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Mapping spatial and temporal dynamics in urban growth: The case of secondary cities in northern Ghana

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ABSTRACT

Urbanization induced growth of secondary cities presents several issues and challenges for sustainable development. Yet, secondary cities continue to receive less attention from scholars, city planners and policymakers in Africa. Understanding the spatial and temporal dynamics of secondary cities is critical for achieving Sustainable Development Goal 11. This paper examines the emerging spatial and temporal evolution of two secondary cities in Northern Ghana. The paper utilizes raster data (1990–2019) and applied landscape metrics to analyze spatial development in Wa and Bolgatanga municipalities along three concentric rings. The results show significant increase in built areas over the study period. Urban development in the two cities is becoming more or less fragmented, dispersed and contiguous. Inadequate spatial planning, weakly regulated development and uncoordinated land markets account for the fragmentated spatial forms. The two cities exhibit a monocentric form that fluctuates, is dynamic, and discontinuous. The paper reflects on the implications of the findings and suggests the need for a planned extension of secondary cities in Africa to generate efficient urban forms, curtail sprawl and protect the natural environment.

KEYWORDS

Urbanization; spatial development; urban planning; sustainability; landscape metrics

Introduction

Since the 20th century, urbanization has gained significant attention in both academic and political discourses worldwide. Urbanization can be understood as an increase in the percentage of the population living in cities or urban areas (Korah et al., 2018). Urbanization is primarily driven by rural-urban migration, natural population increase (birth rates exceeding deaths), and urban reclassification, whereby cities expand to enclose rural areas into the main city (Cohen, 2004, 2006 Seto & Fragkias, 2005; UN DESA, 2018). Between 1950 and 2018, the world's population living in urban areas increased substantially, from 30% to 55%, and projected to hit 60% by 2030 (Seto & Fragkias, 2005; UN DESA, 2018). About 77% of this population lives in cities in developing countries (UN DESA, 2018). Although global urbanization rates are decelerating (UN DESA, 2018), several countries in sub-Saharan Africa (SSA) are experiencing increasing trends of urbanization (Cobbinah et al., 2015).

Much of sub-Saharan Africa's urbanization occurs in *secondary cities* (Roberts & Hohmann, 2014). Secondary cities refer to the second tier or level in the hierarchy of cities within a country or region, which is below the largest and primary city[1] (Roberts & Hohmann, 2014). The definition of secondary cities is malleable, and various countries apply different parameters to classify what constitutes secondary cities. However, the most common metric includes population size (mostly below 1 million inhabitants), administrative functions/services, or the size of urban agglomeration. According to Cohen (2006), there were only 301 secondary cities in 1950 globally. However, by 1970, the figure

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had doubled to 606 and stagnated at 644 by 1980 (Cohen, 2006, p. 43). Today, it is estimated that more than 2,400 secondary cities exist worldwide, and about two-thirds of them are located in Africa and Asia (Roberts & Hohmann, 2014). Although secondary cities constitute the main centers of urbanization in SSA, they tend to have the least capacities to cope, plan and sustainably manage rapid urban growth to promote employment and economic growth (Roberts & Hohmann, 2014).

Urbanization in the developed countries was largely accompanied by rapid industrialization, employments and general economic growth and transformation (UN DESA, 2018). However, in sub-Saharan Africa (and other developing countries), the reverse is often experienced. Urbanization has been characterized by inadequate access to basic infrastructure services (Cohen, 2004; Roberts & Hohmann, 2014); growing unemployment, poverty and socioeconomic inequalities (Cohen, 2004; Roberts & Hohmann, 2014; UN DESA, 2018); substandard housing and poor planning (Korah et al., 2017; Nunbogu & Korah, 2017; Watson, 2009); and conversion of agricultural lands to commercial and residential uses (Korah et al., 2018; Kuusaana & Eledi, 2015). Though urbanization has considerable potentials for reaching sustainable economic growth and development in Africa (Cohen, 2006), the persistence of these challenges and the inability of city managers to address them often tend to overshadow them.

There is a significant amount of research and literature on urbanization, both at the regional or global levels (e.g., Cobbinah & Amoako, 2012; Cobbinah et al., 2015; Korah et al., 2018; Sumari et al., 2019; UN DESA, 2018; Xu et al., 2019). These studies have highlighted urbanization's complexities and changing faces, especially in sub-Saharan Africa. More significantly, scholars have explored the morphologies of Africa's cities under rapid urbanization. Yet there is no consensus among scholars regarding the spatial structure of African cities (e.g., Agyemang et al., 2019; Korah et al., 2018; Oduro et al., 2014). Others have also explored the challenges, drivers, and prospects of urbanization (Cohen, 2004, p. 2006; Roberts & Hohmann, 2014; Wolff et al., 2020) or the consequences of urbanization for urban planning and governance (Cobbinah & Erdiaw-Kwasie, 2018; Cobbinah et al., 2018; Korah et al., 2020) as well as the impacts on land-use and agricultural livelihoods (e.g., Kuusaana & Eledi, 2015). However, urban scholarship has often paid little attention to secondary cities, although they constitute the continent's main centers and drivers of urban transition.

In Ghana, urban scholars have predominantly focused on large cities like Accra, Kumasi, and Takoradi but often neglect the importance of secondary cities in shaping urbanization dynamics. More precisely, not much is known about the emerging spatial and temporal dynamics and drivers that underlie and shape urban growth in secondary cities in Ghana. This limitation in the literature not only limits our understanding of urbanization and how secondary cities evolve over time but also, more importantly, challenge the capacity of city planners and policymakers to plan sustainably, manage and adapt secondary cities in the face of rapid urban growth (Roberts & Hohmann, 2014). Likewise, a better understanding of spatio-temporal dynamics is vital for achieving Sustainable Development Goal 11, which seeks to make cities sustainable. This is because it helps urban planners, city authorities, policymakers, and development practitioners alike to better anticipate and plan for future spatial development and basic infrastructure needs of cities.

In light of this imperative, this paper examines and compares the emerging spatial and temporal evolution of two secondary cities in northern Ghana. This paper aims to answer four important questions: (a) What is the nature and pattern of spatial expansion of secondary cities in northern Ghana? (b) Are there similar patterns in the complexity, size, and spatial growth of cities in northern Ghana? (c) What underlying urban form does the spatial configuration of northern cities reveal? (d) What are the urban planning implications of the spatio-temporal growth patterns and underlying urban form? To systematically address the foregoing questions, we utilize raster data (1990–2019) and apply landscape metrics to analyze spatial development in Wa and Bolgatanga along three concentric rings. Both cities are emerging municipalities situated in the northern part of Ghana. Aside from the similar geographic and climatic conditions, they also have commonalities in their development trajectories, and both function as administrative capitals of their respective regions. These similarities make them ideal for our inter-city comparison. An *inter-city* comparison provides a helpful lens for learning about the spatial and temporal dynamics in urban development across time and space to advance knowledge beyond "place-based" idiosyncrasies (Kantor & Savitch, 2005).

