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Dynamics of Spatial Sprawl and Stormwater Management in the City of Lome, Togo

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Abstract

Controlling the hydrological parameters of watersheds in a city undergoing highly dynamic sprawl remains a considerable challenge for urban planners. Literature review, combined with updated cadastral plans, made it possible to model the dynamics of the spatial expansion of the city of Lome to update hydrological parameters of its new watersheds. The exponential gradient that characterized the spatial evolution of Lome in the years following independence became linear from the 1980s onward. In its exponential phase, the phenomenon can be explained by rural exodus; the second, linear phase is due to the natural population growth of urban dwellers descended from the former peri-urban villages. Currently estimated at 300,000 ha, the surface area of the city of Lome is expected to reach close to 380,000 ha by 2040. The hydrological parameters of Lome's watersheds vary with the dynamics of land use and must therefore be updated on a regular basis.

Keywords: Land use**,** urban; peri-urban**,** hydrological parameters**,** spatial dynamics**,** Lome.

Introduction

Studies of land-use and land-cover change make it possible to track current trends in deforestation, land degradation, desertification and biodiversity loss within a given region[1]. Human activity has been the principal driver of ecosystem transformation over recent decades[2]. Climatic factors in general, and heat islands in particular, are increasingly cited today as a cause of land-use change. Population growth remains a highly significant factor among the causes of land-use change in African cities. These cities are characterized by a peri-urban belt that forms a transition zone between rural and urban environments. Under the pressure of extremely rapid population growth, the peri-urban zone retreats, giving way to urbanized space and, in turn, transforming its own periphery, formerly rural. The unchecked, runaway sprawl of African cities is also attributable to a lack of oversight by the authorities and to the absence of public conservation policies[3]. Owing to the steady rise in urbanization and the expansion of impervious surfaces, urban runoff has become an increasingly important issue over the past thirty years[4].

The management of water in urban areas is a central concern for society today. Urbanization has significant impacts on Stormwater management. The proportion of impervious surface areas in urban zones is particularly high compared with natural environments. Building roofs, parking lots, streets and pavements all concrete, asphalt or tarred infrastructure restrict the infiltration of water into the soil[5]. Impervious surfaces in urban areas increase both the speed and the volume of runoff relative to the natural state, which leads to increased flooding and erosion in receiving watercourses[6]. The water cycle is thereby disrupted. All runoff is channeled into the drainage network, at times exceeding its capacity and consequently causing overflows, flooding and sewer backflows.

Several solutions can be envisaged to mitigate the consequences of urbanization on the drainage network and receiving environments. One of these relies on source control of stormwater[7]. This approach aims to capture and retain runoff before it reaches the drainage network. The traditional approach to stormwater management currently in use seeks to evacuate runoff as quickly as possible[8]. The integrated stormwater management approach, also known as Low Impact Development (LID), seeks to artificially reproduce the natural pathway followed by rainwater on a site prior to human intervention. It is based on natural infiltration as well as on retention techniques to manage runoff locally. This is a form of static control management based on limiting the maximum outflow rate[9].

In Togo, and particularly in Lome, where flooding is a recurrent problem, the existing sanitation network suffers from significant malfunction[5]. One of the solutions considered to mitigate the consequences of urbanization on the drainage network and receiving environments was the development of a stormwater master plan. The current master plan for the city, dating from 2004, covered only the Commune of Lome (85 km² and 800,000

inhabitants), whereas by 2014 its area had reached 250km² with a population of one and a half million. The urban space of the Commune of Lome is today almost entirely saturated (only 4.22% of 600m² plots remain unbuilt). At present, the Lome agglomeration is expanding well beyond the boundaries of the Commune of Lome, with no possibility of anticipating the sanitation and planning measures this expansion requires[10]. The present paper therefore sets out to study the dynamics of land use with a view to integrating stormwater management for the city of Lome, to reduce the risk of flood-related disasters.

Materials and Methods

Study area: The city of Lome is in the extreme south-west of Togo and stretches along the coast of the Gulf of Guinea. It lies between 6°11′ N latitude and 1°5′ E longitude. Lome is bounded to the north-east by the lower Zio valley, to the west by the Togo–Ghana border, and to the south by the Atlantic Ocean (Figure-1).

