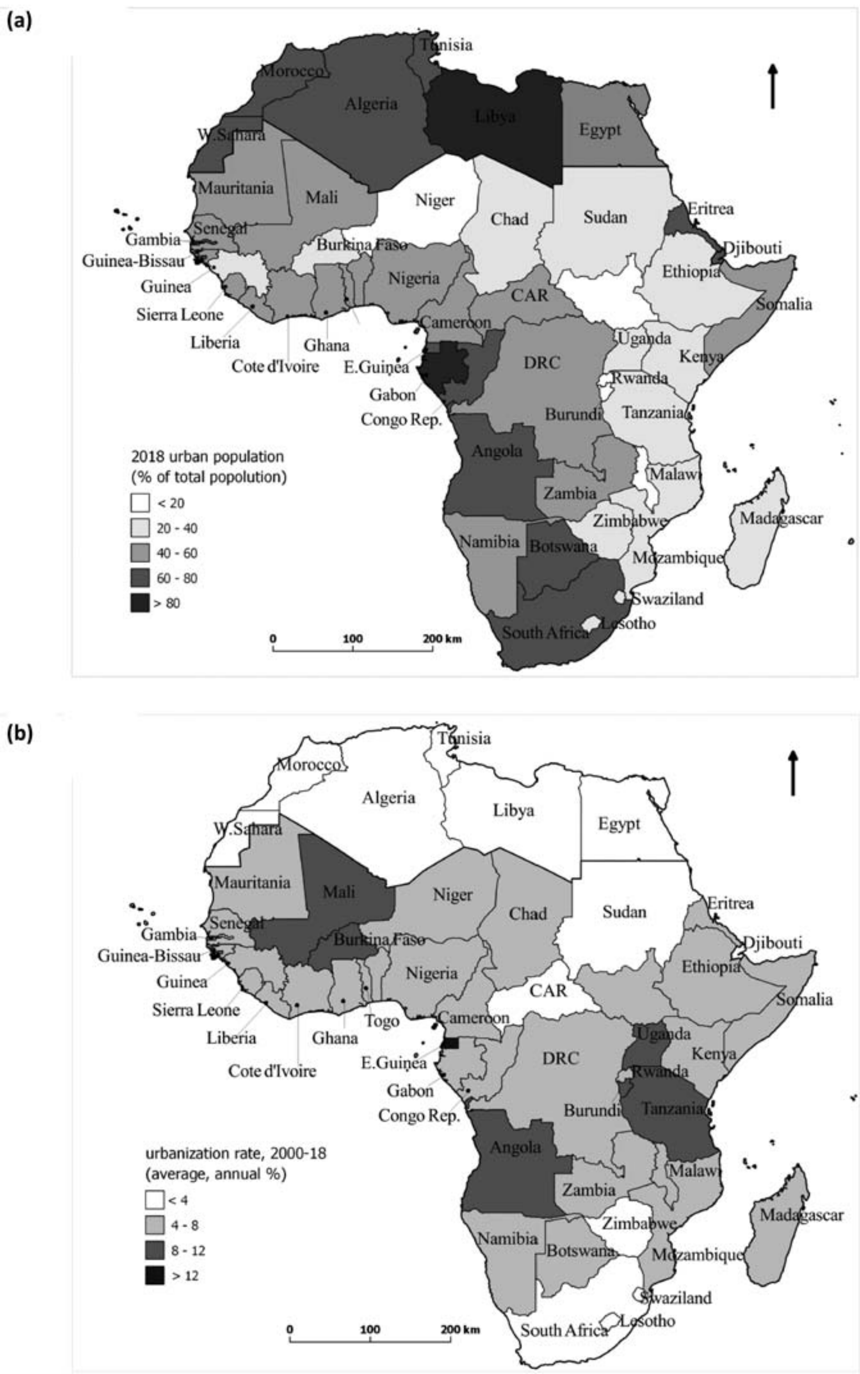


Figure 1. Urban population as share of the total population in 2018 (a), and Average annual urbanisation rate for the period 2000–18 for African countries (b). Data Source: World Bank national accounts data, 2019.

and particularly in Uganda (Vermeiren et al., 2012). Overall, the associated negative effects of urban sprawl should be addressed if the social and economic benefits of urbanisation are to be fully realised (Christiaensen et al., 2013; Agergaard et al., 2018).

As SSA continues to rapidly urbanise, sustainable social and economic development will increasingly depend on how urbanisation is managed (Obeng-Odoom, 2017; ODI, 2018). This is particularly so for secondary towns (McGranahan & Satterthwaite, 2014; Lall et al., 2017). However, such management strongly relies on our understanding of the growth patterns of secondary towns (for example Agergaard & Ortenbjerg, 2017) as well the relation of these secondary towns to the primary city. Hitherto, most studies on urban growth and the role of urban centres on population dynamics have primarily focused on (primary) capital cities (Seto et al., 2011; Zeng et al., 2015; Saghir & Santoro, 2018; Xu et al., 2019). Only a few studies have concentrated on secondary towns (Xu et al., 2019), particularly in SSA countries. Nevertheless, understanding the patterns of urban growth at a national level and, in particular, the link between urban growth in secondary towns and capital cities is imperative to allow for an integrated and controlled urban development.