The remainder of our paper is organized into five more sections. In Section 2, we present the two study cities by presenting their demographic, social, and economic processes and trends since 1990. These variables are essential for shaping our understanding of urban growth in cities and their spatial and temporal patterns and dynamics over the years. Section 3 outlines the materials and methods used. Section 4 presents and discusses the results, while Section 5 presents the conclusions.

Study areas

Wa Municipal

Wa is the regional capital of the Upper West Region (UWR) of Ghana and the administrative capital of the Wa Municipality (WaM), one of the 11 local government units in UWR. The WaM is situated between latitudes 1°40′N–2°45′N and longitudes 9°32′W–10°20′W and covers a landmass of approximately 579.86 km^2. Representing about 6% of the UWR's land area (Ghana Statistical Service [GSS], 2014a). The WaM has an elevation between 160 m and 300 m above sea level and borders Nadowli District to the north, east by Wa East District, west and south by Wa-West District (GSS, 2014a). Like other towns in northern Ghana (such as Bolgatanga), Wa witnessed rapid growth after Ghana's independence in 1957 (Dickson, 1968). The WaM's annual population growth rate was 4.0%, 3.7%, and 3.8%, respectively, between 1960, 1984, and 2000 (GSS, 2005). The total population of WaM in 2010 was 107,214, representing 15.3% of the population in UWR (Table 1).

The increasing urbanization has resulted in a spontaneous expansion in the city's urban form, occurring in fragmented mostly beyond state planning regimes and controls. The total built-up area of WaM increased from 3.7 km^2 in 1986 to about 14.8 km^2 in 2000 and further to 29.2 km^2 in 2016 (Korah et al., 2018). This implies that the urban land cover increased by 25.5 km^2 over the past 3 decades, constituting about 93.8% of the total urban land area of the municipality (Korah et al., 2018). Wa has been the center of rapid urban expansion and development in the municipality. The spatial structure of Wa shows characteristics of classical urban models such as Ernest Burgess's concentric city and Homer Hoyt's sector models (Ahmed et al., 2020). The functionality of the city reflects Burgess' concentric model with a central business district consisting of retail, commercial, administrative, and transport activities. In 1983, a 33-sector model was developed in line with Hoyt's sector model to guide the city's development (Ahmed et al., 2020).

Residential and educational infrastructure development has shaped the growth of the municipality. In particular, the formation of the Wa Polytechnic (now Dr. Hilla Liman Technical University) in 1999 and the Wa Campus of the University for Development Studies (now the Simon Dombo University of Business and Integrated Development Studies) in 2001 have attracted students and private investors to Wa. Subsequently, the demand for housing in Wa has increased, thereby outstripping supply (Ahmed et al., 2020). Like all other urban areas in Ghana, private developers are major housing providers in Wa. The recent increasing demand for detached and semi-detached houses and the poor coordination of physical development and unregulated land market in WaM has led to an uncontrolled intermittent expansion of the city in the suburbs (Ahmed et al., 2020; Korah et al., 2018).

Table 1. Population growth trends in Wa.

Year	Wa Municipal	Upper West Region
1984	52,683	43,8008
2000	98,675	57,6583
2010	107,214	702,110
2021	200,672	901,502

Various census reports of Ghana Statistical Service (1984–2021).

Bolgatanga Municipal

The Bolgatanga Municipality (BoM) is the administrative capital of the Upper East Region (UER) of Ghana, with Bolgatanga as the capital town of the region and the municipality. BoM lies within latitudes ‘10°50′N and longitudes 0°30′W and 1°00′W (see Figure 1: right). It became a municipality in 2004 and had a total land area of about 729 km^2, which is approximately 8.2% of the region (GSS, 2012). Regarding its relative location, BoM shares boundaries to the north with Bongo District; south and east by the Talensi-Nabdam and Bolgatanga East Districts, and to the west by the Kassena-Nankana East Municipal and Kassena-Nankana West District. The municipality lies in the Guinea Savannah Ecological Zone, dominated by short, scattered trees and grassland on relatively flat Birimian Tarkwaian and Voltarian rocks (GSS, 2014a). In 2004, the Talensi-Nabdan District was carved out of the then Bolgatanga district, and the remaining part was elevated to Bolgatanga Municipal. In the year 2010, the BoM’s total population was 131,550, representing 12.6% of the population of UER. The total number of inhabitants in urban areas in 2010 was 65,512, representing 29.8% of urban dwellers in the region (GSS, 2014a). This shows that 49.8% of BoM’s population is urbanized compared to the regional urbanized share of 21% and the national urbanized share of 50.9% (GSS, 2014a).