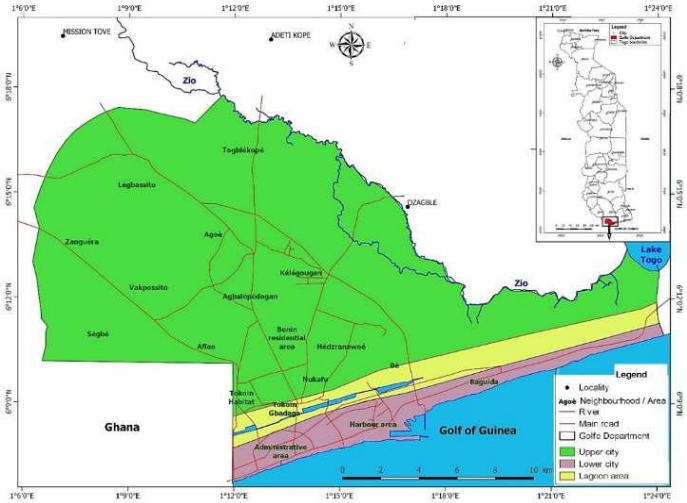


Figure-1: Map of the study area[5].

The population of Greater Lome stands at 2,188,376 inhabitants, representing 63% of Togo's urban population, or 27.03% of the country's total population[11]. Lome lies within a sub-equatorial Guinean climatic zone, itself subdivided into two sub-climates the coastal sub-equatorial sub-climate and the transitional sub-equatorial sub-climate[12]. Mean annual rainfall in Lome barely exceeds 1,000 mm. Some climatologists describe this as a negative climatic anomaly, while others attribute the unusual pattern observed in the rainfall records of Lome's two weather stations to global warming[13].

The vegetation of Lome is characterized by azonal formations typical of lagoon depressions. In these wetlands, water bodies are covered with hydrophytic vegetation, some floating and some submerged. Anthropogenic plant cover consists mainly of fruit trees, dominated by coconut and oil-palm groves, along with several market gardens.

The relief of the city of Lome comprises three main zones: i. The coastal strip is a very flat sand-dune formation with elevations between 2 and 5.5 m. It consists of a series of small depressions on one side and a low, sandy shoreline on the other. ii. The lagoon zone lies roughly 2.5 km from the shoreline and extends across the full width of the city over a bank it's a little more than 200 m wide; in places its elevation is below sea level, with a discontinuous water table. iii. The plateau zone is bounded to the south by the lagoon zone, to the north-east by the main bed of the Zio River, and to the west by the border with Ghana. It presents a marked break in slope immediately north of the lagoon, with an elevation difference of 5 to 15 m depending on the location.

Data collection: The methodological approach used for data collection was based on documentary analysis. This consisted mainly of previous stormwater master plans and earlier work relating to the mapping and cadastral plan of the city of Lome. These documents were obtained from, or consulted at, the following bodies: the General Directorate of Water Resources (DGH), the General Directorate of Energy (DGE), the Integrated Disaster and Land Management Project (PGICT), as well as the Ministry of Infrastructure and Transport (MIT) and the Ministry of the Environment and Forest Resources (MERF).

Updated cadastral plan and hydrological parameters of the watersheds: The cadastral plan of the city of Lome was updated on the basis of satellite imagery through diachronic analysis, the cadastral plans of the Ministry of Urban Planning and Housing (MUH), the flood-vulnerability maps and the electricity-subscriber parcel plan, all processed under AutoCAD[12,14]. Following field observations of runoff behavior, the boundaries of the watersheds and sub-watersheds were delineated on the georeferenced map using QGIS and AutoCAD. The concentration time of each new watershed was calculated using the Kirpich formula (Equation 1):

$$Tc = 0.0195 \times L\ 0.77 \times I\text{^}0.385 \quad (1)$$

where: Tc = concentration time, in minutes (min); L = distance to the most remote point of the watershed from the outlet (m); I = mean slope of the watershed (m/m).

Results and Discussion

Dynamics of the spatial sprawl of the city of Lome: The horizontal expansion of Lome has today earned it the name "Greater Lome" (Grand Lome), which now extends over close to 300 km². Suburbs such as Djagblé and Adétikopé have been absorbed into the agglomeration to the north-east and north respectively, while the area around the oil refinery lies to the east.

During the first twenty years following independence, the area of Lome grew from 1,276 hectares to 3,955 hectares. Since becoming the capital of Togo, the spatial expansion of Lome

followed an exponential pattern (Equation 2) up until 1980, when it reached 3,955 hectares (Figure-2). The city of Lome was covered only a part of the Golfe prefecture in 1999 named Commune of Lome[15].

$$y = 1\times10^{-54}\, e0.0671x \quad (2)$$

The northern and north-eastern suburbs also contain pockets of villages occupied by rural populations. Informal settlements have also developed to the east, specifically around the port area (Figure-3).