In this paper, we are set to establish the spatial distribution pattern of urban centres in Uganda, investigate and explain the population growth of secondary towns relative to the capital city, establish the spatial link with the surrounding rural areas and then draw implications for sustainable rural-urban interaction and development. Therefore, this study has two objectives. First, we aim to analyse the population growth of secondary towns relative to the primary capital city and establish the spatial distribution pattern of urban centres. Second, we analyse factors that influence these observed patterns. We hypothesise that only a few secondary towns have a strong growth potential which depends on their size and their connectivity with the capital city. To meet the research objectives and test this hypothesis, we selected the rapidly urbanising Uganda as a case study and answer research questions, such as: Does the distribution of urban population in Uganda follow Zifp's rank size rule?, How does population in secondary towns grow relative to the capital city?; Does proximity to urban centres contribute to population size change of a given area (rural or urban)?; Which urban size category has much influence on population size change of its neighbouring areas?.

2. Case study country, materials and methods

2.1. Uganda as case study for understanding urbanisation patterns

At an annual rate of 3.2%, Uganda ranks as the 4th country in the world in terms of population increase (UBOS, 2018; UN-DESA/PD, 2018b). The country had a total population of 34.6 million people in 2014, of which 8.4 million were residing in urban centres (UBOS, 2016). Although, Uganda is predominantly rural, it has urbanised at an average rate of 5.4% per year since 2015 (UBOS, 2019). In 2019, the urban population was estimated at 24.4% of the total population and it is predicted to more than double by 2040 (UBOS, 2019).

Consequently, the country's urban structure has expanded from 94 gazetted urban centres in 2002 to 468 in 2019 (MFPED, 2019b). Although, the capital city (Kampala) remains the only urban centre with over a million inhabitants, the number of secondary towns with population size of at least 10 000 people has increased from 75 in 2002 to 141 in 2014 (Figure 2). Kampala's primacy has a historical background where since colonial times it has been a political and economic capital serving as an administration centre and as the main manufacturing and business hub for the country. This central role has influenced Kampala's growth dynamics and as a capital city, it has disproportionately been targeted for development investment relative to other towns (Bidandi & Williams, 2017). Consequently, Kampala has a higher concentration of industries and amenities for business services. The comparatively high concentration of social services, potential business and employment opportunities in the services and industrial sectors, explains the concentration of urban population in Kampala (Kasibante, 2011). Also, the development of a road network that links the city to a series of neighbourhood towns facilitates spatial expansion of Kampala along these link roads leading to convergence of the towns into the equivalent of satellite urban nodes of the capital city (Ruhiiga, 2013). Examples of emerging Kampala's satellite towns include Nansana, Kira, Wakiso, and Mukono municipalities (UBOS, 2016).

Apart from the capital city and its neighbouring satellite towns, the growth of secondary towns across the country relies on the demand of urban services from the agriculture hinterland communities. The more prosperous the agricultural hinterland, the more demand for urban services (Mukwaya et al., 2012). As such, the high potential agricultural zones of the slopes of Mount Elgon in the east, the northern shores of Lake Victoria, and districts in the southwest are expected to have a relatively higher concentration of urban centres. The large towns seen in northern Uganda in 2002 (Figure 2(a)) reflect many rural households who, due to security concerns associated with the Lord's Resistance Army insurgency in this region, moved to these urban centres for safety. With the return of peace, since early 2000, these towns in northern Uganda registered a reduced pace of population growth as many of the people that had sought refuge in them returned to their rural homesteads (Kasibante, 2011).

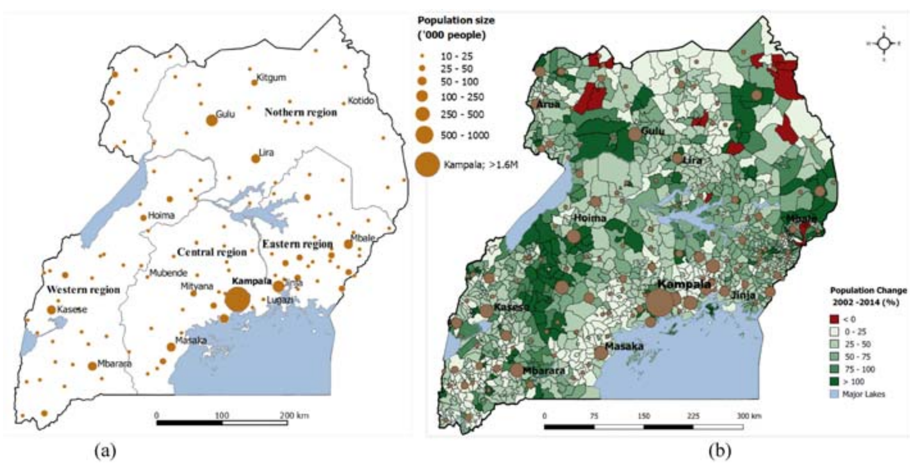


Figure 2. Spatial distribution of urban centres in Uganda by population size in (a) 2002 and (b) 2014, and Population size change (increase or decrease) in towns and rural sub-counties for the period 2002–14. Data Source: Uganda Bureau of Statistics (UBOS), census data of 2002 and 2014.