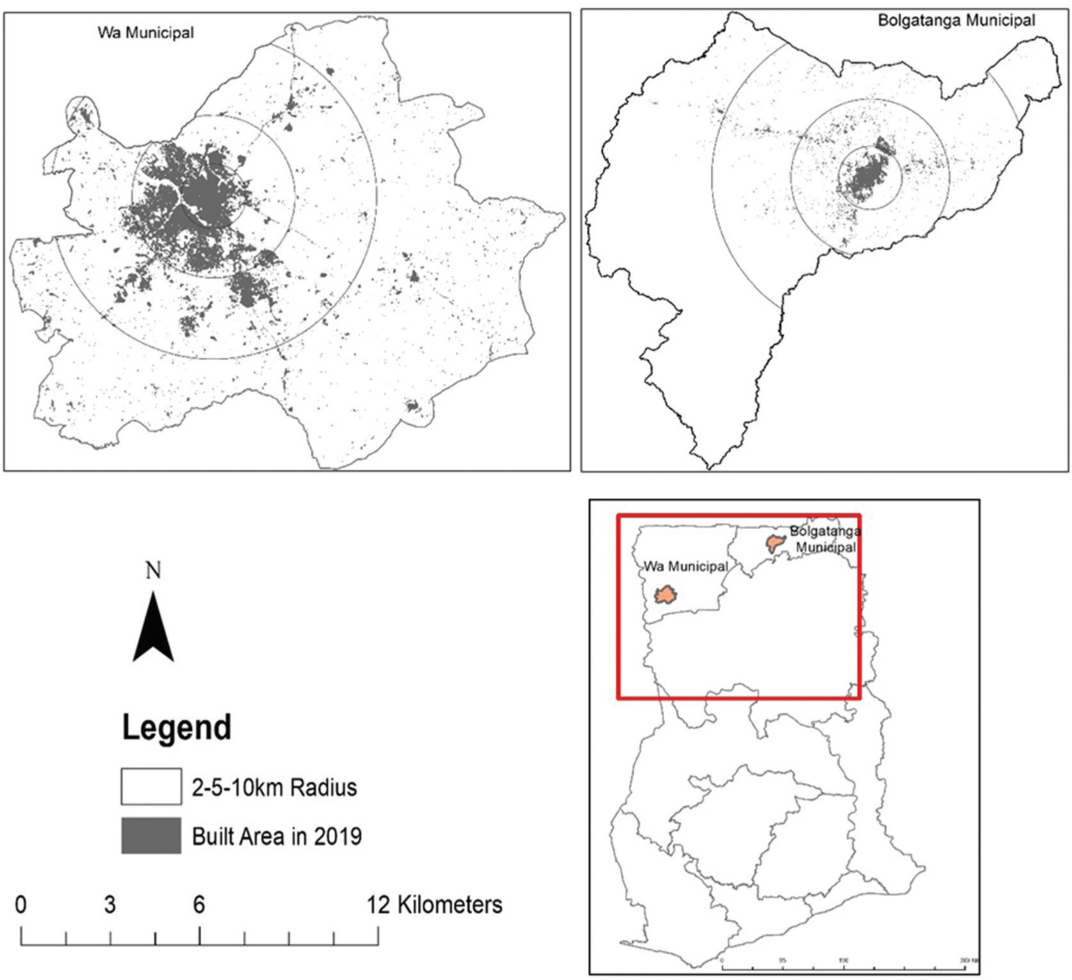

Figure 1. Geographic location of the study cities. Source: Authors.

Infrastructural development has shaped the urban form of BoM. The demand for residential accommodation in BoM far outstripped supply and has resulted in the rise of unauthorized development (Tengan et al., 2017). Increasing demand for residential housing and the uncoordinated regulation of physical development in BoM caused a patchy extension of the city. Like in WaM, the urban form and structure of BoM possess characteristics of both the concentric city and sector models (Hoyt, 1964). The functionality of the city is consistent with Burgess' concentric model as it has a dominant central business district (CBD) consisting of commercial (banking/ non-bank insurance companies), retail and transportation activities. The municipal has prepared sector schemes to guide urban growth. Examples are the Sabon-Zongo, Dagweo, and Tanzui residential area sector schemes. However, the implementation of these plans has been undermined by weak development control in the face of increasing urbanization (Bolgatanga Municipal Assembly, 2018).

Materials and methods

This paper used spatial data comprising classified Landsat Satellite images obtained from the Land Use and Spatial Planning Authority (LUSPA)[2] in 2018. The data consists of classified images for Ghana in 1990, 2000, and 2010. The land use classes were built and non-built. The two use classes were adequate for this paper since it is about understanding the dynamics of built areas. Wa and Bolgatanga municipalities were chosen for this study because they are regional capitals of Upper West and East regions respectively. Both cities are undergoing significant spatial transformation and the most developed in the two regions. The proximity of both cities to Ghana's northern border with Burkina shapes their economic activities because of cross-border trade. Textiles and food stuffs including tomatoes are some products that are imported from Burkina. Cross-border trade and informalization of the economies of both cities intensified following implementation of structural adjustment program, a range of macroeconomic policies in the 1980s that liberalized the Ghanaian economy, led to a roll-back in subsidies and a reduction in the size of the civil service (Overå, 2007). The structural adjustment also led to a rapid uncontrolled expansion of these cities following the importation of cheap building materials (c.f. Yeboah, 2000). In addition, the two cities shared similar administrative history and were part of the then Upper Region of Ghana before its split in 1983 to create the regions mentioned earlier. Despite their similar geographic, administrative, and economic history, the two cities differ in demographics, as shown in Tables 1 and 2. Whilst the population of WaM has been increasing consistently since 1984, that of BoM is inconsistent. A study of these cities addresses the limited empirical scholarship on the spatio-temporal dynamics of secondary cities in Ghana and SSA (Anarfi et al., 2020). WaM and BoM were extracted from the larger raster feature. The classified images had a 30 m spatial resolution. Notwithstanding that the 30 m spatial resolution is not ideal for displaying spatial details, these have been used in earlier studies to examine urban land change (Acheampong et al., 2017; Asabere et al., 2020; Korah et al., 2019).

For 2019, images from Landsat 8 Operationalized Landsat Imager/Thermal Infrared Sensor (OLIS/ TIRS) 2019 were used. These images were downloaded using path 194 and row 52 (Bolgatanga Municipal) and path 195, row 53 (Wa Municipal) from the United States Geological Survey Earth Explorer (2019). Only images with a maximum cloud cover of less than 10% were downloaded to guarantee the quality of the images used. Training samples were generated for two land use classes, i.e., built and non-built. Using the *interactive supervised classification* tool in ArcGIS 10.7, training samples

Table 2. Population growth trends in Bolgatanga.

Year	Bolgatanga Municipal	Upper East Region
1984	87,739	772,744
2000	228,815	920,089
2010	131,550	1,046,545
2021	139,864	1,301,226

Various census reports (1984–2021).

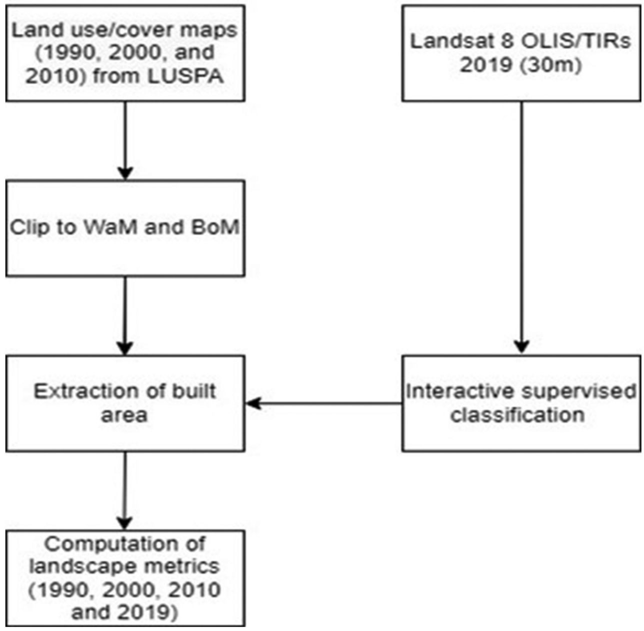

Figure 2. Methodological framework of the study.

were tested for accuracy, and more samples were added to ensure the representativeness of each class. Finally, the images were categorized into the two land use classes. Figure 2 is a summary of the methods adopted in this paper.