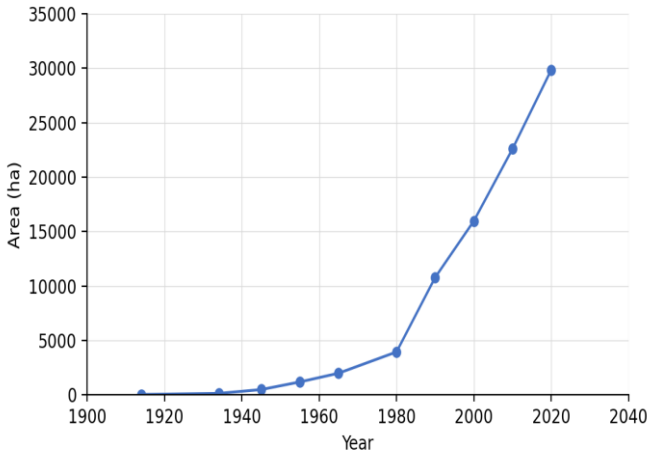


Figure-2: Spatial evolution of the city of Lome, 1914–2020.

From 1980 onward, the expansion entered a linear phase (Equation 3), with the city's surface area growing from 15,983 ha in 2000 to 29,843 ha in 2020, earning the agglomeration the official designation "Grand Lome" following the merger of the formerly distinct Golfe and Agoè-Nyivé prefectures into a single agglomeration of thirteen communes.

$$y = 623.2x - 1\times10^{6} \quad (3)$$

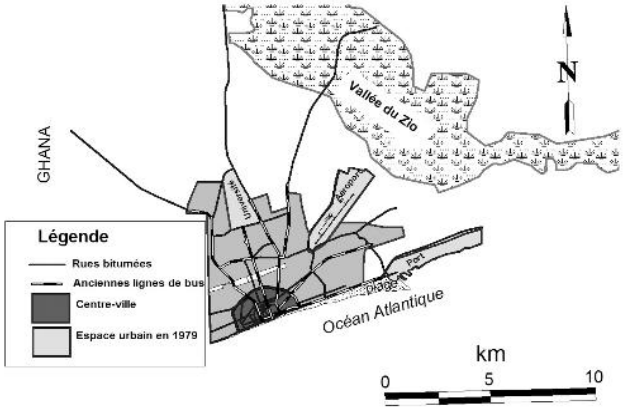


Figure-3: Land use in the city of Lome in 1980[15].

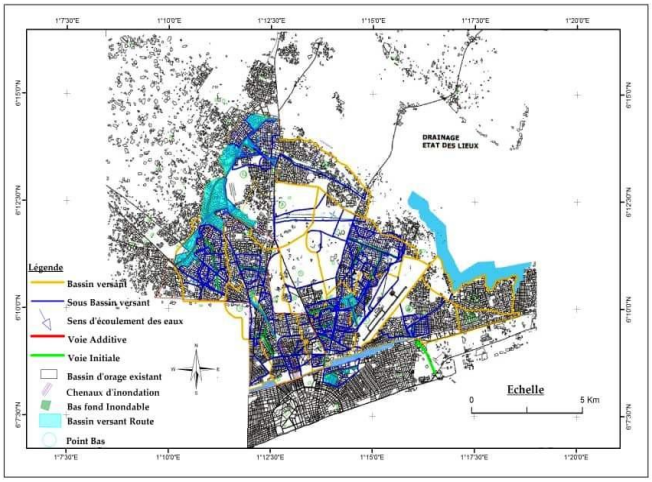


Figure-4: Land use in the city of Lome in 2004[16].

By 2004, the Commune of Lome had absorbed the last remaining rural areas of the Golfe prefecture and had begun an irreversible encroachment into the territory of the Agoè-Nyivé prefecture (Figure-4).

Updated hydrological parameters of the city's watersheds: The major areas of expansion of the city of Lome fall broadly into two zones: the eastward extension from the Baguida district, which shows a tendency to merge into a single metropolitan area with the town of Aneho; and the northward branches that follow the main district through the thoroughfares. In total, nine (09) new watersheds were identified in the northern periphery of Lome, covering a combined area of 114 km². Their individual areas range from 4.70 to 44.39 km², and their perimeters from 12.95 to 47.67 km (Table-1 and Figure-5). Their mean slope and mean flow-path range from 1.7% to 1.97%, and from 3.91 km to 13.44 km, respectively. The concentration times of the new watersheds range from 47 to 138 minutes (Table-1).

Table-1: Hydrological parameters of the new watersheds of Greater Lome.