The pace of Uganda's urbanisation started rising in 2000, with urban population growing from 12.6% of the total population in 2002 to 24.4% in 2014 (UBOS, 2016). The country's urban footprint (Figure 2) is dominated by various sized secondary towns, some of which are along the growth corridors that connect the capital city to hinterland neighbouring countries; Rwanda in the south, DRC in South-west and South Sudan in the North. Through its Vision 2040, the government of Uganda targets to promote systematic urbanisation with balanced urban system that optimises the complementary role of different towns (MFPED, 2019a). To achieve this development target, it is important to understand the growth patterns of these secondary towns relative to the capital city, as well as understand the contributing factors.

2.2. Data sources

To analyse urban population growth and patterns in Uganda, we used the national population and housing census (NPHC) data from the Uganda Bureau of Statistics (UBOS). The data were collected during the 2002 and 2014 census years. For both years, a standard questionnaire was administered to all households in rural and urban areas throughout the country. The similarity in data collection approach for 2002 and 2014 enables comparison. For rural areas, the geographical unit of our analysis was the sub-county, i.e. the lowest level of census data tabulation and disaggregation. A sub-county is a collection of 7–12 rural villages. It is also the lowest gazetted local administrative and planning unit mandated under both the decentralisation policy and the local government act to implement and monitor government development programmes (MFPED, 2014). Sub-counties that are hosting refugees, those that were host communities for the internally displaced persons during the northern Uganda insurgency, and those that experienced people resettlement due to landslides (particularly in Mount Elgon region) were excluded from our analysis.

The urban centres considered in this study were those already gazetted by the government of Uganda as either a city, municipality, town council or a town board. However, the capital city of Kampala constitutes several gazetted units. In order to allow for consistent and realistic comparisons between the capital and secondary towns over the different census periods, we considered the 'Greater Kampala' metropolitan area as being composed of Kampala capital city and the secondary towns in Mpigi, Mukono and Wakiso districts that are located within a 30km radius from the Kampala Central Business District (CBD).

2.3. Data analysis methods

2.3.1. Spatial patterns and rank-size distribution of urban centres

Thematic maps were constructed to visualise the spatial patterns of the urban centres over the two census years (2002 and 2014). Using QGIS (version 3.4.2), we classified secondary towns based on the population sizes according to the 2002 and 2014 census data. Additionally, the intercensal population size change for both rural sub-counties and the urban centres was computed, classified and plotted onto the Ugandan map to facilitate visualisation of population changes and regional comparisons.

To analyse the distribution of urban population per region of Uganda, a location quotient (LQ) of urban population size was computed and compared for the two census periods. This was done using the following formula (Yadav, 1986):

$$LQ = (UPx/\ TPx)/(UPn\ /TPn) \quad (1)$$

where LQ is Location Quotient, UPx and TPx are Urban Population size and Total Population size of region x and UPn and TPn are the Urban size and Total population size of Uganda respectively.

To further explore the relative growth in the population of secondary towns as compared to the capital city, we conducted a population rank-size distribution analysis. Following Zipf's rank-size rule (Zipf, 1946), we conducted this analysis in three steps. First, all urban centres were ranked from largest to smallest according to their population size. Then the top ten urban centres were selected. Second, the population size of each urban centre according to the 2002 and 2014 census periods was plotted against its rank. Finally, this plot was compared to a theoretical rank-size distribution. The theoretical rank-size distribution predicts that the second largest town is half the size of the largest town, the third is one-third the size of the largest town, and so on (Zipf, 1946; Sidra et al., 2018). This prediction is based on empirical assertion that towns follow a proportional growth process and that larger towns require less equal-sized towns in their surroundings (Zipf, 1946).

For every rank, we calculated the difference between the actual and theoretically expected population size and expressed this as a percentage of the corresponding actual population size. This produced a discrepancy quotient, showing the relative increase or decrease in urban population size required to match the theoretical population rank-size distribution (Yadav, 1986). These analyses were conducted for both census periods.

2.3.2. Correlation and multiple linear regression analyses

To understand how (changes in) population sizes of urban centres relate to the population of its surrounding areas (rural or urban), we conducted correlation and multiple linear regression analyses. For this, we constructed a correlation matrix between the intercensal (2002–14) population size change (increase or decrease) and possible explanatory variables. To allow conciseness and ease to read, the 'intercensal population size change between 2002 and 2014' will subsequently be referred to as 'population change'.

Overall, the selection of the considered explanatory variables was based on earlier studies on the drivers of population growth of an area for example: 'initial population stock, distance between origin and destination, migration flow rate (Cameron & Poot, 2019); in-migration rate (Crankshaw & Borel-Saladin, 2019); proximity to urban centre (Lucas, 2001); migration distance, area population level, relative attractivity score (Yang et al., 2019); population growth rate (Tacoli, 1998); population size, distance (Stewart, 1941; Zipf, 1946; Schwartz, 1973)'. Note that each 'data point' in our analysis is either a rural sub-county or an urban centre. We, therefore, considered the following relevant explanatory variables: the estimated natural growth rate in population, in-migration rate, rural (0) or urban (1) status of the data point, the population size in 2002, and the travel distance between the data point and the nearest urban centre in each of the urban centre categories. The computed population change was adjusted by the corresponding natural population growth rates of each area to obtain the population size change due to in/out-migration. Population natural growth rates for each rural sub-county and urban centre were obtained from UBOS census and population prediction database (UBOS, 2018). These variables were fitted in a regression model (Equation 2) as explanatory variables for the intercensal population size change.