Landscape metrics are essential for quantifying and characterizing urban spatial growth (Asabere et al., 2020; Korah et al., 2019). These metrics can be applied to thematic maps to compute complexity, fragmentation, and variation of urban growth. McGarigal et al. (2012) developed a spatial pattern analysis program called FRAGSTATS Version 4 for characterizing the structure (i.e., shape and composition) of landscapes (McGarigal et al., 2012). Table 3 provides a summary of the spatial metrics applied in this paper. While several landscape metrics are available, many of these metrics are shown to correlate except those that represent complexity, compactness, and size (Riitters et al., 1995). In this study, we selected metrics that capture aspects of the built landscape: complexity, relative size, absolute size, and aggregation (Table 3). Complexity is measured by the area-weighted mean patch fractal

Table 3. Landscape metrics applied in this paper.

Metric	Category	Description/equation	Units	Range
ULA	Area	Total urban land area	Sq.km	ULA > 0
AWMPFD	Shape complexity	$\sum_{t=1}^{m}\sum_{j=1}^{n}\left[\left(\frac{2\ln\left(0.25_{p_{ij}}\right)}{\ln_{a_{ij}}}\right)\left(\frac{a_{ij}}{A}\right)\right]$ Where m is number of classes, n is number of urban patches, p(ij)—perimeter of patch ij, a(ij)—area of patch ij, and A—total landscape area.	None	1 ≤ AWMPFD ≤ 2
NUMP	Variability and size	Number of urban patches	None	CA > 0, no limit
MPS	Variability and size	Mean urban patch size	None	CA > 0, no limit
PSCOV	Variability and size	Urban patch size coefficient of variation	None	CA > 0, no limit
CONTIG	Urban spatial structure	$\frac{M(a_i)}{TBA_i} \times 100$Where $M(a_i)$ is area of the largest urban patch in a city and TBA_i is total built area of the city.	Percent	0 < CONTIG ≤ 100

Based on (Angel et al., 2005; Herold et al., 2003; McGarigal, 2015) dimension (AWMPFD). Relative size is measured by urban patch size coefficient of variation (PSCOV), number of urban patches (NUMP), and mean urban patch size (MPS). Finally, aggregation and absolute size are measured by Contiguity Index (CONTIG) and Urban Land Area (ULA) respectively. Below is a description of the metrics.

The AWMPFD metric measures the complexity or irregularity of the shape of an urban area. It describes the fragmentation of urban land area by the perimeter-area ratio (Herold et al., 2003). The AWMPFD value ranges between 1 and 2 and is normalized. AWMPFD values approaching one indicate that the built area is less fragmented and the shape is simple, while those approaching two signify complex and irregular shapes (Seto & Fragkias, 2005). AWMPFD is expected to rise during the initial stages of built area expansion when new urban patches and growth of already built areas create irregularly shaped landscape patterns; it is, however, expected to decline as built areas merge to form compact clusters (Seto & Fragkias, 2005).

The NUMP measures disconnected built areas in a landscape and is anticipated to increase during rapid urban patch growth stages but may decline if built areas fuse and become contiguous (Seto & Fragkias, 2005). The NUMP is often interpreted in relation to the mean patch size (MPS). The MPS describes relative size of built patches. MPS is a function of NUMP and can decrease or increase over time. Low MPS and high NUMP values signify a highly patchy landscape (Kim et al., 2016). Declining MPS signifies that newly built patches are developing quicker than existing urban areas (Seto & Fragkias, 2005). The PSCOV is a normalized metric of built area and can increase or decrease. PSCOV is a measure of the degree of variation within the built areas.

Using FRAGSTATS software comprising *Patch Analyst and Patch Grid* functions (McGarigal et al., 2012), we measured the above landscape metrics. The FRAGSTATS was incorporated in ArcGIS 10.7 for analysis of the raster data. The analysis was under a series of concentric rings comprising 0–2, 2–5, and 5–10 km (Figure 1). Analyzing urban development along a series of concentric rings (Agyemang et al., 2019; Korah et al., 2019; Sumari et al., 2019) is based on the hypothesis that urban spatial growth proceeds from the central core (Blumenfeld, 1954). Yet there is no normative procedure for establishing the radius of the central core and ensuing rings. The selection of concentric rings is primarily a function of the knowledge of the author/s (e.g., Agyemang et al., 2019; Korah et al., 2019). A number of factors shaped the creation of buffer rings for the two study areas.

First was the need to have a standard concentric ring for comparing urban growth within the two cities for 1990, 2000, 2010, and 2019. Secondly, the concentric rings need to capture variations within and between the two cities. Concentric rings drawn too close to the central core will only capture differences within the core area which has less undeveloped lands (see, Seto & Fragkias, 2005). If concentric rings are drawn too far from the central core, the rings will capture variation over a much larger area. For these reasons, we chose three standard rings for both municipalities that sought to describe variations within the inner city and surrounding areas. Finally, the spatial extent of the two cities was considered in deciding the maximum radius of 10 km necessary to ensure no substantial part of built area was excluded. Each concentric ring is unique and considered an autonomous zone. After the first ring of 0–2 km, the next was 2–5 km and then 5–10 km. During interpretation, a 2 km ring is not considered part of the 5 km buffer, and the two are not treated as part of the 10 km. During the analysis, treating each buffer zone independently helps capture variations across the zones for the different years.

Contiguity index (CONTIG), which describes the level of clustering in a landscape (O'Neill et al., 1988), was used to establish the spatial structure of the two cities. High CONTIG signifies landscapes with large, aggregated patches in landscape analysis, while low CONTIG signifies landscapes dominated by disjointed patches. Previous studies (e.g., Angel et al., 2005; Korah et al., 2019) have applied CONTIG to understand urban spatial structure. To establish whether an urban area is polycentric or monocentric using raster data, the CONTIG can indicate the presence of a large urban patch or the existence of other urban centers and sub-centers. CONTIG is a fraction of the maximum urban patch (UP_m) to the total area of all urban patches (UP_s) at times T1, T2, and T3. See Angel et al. (2005, pp. 64–67) for a detailed description of this process. By categorizing urban land area into various cluster sizes based on the areas of urban patches (e.g., 0–10, 10–100, 100–1,000, 1,000–10,000 hectares, etc.), and computing the percent of the built area under each cluster, it is possible to determine whether the city has a clear spatial structure or not (Angel et al., 2005). A higher proportion of urban patches under the 10 ha (0.1 km^2) cluster size may suggest an amorphous spatial structure.