Description	Area (km²)	Perimeter (km)	Mean slope %	Flow length (km)	Conc.n time (min)
Togblékopé West	24.45	40.75	1.76	13.44	138
Atiégou	6.45	19.75	1.71	6.47	79
Yokoè	4.70	12.98	1.70	3.91	54
Zanguéra West	44.39	47.67	1.91	13.32	132
Zanguéra East	33.36	42.93	1.97	8.45	92
Légbassito	20.64	27.132	1.65	4.44	60
Vakpossito	17.17	17.21	1.64	4.911	65
Ségbé East	17.51	17.20	1.68	4.343	59
Adidogomé	16.94	19.05	1.57	3.13	47

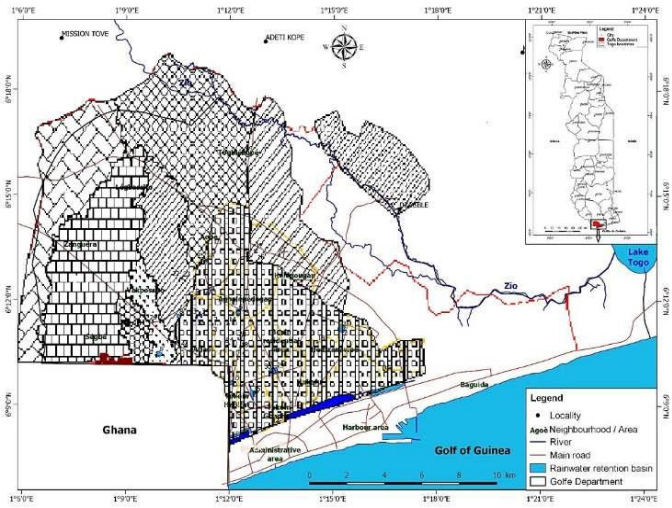


Figure-5: Delineation of the new watersheds of the city of Lome.

Discussion: Fragmentation considerably alters the hydrological parameters of the watershed concerned, as well as those of its entire surroundings, not to mention all downstream watersheds[17]. This situation calls for a comprehensive resolution of the flooding problem, in contrast to piecemeal interventions that merely displace the problem spatially. One gets the impression that urban planners' concerns are limited to draining the water that falls onto paved surfaces.

The present study made it possible to update the cadastral plan of the city of Lome and to identify its major areas of expansion. It emerges that the former rural areas to the north-east and north of the city have progressively lost their rural status in favor of urbanized land. This is explained by the persistence of village enclaves: landowners in the suburbs sell their farmland to civil servants and traders from the city, who then build residences and move in without any prior planning intervention by the authorities. Informal settlements have also developed around the port area, the city's eastward extension, owing to the highly precarious situation of the unskilled labor force employed by companies typically located in the free-trade zone. This mixing of long-standing rural residents with urban newcomers complicates planning efforts. This situation was already noted in 2004[16]. The 2004 master plan indicated that the urban space of the Commune of Lome was already almost entirely saturated (only 4.22% of plots remaining unbuilt). The Lome agglomeration is expanding beyond the boundaries of the Commune of Lome into the territory of the Golfe prefecture, particularly northward along the RN1 (the Agoè-Nyivé sector) and north-westward along the Kpalimé road. Between 1970 and 1981, the urban area of Lome grew from 1,900 ha to 6,100 ha (an increase of 221% in 12 years), reaching close to 9,000 ha by 2014[16,18]. Urbanization has taken place almost systematically across numerous depressions on the Tokoin plateau, in the north-eastern and north-western extension districts of the city. These naturally flood-prone depressions, once urbanized, become areas of particularly severe and recurrent flooding. A further difficulty lies in public perception, which does not always readily accept seeing water return to the surface; a commonly expressed fear, for example, concerns the risk of drowning associated with retention basins, whether dry or holding water. The ongoing expansion of Lome therefore calls, on the one hand, for the implementation of a new stormwater sanitation master plan that accounts for the updated hydrological parameters of the watersheds and the updated cadastral plan of the city, and, on the other hand, for the regular maintenance of existing infrastructure.

Integrated stormwater management offers an attractive alternative to the traditional drainage network. It encompasses a wide range of source-control measures. Their use would reduce the volume of water conveyed to the drainage network, lower peak flows, and reduce the quantities of pollutants carried by runoff. These measures include, among others, bioretention areas, infiltration wells, filter strips, vegetated swales, rainwater harvesting systems, retention basins and other filtering marshes. They also include green roofs and the enhancement of urban forests[17,19].

Conclusion

The city of Lome is undergoing continuous spatial sprawl. This pressure on the periphery is intensifying the unplanned occupation of administrative reserves and flood-prone areas. Lome experienced an initial phase of exponential horizontal sprawl from 1914 to 1980, followed by a linear phase lasting until 2020. Forward planning of housing and development policy could substantially reduce flood risk and support integrated water-resource management in a city expected to cover an area of 400,000 hectares by 2040.

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