We generated the travel distance between each data point and the nearest urban centre of a specified population size as follows. First, we categorised urban centres considering the 2014 population size: (1) over 100 000 persons, (2) between 50 000 and 100 000 persons, (3) between 10 000 and 50 000 persons, and (4) less than 10 000 persons. We used the natural breaks criterion in QGIS to optimise the number of urban centres in each category. As explained above, Greater Kampala was considered to be one separate unit. It is the only urban centre with a population size above one million inhabitants. Second, we generated the shortest route distances (physical /road travel distances following the Open Street Map (OSM) road network) between each data point (an urban centre or rural sub-county) and the nearest urban centre in each of the urban categories mentioned before. This road travel shortest distance was calculated and generated through open route network analysis in QGIS (Mandel et al., 2016).

The generated distances did not exhibit a normal distribution. Given this non-normal distribution, we considered non-parametric spearman rank correlation coefficients (Myers & Sirois, 2004) to examine the explanatory variables in explaining the population change. To correct for possible inter-correlations amongst the considered variables, we also calculated non-parametric partial correlations (Steel & Torrie, 1960). These partial correlations were computed based on the standard correlations between each of the explanatory variables and the population change percentage while holding all the other contributing variables constant. Further, to examine the potential importance of these variables in explaining the population change, we also conducted a stepwise multiple linear regression analysis (Draper & Smith, 1998). We fitted the regression model as:

$$\text{Intercensal population size change} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots \ \beta_7 X_7 + \ \varepsilon_i \qquad (3)$$

where β is the regression coefficient indicating the explanatory power of the $X_1 \ldots X_7$ considered explanatory variables, namely: Population natural growth rate, Population size in 2002, Population size change due to in-migration, Distance (km) to nearest secondary town of 10–50 (000'persons), Distance (km) to nearest secondary town of 50–100 (000'persons), Distance (km) to nearest secondary town of above 10 (000'persons), Distance (km) to Kampala city. At each step of the regression analysis, the most important contributing variable that most significantly increases the explanatory power would be evaluated (based on an F-statistic) (Draper & Smith, 1998) and subsequently added into the model. We interpreted the absolute value of β (Table 4) to indicate the order of importance of the explanatory variables in explaining the intercensal population size change; where a variable with the highest β value relatively contributed the most explanatory power.

3. Results and discussion

3.1. Uganda's expanding urban structure and its spatial distribution

Secondary towns in Uganda have increased both in terms of the number as well as their population size (Figure 2). During the intercensal period (2002–14), 66 urban centres had a population size increase of more than 50%. For 36 secondary towns, this increase was more than 100%. These urban centres are characterised by an uneven spatial distribution pattern across the country (Figure 2). The south and central areas in Uganda, especially around Lake Victoria, are characterised by a higher density of these urban centres. Noticeably, these relatively bigger-size secondary towns are located along the border to border growth corridors, particularly the East to South-west corridor (Tororo-Jinja-Lugazi-Kampala-Masaka-Mbarara-Kabale) connecting Rwanda and the East to North corridor (Tororo-Soroti-Mbale-Gulu-Arua) connecting South Sudan and Democratic Republic of Congo (DRC).

In terms of distribution of urban population and urban centres, the central region had consistently higher location quotients (LQ; see Equation 1) than the national value in both 2002 and 2014 (Table 1). It is therefore the most urbanised region of the country, followed by the western region (see Figure 2). This stronger urbanisation in the central region is likely linked to the influence of the capital city, which is relatively more developed and offers more employment, education and other socio-economic opportunities (Mukwaya et al., 2012; World Bank, 2015; Bidandi & Williams, 2017; MFPED, 2019a). This makes the capital city the most preferred destination for internal migrants (MFPED, 2019a). Nevertheless, in 2014, the northern and western regions also had an increase in LQ values, implying an increased urbanisation in these regions as well. The western region had the highest percentage increase in its location quotient value, indicating that the region urbanised faster than the others between 2002 and 2014.

Regions with large population size increases (Figure 2(b)) also have a high concentration of urban centres of various sizes. Relatively, larger urban centres (population size of above 50 000 inhabitants) are in close proximity to rural areas with a population size increase of more than 25% (see Figure 2(b)). For example, Fort Portal, Gulu, Jinja, Kasese, Kitgum, Lira, Masaka, Mbale, Mbarara, Masindi, Mityana, Mubende and Mukono Municipalities are surrounding by rural sub-counties that had an intercensal population size change percentage of above 50%. This suggests a potential connection and influence of the urban centres on population dynamics of their surrounding rural areas. More specifically, it agrees with earlier empirical studies on rural-urban interactions, indicating that urban centres influence the population dynamics in their surrounding areas: for example in Ghana (Awumbila, 2017), and in Wisconsin, USA (Chi

Table 1. Location quotient (LQ; Equation 1) of urban population per region of Uganda.

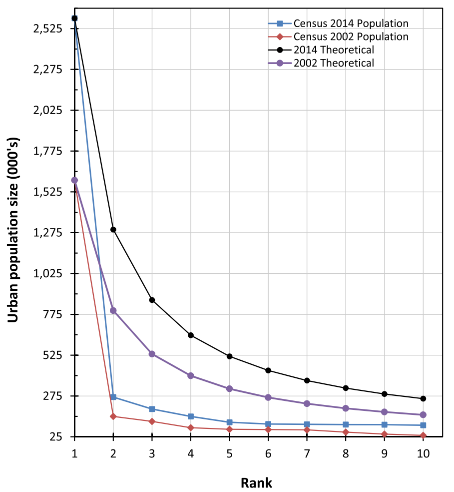
Regions of Uganda	2002	2014	Change (%)	Interpretation
Central	1.68	2.06	23	LQ > 1, thus the concentration of urban population is relatively higher than the national.
Eastern	0.51	0.49	−4	LQ < 1, thus the concentration of urban population is relatively lower than the national
Northern	0.42	0.49	17	
Western	0.51	0.81	59	

& Ventura, 2011). We further analyse and discuss these potential interactions in a later section on ‘contributing factors to population size change’.