Results and discussion

Urban expansion in Wa and Bolgatanga

The raster data show that urban land area in the two cities has been growing. The average annual rate of built area growth for 1990 and 2019 was 4.4% and 3.2% for Wa Municipal (WaM) and Bolgatanga Municipal (BoM), respectively (Figure 3). The most significant increase in built area for WaM within this period occurred between 2010–2019, with a growth rate of 6.4%. Similarly, the largest growth of 4.1% for BoM occurred between 2000–2010 (Figure 3). Total urban land area (ULA) for WaM nearly increased fourfold during the study period, from 15.64 km^2 in 1990 to 55.32 km^2 in 2019 (Figure 4). ULA for BoM more than doubled, increasing from 5.96 km^2 in 1990 to 14.88 km^2 in 2019. The rapid growth of the built area is consistent with other Ghanaian cities, as reported by previous studies (e.g., Acheampong et al., 2017; Asabere et al., 2020; Cobbinah & Amoako, 2012; Fuseini et al., 2017; Osumanu et al., 2019). In Kumasi, for instance, Acheampong et al. (2017) found that the city grew at a rate of 5.6% between 1986 and 2014, with built area increasing about 4.5 times between the same period.

Several factors account for the rapid expansion of WaM and BoM. The first is population increase, consistent with Kleemann et al. (2017). WaM and BoM, as the capital cities of the Upper West and Upper East regions, respectively, have become important administrative, commercial, and economic centers. Natural population increase and rural to city migration in pursuit of employment opportunities have resulted in significant population increase in the two cities. In the year 2010, WaM recorded a total population of 107,214, representing 15% of the inhabitants of the Upper West Region (GSS, 2012c). The 2010 population of WaM represents about a 54% increase over the 2000 population of 66,441 and a 5.4% increment per annum. Similarly, BoM recorded a total population of 131,550 in 2010, accounting for 12.6% of the total population in the Upper East region (GSS, 2014a, p. 15).

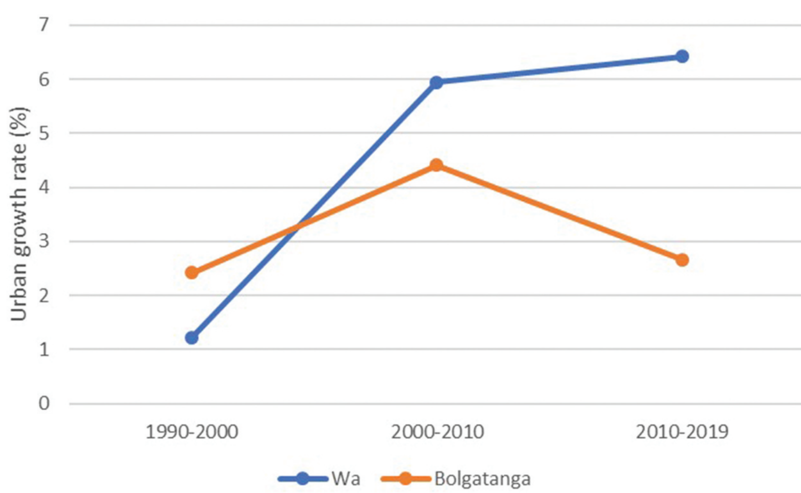

Figure 3. Average annual urban land growth rates.

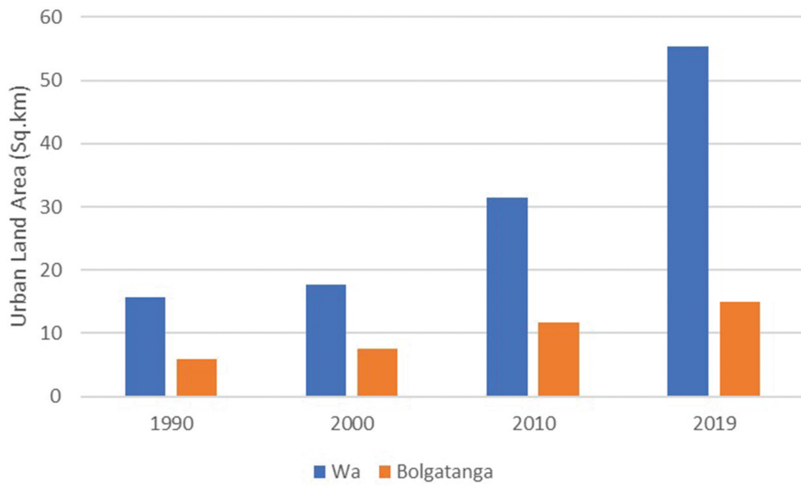

Figure 4. Urban land area for Wa and Bolgatanga Municipalities.

The growing population in both towns has resulted in rising demand for housing, infrastructure, and other municipal services. The GSS (2014b) reported 9,592 houses and 18,891 households in WaM as of the year 2010, translating into an average household per house of two (2). The population per house (11) in WaM is higher than the regional and national average of 8.4 and 7.1, respectively (GSS, 2014b, p. 47). The total number of houses and households in BoM in 2010 was 14,523 and 26,706, respectively, translating to an average household per house of 1.8. The population per house of 8.9 in BoM is slightly lower than the regional figure of 9.1 and higher than the national figure of 7.1 (GSS, 2014a, p. 54). Physical development in both municipalities, especially the construction of new houses, is weakly institutionalized and regulated in both cities. Following decentralization of spatial and development planning in Ghana during the early 1990s, the municipalities became responsible for guiding physical development in their territories. In both cities, however, challenges such as inadequate budgetary support, insufficient planning professionals, complex land tenure system and lack of awareness of developers on land acquisition and permitting process, among others, mean that urban development often does not align with city's physical development plans (Ahmed & Dinye, 2011; Boamah et al., 2012).

The approach to physical development in both cities is ad-hoc and incremental as there is a lack of commitment to development control on the part of the Physical Planning Department (Ahmed & Dinye, 2011). While these cities often have stated plans, guidelines, permits, layouts, and zoning regulations to guide their development, they mainly exist on paper. Implementing such plans and layouts is often complex and problematic because these institutional arrangements are unenforced. Hence, residents and city administrators, and planning professionals can manipulate them. Like Roy (2009) and Watson (2009) argued, this complicates physical development in southern cities because development precedes the law/schemes/regulation. When this happens, the city's development plan or scheme is complicated and useless, while "individual planning" takes the lead. In Bolgatanga, only the core areas and a few peri-urban settlements like Zorbisi, Zuarungu, and Yikene have layout schemes to guide their growth. Peripheral areas such as Zaare, Damweo, and Yorogo have no physical plans to guide their development (UNDP, 2011). Both Wa and Bolgatanga have experienced growth in unauthorized structures such as buildings in waterways, encroachment of road reservations, and areas designated as schools. In addition, unauthorized temporary structures such as kiosks and metal containers have emerged in the core areas, especially by roadsides. Therefore, it is imperative to understand the temporal and spatial patterns of physical development in both cities to guide urban planning.

Unpacking the patterns and complexities of urban expansion: From fragmentation to merger

The area-weighted mean patch fractal dimension (AWMPFD) was discontinuous temporally across the two towns. As expected, the AWMPFD for the 0–2 km concentric rings was high in 1990 and decreased slightly in 2000 (Figure 5a). At the early stages of development, new urban clusters create complex spatial configurations. This complexity, however, declines as the urban areas fuse. By the year 2000, urban development within 0–2 km buffer zone for both towns seemed to have merged, resulting in a more compact form as evidenced by AWMPFD of 1.35 and 1.37 for Wa and Bolgatanga, respectively. The AWMPFD for the 0–2 km buffer increased in 2010 before reducing in 2019 (Figure 6a). The fragmented urban core could be explained by ongoing property redevelopment and construction at the CBD (see Figure 5). The 2–5 and 5–10 km buffers zones show similar patterns by increasing in 1990, declining in 2000, and increasing in 2010 and 2019. The AWMPFD figures generally show the incremental housing development in both municipalities (Figure 5) and other Ghanaian cities (see Asabere et al., 2020). Increasing AWMPFD for both cities' 2–5 and 5–10 km buffer zones indicates growing fragmented spatial development. Instead of the AWMPFD declining as built areas merge, it instead fluctuates in the case of both cities. Within the 2–5 km buffer zones, the urban patterns for Wa were more fragmented and irregularly shaped than that of Bolgatanga.

This is the case after the year 2000. Whilst Wa recorded an AWMPFD of 1.43 in 2019, Bolgatanga recorded 1.35. This indicates that Wa is more fragmented compared to Bolgatanga in 2019. The presence of tertiary institutions such as the University for Development Studies now SD Dombo University of Business and Integrated Development Studies, Wa Technical University, nursing and teacher training

Figure 5. Field photos of incremental housing development in Wa (a–c) and ongoing construction at the central business district (d and e). Source: Authors, July 2021.

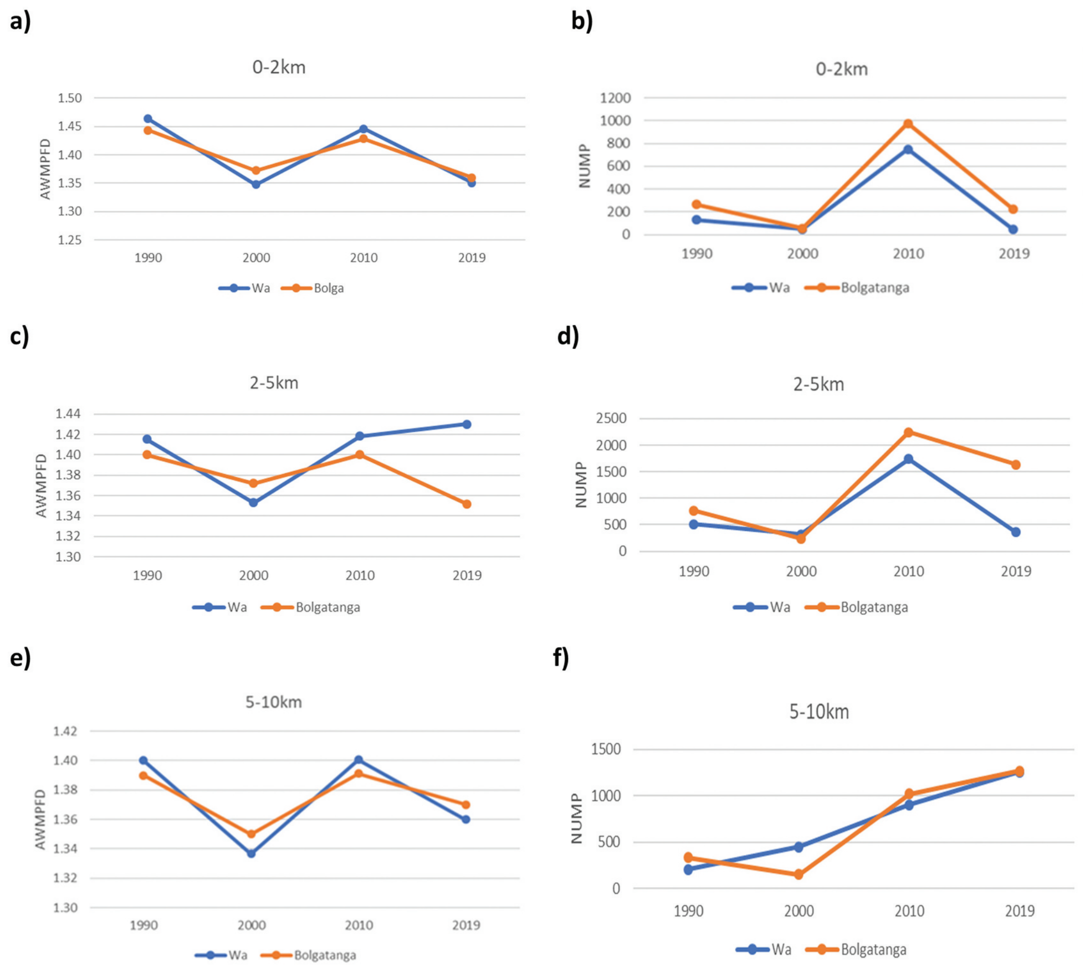

Figure 6. Complexity and fragmentation metrics. (a, c, e) Area weighted mean patch fractal dimension 0–2, 2–5, 5–10 km; (b, d, f) Number of urban patches 0–2, 2–5, 5–10 km.

colleges are attracting students and workers to the WaM. Consequently, Wa is fast developing and sprawling in all directions, such as the north, south, northwest and southwest (see, Korah et al., 2018). The AWMPFD for both cities' 5–10 km buffer zone showed decreasing complexity between 2010 and 2019 (Figure 6e). The findings show that Wa and Bolgatanga do not mirror a conventional urban growth model, where urban spatial complexity rises at first, reach an apex, and then declines through time as urban nuclei fuse (Herold et al., 2003; Korah et al., 2019; Seto & Fragkias, 2005).

The number of urban patches (NUMP), which assesses the temporal dynamics of new urban patch development, followed the expected trajectory for the 0–2 and 2–5 km zones (Figure 6b,d) for both cities. Between 1990 and 2000, the NUMP increased and then declined (Figure 6b,d) while MPS increased (Figure 7a,c), indicating that urban growth in these zones happened mainly through the annexation of vacant land by existing urban areas rather than the development of disconnected patches. For example, WaM had NUMP of 128 and 49 in 1990 and 2000 respectively for the 0–2 km zone, while BoM had NUMP of 264 and 56 respectively for 1990 and 2000 for the same zone. These results suggest that urban development in these zones became more aggregated in 2000, evidenced by the rising MPS (Figure 7a). However, the dynamics of urban development are most striking for 2010 when the NUMP for both cities increased for the 0–2 km and 2–5 km buffer zones after declining in 2000 (Figure 6b,d).