3.2. Rank-size distribution of Uganda urban centres

As shown in Figure 3, Uganda’s urban population rank-size distribution clearly deviates from the theoretical rank-size distribution. This indicates a disproportionate population size distribution amongst towns. The second largest town was 11 times smaller than Greater Kampala in 2002 and 9 times smaller in 2014 (Figure 3). During this period, the population size of Greater Kampala remained significantly larger than the population size of other secondary towns across the country. Historically, since the colonial days, Kampala has been disproportionately targeted and developed as an administrative centre for political and central government governance, and also as a commercial hub for trade and business (Bakwesegha, 1974). The concentration of political, administrative and trade functions and opportunities in Kampala enhances its dominance for urban population concentration over the other secondary towns.

Nevertheless, the calculated average discrepancy quotient decreased from 379% in 2002 to 239% in 2014. This decrease indicates that over the 2002–14 study period, secondary towns did grow relatively faster than Greater Kampala and therefore, the rank-size distribution of towns in Uganda may be evolving towards this theoretical distribution. Already, larger towns with above 100 000 inhabitants increased from 2 in 2002 to 16 in 2014 (UBOS, 2016; see Figure 2).



Rank	In 2002	In 2014	Rank	In 2002	In 2014
1	Greater Kampala	Greater Kampala	6	Mbarara	Masaka
2	Greater Jinja	Greater Jinja	7	Masaka	Kasese
3	Gulu	Mbarara	8	Kasese	Hoima
4	Lira	Gulu	9	Kitgum	Lira
5	Mbale	Lugazi	10	Mityana	Mityana

Figure 3. Rank size distribution of urban population of Uganda towns, based on 2002 census data and 2014 census data. The ‘theoretical’ rank size distribution corresponds to a theoretical distribution where the second largest town is half the size of the biggest town, the third is one-third the size of the biggest town, etc. (Sidra et al., 2018). Data Source: Uganda Bureau of Statistics, census data of 2002 and 2014.

Over the two census years, several secondary towns also shifted ranks in these distributions. For example, Lira was ranked fourth in 2002, but ninth in 2014, and Mbarara was ranked sixth in 2002, but third in 2014 (Figure 3). Some secondary towns are growing fast because of their functional role as development growth poles; serving as trade and business hubs, and transportation nodes connecting regional catchment area including the neighbouring hinterland countries such as Rwanda, South Sudan and DRC. For example, Mbarara serves the South-western Uganda region, Rwanda and South-eastern DRC, Gulu serves the Northern Uganda region and South Sudan. Also, the evolving trade corridors that link the capital city to the gazetted strategic cities that offer a functional specialty for national economic development, such as Jinja and Nakasongola as industrial cities, Fort Portal as a tourism city, Moroto and Hoima as mining and oil cities, have catalysed the rapid growth of these secondary towns (MFPED, 2019b).

The shifts in population size ranking are an indication of the dynamic urbanisation process in Uganda with emerging secondary towns of various population sizes. It also indicates that the current size of an urban centre is not necessarily the best predictor of population increase.

3.3. Contributing factors to population size change

Therefore, we inquired the possible explanatory factors of the observed population size increase in the rural sub-counties and the urban centres. For both areas, the correlation between the population change (2002–14) and the natural growth rate was the strongest and significant (see Table 2), implying that population change is highly associated with natural population increase. This could be explained by the country's high total fertility rate, at an annual average of 6.3 births per woman (UBOS, 2016). It could also be explained by the improvement in social welfare where the population is healthier with increased life expectancy (from 50.9 years in 2002 to 60.7 years in 2014), reduced maternal and infant mortality rates (UBOS, 2016).

The population size change also correlates significantly with the binary variable for the area status: rural (0) or urban (1) (Table 2). This indicates that urban areas were generally characterised by higher population increases. The fact that this correlation is stronger when considering only the population size change due to in-migration further shows that the contribution of in-migration to population size change is clearly more important in urban areas than rural areas. Indeed, 66% of the 1.4 million internal migrants enumerated during the 2014 NPHC had permanently settled in urban areas (UBOS, 2016).

The distance to the nearest town showed significant negative correlation with population change for every town size category considered (Table 2). These negative correlations imply that areas closer to urban centres are associated with stronger population size increase, indicating that urban centres are acting as attraction poles for population growth. This also concurs with other empirical evidence showing that urban growth influences the population dynamics in its surrounding areas (for example, in Wisconsin USA (Chi & Ventura, 2011); in Brazil (Costa da Silva et al., 2017); in USA (Dobkins & Ioannides, 2001; Duranton & Overman, 2005; Partridge et al., 2009; González-Val, 2019; Jedwab & Vollrath, 2019); in Japan (Hsu et al., 2014)). Furthermore, the correlations tend to be stronger with the distance to larger urban centres. Of all urban size categories, the distance to Kampala (the capital city) shows the strongest negative

Table 2. Spearman's rho correlation coefficients between all considered potential explaining variables and the intercensal population size change for both rural and urban areas ($n = 830$).