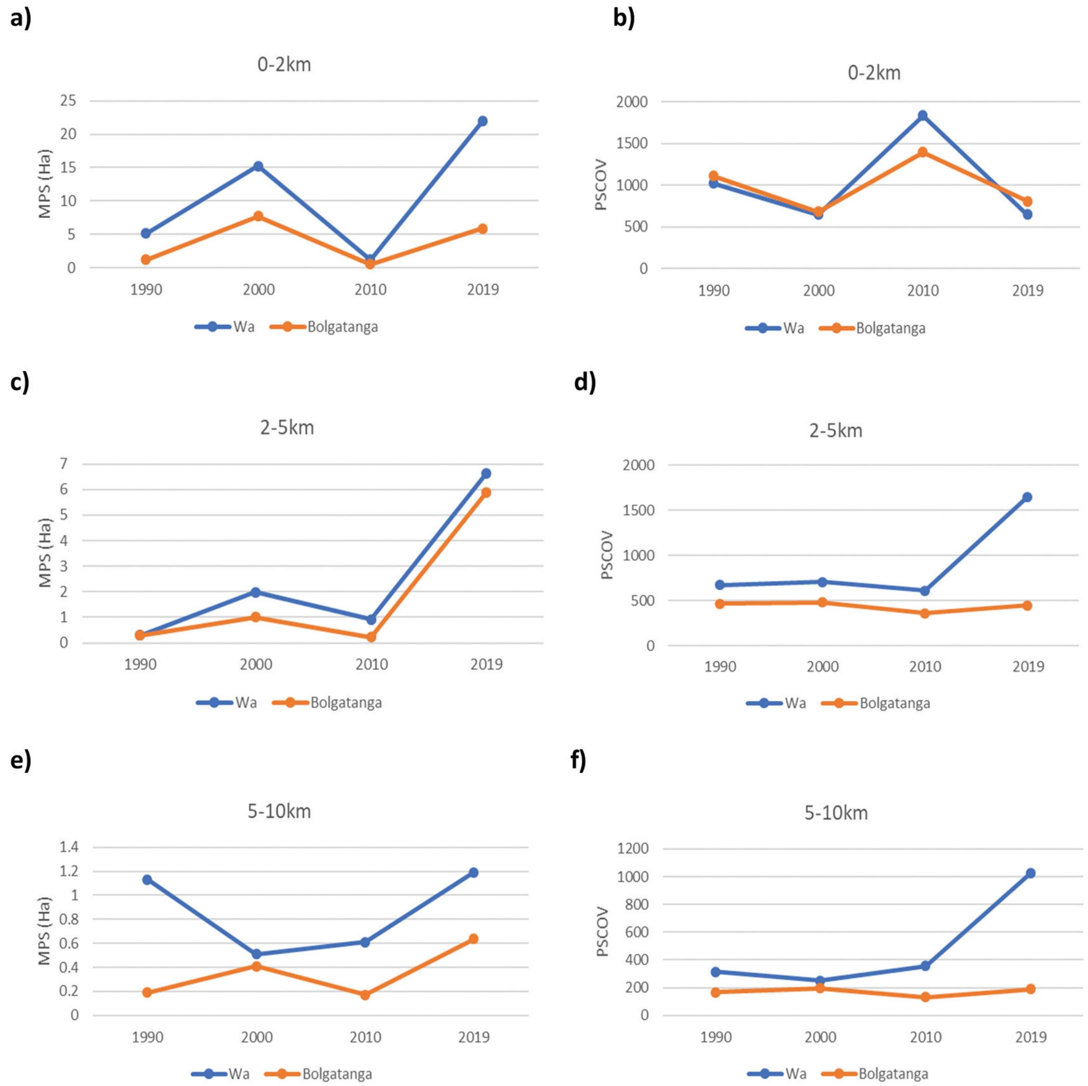

Figure 7. Size and variability metrics. (a, c, e) Mean patch size 0–2, 2–5, 5–10 km; Patch size coefficient of variance 0–2, 2–5, 5–10 km.

The number of urban patches for both cities continue to increase after 2000 for the 5–10 km buffer zone (Figure 6f). This zone represents the peri-urban area where relatively lower land values are attracting developers. One noticeable difference between the two cities is that while the MPS for Wa increased between 2000 and 2010 for the 5–10 km buffer zone (Figure 7e), that of Bolgatanga declined. This implies that growth in this zone for Wa between 2000–2010 was primarily an outcome of the growth of existing built areas instead of new urban patches, while the reverse is true for Bolgatanga. The emergence of new urban patches and fragmentation in Bolgatanga within the said period is associated with land tenure regime (Kleemann et al., 2017). Traditional authorities and families, who own most of the land, are engaged in subdivision of customary lands into smaller parcels. This contributes to spatial fragmentation as the small parcels are more suited for settlements rather than agriculture or industrial use. Furthermore, the direction and occurrence of urban development depend on when families are willing to release a portion of the family land to prospective developers (see also Ahmed et al., 2020).

The patch size coefficient of variance (PSCOV) indicates the variation within the urban areas. The findings show that in areas nearer to the city (0–2 km), there is a shared temporal pattern in the variation of the two towns (Figure 7b). For the 0–2 km buffer zone, both municipalities exhibit a slow increase in variation between 2000 and 2010 followed by a reduction in variance in 2019. For the 2–5 and 5–10 km buffer zones, there is a wide variation between Wa and Bolgatanga in 2019, signifying that the two cities do not congregate toward a contiguous urban fabric (Figures 7d,f). The next section explores the urban form of the two cities.

Understanding the urban form of the two cities

The largest contiguous built areas for WaM in 1990, 2000, 2010, and 2019 were 651, 738, 752, and 3,437 ha, while total urban land areas were 1564, 1766, 3146, and 3437 ha, respectively (Figure 8). Similarly, the largest contiguous built areas for BoM in 1990, 2000, 2010 and 2019 were 209, 398, 211, and 862 ha, respectively (Figure 8). Total built areas for BoM in 1990, 2000, 2010, and 2019 were 596, 758, 1,168, and 1,488 ha, respectively. The contiguity index (CONTIG) (expressed) in percentage terms of 42, 53, 23, and 62 for 1990, 2000, 2010 and 2019 respectively depicts that, Wa's spatial structure is less polycentric and more monocentric despite the spatial fragmentation in 2010. The CONTIG for BoM was 35, 52, 34 and 58 percentage in 1990, 2000, 2010, and 2019 respectively, depicting a monocentric rather than polycentric structure. However, the decrease in CONTIG for 2010 and subsequent increase in 2019 for both cities indicates a complex urban form that is evolving and discontinuous.