Variables	Intercensal population size change 2002–14	Population size change due to in-migration	Area is rural or urban	Population size in 2002	Population natural growth rate	Distance to nearest secondary town of 10 –50 (000'persons)	Distance to nearest secondary town of 50–100 (000'persons)	Distance to nearest secondary town of above 100 000 persons	Distance to Kampala
Intercensal population size change 2002–14	1								
Population size change due to in-migration	0.55**	1							
Area is rural or urban	0.15**	0.34**	1						
Population size in 2002	−0.08*	−0.05	−0.04	1					
Population natural growth rate	0.85**	0.22**	−0.06	−0.07	1				
Distance to nearest secondary town of 10–50 (000'persons)	−0.14**	−0.17*	−0.47**	−0.03	−0.05	1			
Distance to nearest secondary town of 50–100 (000'persons)	−0.37**	−0.25**	−0.11**	0.01	−0.25**	0.21**	1		
Distance to nearest secondary town of above 100 000 persons	−0.36**	−0.27**	−0.20**	−0.18**	−0.25**	0.13*	0.19**	1	
Distance to Kampala	−0.56**	−0.25**	−0.10**	−0.03	−0.44**	0.18**	0.48**	0.32**	1

Notes: Correlation coefficients with ** and with * are significant at 0.01 and 0.05 levels, respectively. Values without asterisk are insignificant ($p < 0.05$). Values without asterisk are insignificant ($p > 0.05$).

correlation with population change. This clearly indicates that the capital city exerts an important influence on the population growth of its surrounding areas. Amongst the secondary towns, the distances to urban centres with at least 50 000 persons also show a negative correlations with population change. This indicates that the presence of larger secondary urban centres exerts an influence on the population size increase in their surrounding areas as well. For smaller urban centres (< 50 000 persons), the correlation is clearly much weaker, suggesting that their role as an attraction pole is limited. Proximity to larger urban centres, therefore, has a greater influence on population increase in their surrounding areas than proximity to smaller urban centres.

As shown in Table 2, several of the considered potential explanatory variables may also be inter-correlated. To explore to what extent our considered explanatory variables remain significant in explaining population change when accounting for such inter-correlations, we calculated partial correlation coefficients. These partial correlations were calculated while controlling for the effect of all the other variables. As Table 3 indicates, most partial correlations coefficients remain significant. This strongly indicates that the observed correlations are not merely a result of inter-correlation with other contributing variables, but that they play a significant role in explaining the observed population changes. In this regard, larger towns independently influence population increases in their surrounding areas.

We further assessed this relative influence of urban centres on population size changes in their surrounding rural areas, using a stepwise multiple linear regression analysis. The resulting model (Equation 4) expresses the rural area's population change as a function of the population size in 2002 and the distances to the nearest urban centre of different sizes.

$$\begin{aligned} \textit{Intercensal Population size change} = {} & 72.76 - 0.44\ \textit{distance to Kampala} \\ & - 0.21\ \textit{distance to secondary} \\ & \quad \textit{town of above}\ 100\ (000'\textit{persons}) \\ & - 0.21\ \textit{distance to secondary town of}\ 50 \\ & - 100\ (000'\textit{persons}) \\ & - 0.14\ \textit{population size in}\ 2002 \end{aligned} \tag{4}$$

All distance variables (reflecting the distance to the nearest urban centre of a given size) showed significant and negative coefficients (Equation 4 and Table 4). This demonstrates

Table 3. Partial correlation coefficient (partial *r*) and corresponding *p*-value between intercensal population size change and each considered potential explanatory variable.

Variable	Partial *r*	*p*-value
Population natural growth rate (%)	0.82	0.0001
Population size change due to in-migration	0.70	0.0001
Rural or Urban	0.11	0.0137
Population size in 2002	−0.26	0.0001
Distance to nearest secondary town of 10–50 (000'persons)	*−0.08*	*0.6058*
Distance to nearest secondary town of 50–100 (000'persons)	−0.30	0.0001
Distance to nearest secondary town of above100000 persons	−0.28	0.0001
Distance to Kampala	−0.38	0.0001

Notes: We calculated all partial correlations by controlling for all other explanatory variables. Variables in bold and in normal font are significant at a level of 0.01 and 0.05, respectively. Variables in italic have an insignificant partial correlation.

Table 4. Multiple linear regression estimates for rural and urban areas (dependent variable: Intercensal population size change (%)).

Variable	Unstandardised beta coefficient	Standard error	Standardised beta coefficient	*p*-value
Rural areas: R^2 is 0.383, n = 704				
Intercept	72.775	1.949		0.001
Distance to Kampala of 1.5million persons	−0.076	0.006	−0.444	0.001
Distance to nearest secondary town of above 100 000 persons	−0.068	0.010	−0.214	0.001
Distance to nearest secondary town of 50–100 (000′persons)	−0.029	0.008	−0.124	0.001
Population size in 2002	−0.0001	0.0003	−0.136	0.001
Urban centres: R^2 is 0.381, n =126				
Intercept	76.547	4.007		0.001
Distance to nearest secondary town of above 100 000 persons	−0.122	0.026	−0.388	0.001
Distance to Kampala	−0.056	0.012	−0.355	0.001
Population size in 2002	−0.0002	0.0008	−0.211	0.006

that communities that are situated further away from urban centre generally have a slower population increase. The capital city, Kampala, has the largest standardised beta coefficient (Table 4), suggesting that it has a bigger influence on population size changes than secondary urban centres. Proximity to Kampala by one more kilometre would influence intercensal population size increase of the sub-county by a factor of 0.44. Whereas proximity to a secondary town of above 50 000 persons by one more kilometre would influence intercensal population size increase of a rural sub-county by a factor of 0.21.

The magnitude of the coefficients decreases with a decreasing size of the urban centres (Table 4), supporting our previous result that larger urban centres exert a relatively greater influence on population size changes. Likewise, the distance to the nearest town with a population below 50 000 inhabitants did not make a significant contribution and was therefore excluded from the regression model. More variables that did not make a significant contribution and were excluded from the regression model included the population natural growth rate, and population growth rate due to in-migration. Overall, these results agree with the findings of studies asserting that population dynamics of rural areas partly depend on their distance from urban centres (for example: in Wisconsin USA (Chi & Ventura, 2011); in Brazil (Costa da Silva et al., 2017)). They also concur with the observed spatial pattern of Uganda's population changes, with regions showing the largest change also being characterised by a high concentration of urban centres (see Figure 2(b)).

We also conducted a multiple linear regression analysis to predict the population size change in urban centres, considering the population in 2002 and the shortest road travel distance to larger urban centres (for example, for urban centres in the category of 50 000–100 000 inhabitants, we considered the distance to the nearest towns of >100 000 inhabitants). The resulting model is as follows:

$$\begin{aligned} \textit{Intercensal Population size change} = 76.55 &- 0.36\ \textit{distance to Kampala} \\ &- 0.39\ \textit{distance to secondary town} \\ &\quad \textit{of above}\ 100\ (000'\textit{persons}) \\ &- 0.14\ \text{population size in}\ \ 2002 \end{aligned} \tag{5}$$

Our results illustrate that especially the distance to urban centres with over 100 000 inhabitants has a strong negative coefficient (Table 4). The nearest distances to urban centres with less than 100 000 inhabitants were insignificant. As such, these findings further substantiate that it is mainly the larger secondary urban centres which play a catalytic role in the country's urbanisation process.

For both rural and urban areas, the initial population size also shows a significant contribution to the population change of an area. However, in terms of the magnitude of the coefficients (Table 4, Equations 4 and 5) the importance of this variable on the population change is relatively small. Overall, our results (Table 4) reveal that population size changes of urban areas are mainly influenced by other urban centres with a population size of at least 100 000 persons. For rural areas, also urban centres with a population of at least 50 000 persons have an influence. This highlights the catalytic role of urban centres of various sizes in the population dynamics of their surroundings.

Generally, urban centres act as poles of population growth and may influence population size changes in two ways. First, they may attract or 'pull' people from rural areas and other (typically smaller) urban centres as they offer relatively better social services (access to education, health and public administration services) and more opportunities for economic, cultural and political participation (Jedwab et al., 2017; UN-DESA, 2020). In Uganda, urban centres generally offer better services and opportunities than rural villages regarding, for example, health institutions, educational institutions (schools, colleges and universities) and economic infrastructure like industries, factories, markets (MFPED, 2019a; Mukwaya et al., 2012; World Bank, 2015). Ugandan cities also offer a larger and steadier supply of basic facilities like clean water and electricity, contributing to a better standard of living (UBOS, 2016). More so work opportunities in urban areas offer better remuneration than in rural areas: with young wage earners and salaried workers in urban areas earning an average of 259 000 Uganda shillings (about 70 US dollars) per month, whereas their counterparts in rural areas obtain an average of 172 000 (about 46 US dollars) Uganda shillings per month (UBOS, 2019). This is a pull factor for employment seekers to urban areas.

Second, the proximity of an urban centre and the spatial interactions that result from it can create locational benefits for the surrounding areas. Overall, towns are part of a wider geographical network and their provision of social and economic services, goods and opportunities reaches beyond their administrative boundaries into the neighbouring areas. This is especially the case when the neighbouring areas are well connected through a good road network (Chi & Ventura, 2011). Such interactions, can enhance the quality of life of people living in those surrounding areas and consequently influence the areas' population dynamics (Veneri & Ruiz, 2016, 3–24; Costa da Silva et al., 2017).

For both rural and urban communities, our fitted models explain about 38% of the observed variation in population change (Figure 4).

Nevertheless, with an explanatory power of 38%, these models already allow a fair description of the population changes in rural and urban areas. This is also evident when mapping the model residuals (Figure 5). For 95% of the rural and urban areas, the predicted value deviated less than 25% of the corresponding observation. Moreover, the over or under predictions (Figure 5) reveal no clear spatial pattern. Some of the urban centres that grew less than expected are situated in former conflict zones such as the borders with South-Sudan or in zones with government organised resettlement due to