It is established in urban studies scholarship that the form of cities evolves slowly, fundamentally because of the installation of infrastructure such as utility lines and roads which mediate the pattern of urban growth (Jenks & Burgess, 2002). Indeed, once a city has a basic form in place, it becomes difficult to change the trajectory of the city structure. While some level of path dependency in the growth of Wa and Bolgatanga can be observed, the findings show that the spatial structure of urban areas can vary significantly during growth processes, as evidenced by the rise and fall of the CONTIG in 2000 and 2010 respectively. For Bolgatanga, Kleeman et al. (2017, p. 290) found that roads and other infrastructure such as hospitals, schools, and electricity were uncorrelated with urban development. In Ghana, like most sub-Saharan African countries, urban development usually precedes infrastructure

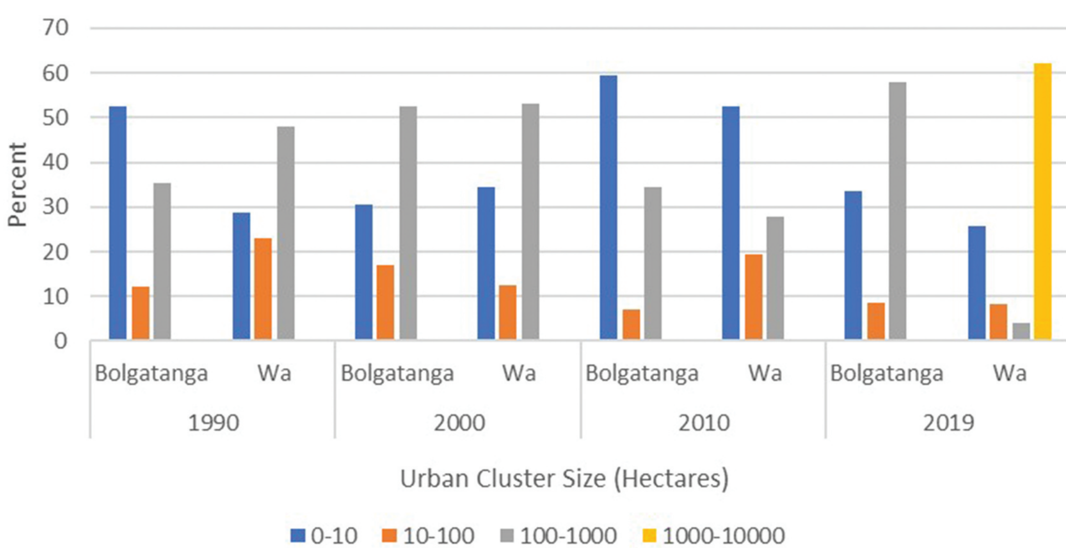

Figure 8. Urban area under the various cluster sizes in Bolgatanga and Wa Municipalities.

development due to city authorities' limited fiscal capacity. The results thus suggest that given an undeveloped landscape without infrastructure or zoning restrictions, urban growth can manifest in several spatial patterns and results in an unsustainable form.

Furthermore, the decline in CONTIG for 2010 for both cities can be supported by the fact that there are areas where ongoing housing construction occur, characterized as urban open space, that is fluid and mediates the transition between urban area and vegetation and vice versa (Asabere et al., 2020). In most Ghanaian cities, housing construction occurs on an incremental basis (Amoako & Boamah, 2017) where lands cleared for buildings can later become vegetation due to the length of time it takes to roof such houses (Figure 5). The findings in terms of the monocentric structure of both cities confirm that of previous studies (Korah et al., 2019; Oduro et al., 2014).

Conclusion and recommendation

In this paper, we quantified spatio-temporal dynamics of urban growth under three distinct concentric rings and compared the results for two rapidly growing regional capital cities in northern Ghana. An insight into the transformation of cities and their spatial configuration through time is essential for quantifying—and possibly alleviating—the effects of rapid urban expansion. In the past 30 years, urban land area in Wa and Bolgatanga has been continuously increasing. The spatial patterns in these cities revealed fragmented, dispersed, and irregular urban configurations. While debates about the advantages and drawbacks of the compact city are ongoing (Bibri et al., 2020; Mouratidis, 2018; Neuman, 2005), for secondary cities like Wa and Bolgatanga, with limited fiscal capacities of city authorities and inadequate infrastructure, a compact form could be more appropriate for promoting sustainable development than dispersed forms (Jenks & Burgess, 2002). The per capita cost of infrastructure provision is less with a compact form as opposed to dispersed form. The spatial morphologies of the two cities exhibit a monocentric form that fluctuates, is dynamic, and discontinuous, suggesting that urban growth is not shaped by infrastructure such as roads but by customary landowners. These landowners (e.g., chiefs and families) shape spatial growth patterns through sub-division and release of lands to developers. On the contrary, growth in Ghana's largest cities (i.e., Kumasi and Accra) occur along highways. As the first comparative study of secondary cities in Ghana, this paper is relevant for two main reasons. First, it advances knowledge in urbanization and urban transitions debates in Africa. Our analyses builds on city-specific level dynamics to provide more general explanations of how, why, and what accounts for rapid urban growth in secondary cities in Ghana and elsewhere in SSA. As secondary cities are rapidly growing, we imagine our paper will stimulate further studies on such cities.

Second, the findings have several practical implications for urban planning and management for sustainability. There is a need for efficient planning and development control to curtail urban sprawl and produce functional urban forms in secondary cities in Ghana and other SSA countries. The fragmented spatial development recorded in the two cities is unsustainable and may lead to environmental problems such as flooding (Abass et al., 2020) and destruction of important ecological resources such as wetlands (Ekumah et al., 2020). There is the need for a planned development of Wa and Bolgatanga and other secondary cities with similar spatial development patterns. Such planned strategies will seek to create growth boundaries to limit urban sprawl and ensure compact development and mixed-uses while balancing physical and natural environments. Socio-cultural factors play an important role in shaping spatial development dynamics in secondary cities. More importantly, the issue of land ownership and control plays a significant role in the successes or failures of spatial planning in SSA. More needs to be done to improve the technical capacities and abilities of city managers to adapt and deploy decision support systems to simulate the growth dynamics of secondary cities such as Wa and Bolgatanga. Without an adequate understanding of urban growth patterns, plans can become obsolete before implementation begins.

Notes

1. The primary city is the leading city in its country which is disproportionately larger than any others in the urban hierarchy.
2. https://www.luspa.gov.gh/.

Disclosure statement

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