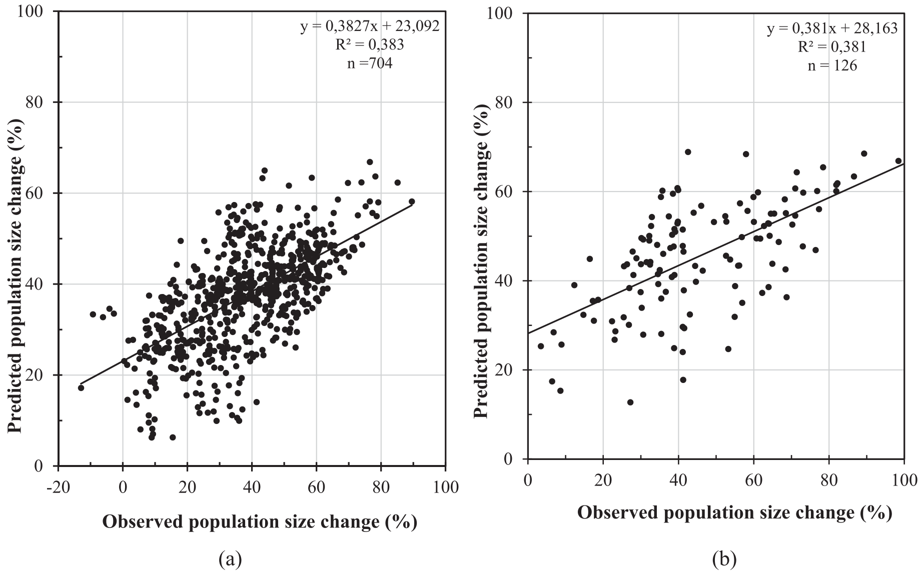


Figure 4. Predicted versus observed intercensal population size change (2002–14) for (a) rural areas and (b) urban centres in Uganda. The residual values are obtained from the regression models specified in Table 4. Data Source: Uganda Bureau of Statistics, census data of 2002 and 2014.

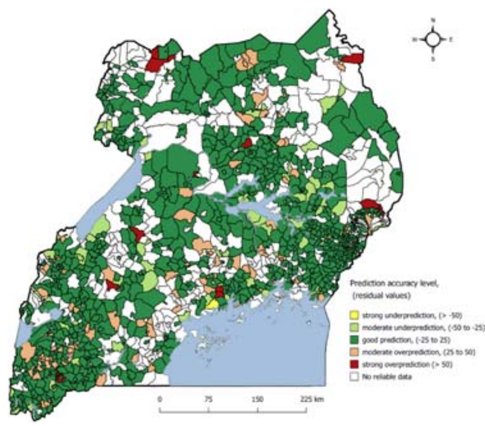


Figure 5. Prediction accuracy level for the intercensal population size change of both rural and urban areas expressed as a function of the initial population size (size in 2002) and the distances to the nearest urban centre per urban size category considered in this study. The class 'no reliable data' consists of areas that are refugees hosting communities, island communities, landslides affected areas with inhabitants relocation, relocation recipient communities, areas with very poor road networks (for which the distance to nearby towns could not be reliably estimated), and some of the sub-counties and urban centres that underwent reclassification as new districts and constituencies were created during the intercensal period. Data Source: Generated by authors from regression models.

land slide displacement in hot spot areas like Mount Elgon in the east of the country. Over all, the findings illustrate the significance of the distance to an urban centre as a predictor of population size changes and, by extent, the significant role that (especially larger) secondary towns may play in the population dynamics of their surrounding areas.

While this study mainly focussed on assessing the relative influence of the size and proximity of urban centres on population size changes, considering additional factors that better describe the demographic and socio-economic characteristics of communities may lead to further improvements. Additional factors that generally influence population size change, such as reproductive age ratios, population age distributions, and area reclassification contribution rates (Awumbila, 2017; Jiang & O'Neill, 2018, 363–89), once included in the model would improve the explained variance of the population size change.

4. Conclusion

As this study revealed, Uganda's urban structure has expanded significantly over the past decades, both in the count and population sizes of urban centres. This urbanisation tendency shows significant spatial differences with the country's Central region remaining the most urbanised. Nonetheless, the Northern and Western regions showed the strongest increases in location quotients, indicating a more rapid urbanisation in those regions. Analysing urban population rank-size distributions further showed a disproportionate population size distribution with the capital city – Kampala remaining comparatively larger than any other town in the country (Figure 3). Nevertheless, this disproportionality was already smaller in 2014 than in 2002. Likewise, observed shifts in ranks between secondary towns show the increasing importance of several secondary towns of various sizes. Overall, our results illustrate the unbalanced urban structure of Uganda but also the rapid (and spatially highly variable) rate at which the urbanisation is taking place. This indicates the need for integrated and well-informed urban development policies and systems.

To further contribute to such informed decision making, we explored the potential influence of urban centres to population size change in their surrounding areas. Overall, we observed that larger urban centres are in close proximity to rural areas with a population size increase of over 25% (Figure 2(b)). Correlation analyses further revealed that especially the distance and size of urban centres influence population size changes of surrounding areas. Especially urban centres with over 50 000 inhabitants seem to significantly influence the population dynamics in their neighbouring areas. Nevertheless, we recommend more research to further fine-tune and validate this threshold. Such additional insight could be important in contextualising the dynamics of population growth and distribution. Overall, our study results indicate that both secondary towns and the capital city act as population attraction poles, therefore, they influence population size and spatial distribution in their surrounding areas. This understanding could set a basis for an integrated urban development planning. Currently, Uganda's social and economic transformation framework calls for a shift in public investment towards secondary towns (MFPED, 2019a). The results of this study may therefore contribute to a better guided and integrated urban development process in Uganda and other Sub-Saharan African countries.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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