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A New Approach to the Collection and Spatial Analysis of Land Values in Lomé and Yaoundé

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ABSTRACT

Understanding the land market is crucial when analyzing the spatial dynamics of cities. Spatial models, which are widely used to describe the growth of cities, are underdeveloped in Africa, due in part to the lack of urban data and/or the difficulty of collecting it. This paper presents a methodology for collecting analyzing land values in major sub-Saharan African cities. Through two case studies in the cities of Lomé and Yaoundé, it describes the implementation of such a methodology for collecting data on land prices and analyzing variations on an urban scale. It offers effective means of developing more accurate models for analyzing the dynamics of the land market.

Keywords:
Land Value
Spatial Models
Urban Data
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Résumé en Français

La compréhension fine du marché foncier est déterminante pour l'analyse des dynamiques spatiales des villes. Les modèles spatiaux, largement étudiés pour décrire la croissance des villes, ont été peu développés en Afrique en partie à cause de l'absence de données urbaines ou de la difficulté d'en collecter. La communication proposée présente une méthodologie d'analyse des valeurs foncières dans les grandes villes d'Afrique subsaharienne. À travers deux cas d'étude, Lomé et Yaoundé, elle discute de la mise en œuvre d'une telle méthodologie pour collecter les prix du foncier et analyser leur variation à l'échelle urbaine. Cela constitue une piste valable vers l'élaboration de modèles plus précis d'analyse des dynamiques du marché foncier.

Mots clés :
Valeurs foncières
Modèles spatiaux
Données urbaines
Lomé
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1. INTRODUCTION

The centrality of land issues in urban debates in sub-Saharan Africa is no longer to be questioned (Sietchiping, Permezel, and Ngomsi 2012). Among the many repercussions of uncontrolled urban land use, the difficulty of monitoring spatial growth in major cities is by far the most criticized. Not only are the dynamics extremely fast-paced (Lall, Henderson, and Venables 2017), but the tools used to plan and organize the urban space are also ineffective (Chenal 2015).

Land also plays a key role in determining cities' layouts, due to the link between the land market and spatial models of urban growth (Capozza and Helsley 1989; Fujita 1976; Mills 1981). These models have been the subject of numerous theoretical and empirical studies, most of which attempt to explain choices in terms of residential location choices (Lecat 2004; Napoléone 2012) and cities' trajectories in the context of urban sprawl (Aguejdad et al. 2016; Bhatta, Saraswati, and Bandyopadhyay 2010; Irwin and Bockstael 2007; Oueslati, Alvanides, and Garrod 2015; Reis, Silva, and Pinho 2016). Unfortunately, few studies on African cities have actually aimed to create such models (Linard, Tatem, and Gilbert 2013; Mundia and Murayama 2010). Though likewise struggling with the issue of urban sprawl, these cities are far from center stage in the global debate. While we may know why central Paris is rich and Detroit poor (Brueckner, Thisse, and Zenou 1999), we have little idea of what is happening in Lomé, Yaoundé or Dakar, beyond the generic image of the city dweller who migrates towards the urban periphery in search of affordable land (Canel, Delis, and Girard 1990; Piermay 1993).

Ggenerally speaking, urban land markets in Africa are little studied, due perhaps to their complexity and the fact that an entire portion of activity surrounding them eludes state institutions (Lusugga Kironde 2000). Given this, implementing effective urban management tools capable of withstanding strong growth now and in the future is a difficult task (Lall, Henderson, and Venables 2017).

This article aims to fuel the development of urban planning policies in order to create more sustainable growth models for cities. It presents, describes and discusses the research methodology, whose overall goal is to spatially analyze land values in African cities. More concretely, it attempts to answer the following two-fold question: how to observe urban land prices, and how to analyze their dynamics? The article begins by describing the methodology used to collect current, reliable information on land prices that is coherent with the reality of practices across the city. It then goes on to discuss how it was applied to the two large, sub-Saharan African cities of Lomé and Yaoundé, describing both its feasibility and its reliability. Finally, we offer suggestions for future research and other potential applications of our method.

2. APPROACHES TO A SPATIAL ANALYSIS OF THE DYNAMICS OF LAND MARKETS

The study of land markets was first used to analyze the residential location of city dwellers, and later for the analysis of cities' spatial structures and urban growth dynamics (Capozza and Helsley 1989). Two main types of models were used for this: static models based on the state of an urban system at a given time, and dynamic models, which consider the morphological development process based on the conditions that influenced this development (notably the regional economy, migration and/or environmental policies) (Capozza and Helsley 1989; Linard, Tatem, and Gilbert 2013). The approach of spatio-temporal urban models has also evolved from a top-down perspective, which considers that

structure is the result of a process, to a new, bottom-up approach whereby cities are considered complex systems that result of individual behaviors (idem).

Schematically, in urban economics, residential land prices depend on proximity to the city center, or "downtown area," where jobs and services tend to be concentrated (Cavailhès, Hilal, and Wavresky 2011). Households thus seek a middle ground between the cost of daily travel and land prices; in other words, between a peripheral location (lower land costs but higher transportation costs) and a more central location, which implies the opposite (idem). Land value thus decreases from the center outwards towards the city limits.

This basic hypothesis is further enriched by other parameters. For example, given that the size of lots increases with distance from the center while prices decrease, studies show that price variation is not linear but rather an increasing concave function of distance from the city center (Colwell and Munneke 1997). More complex dynamic models consider urban growth rates as a determinant of property value. In such models, we must also add the future rent prices anticipated by economic agents to the current one so as to estimate land prices. These future rent prices are a function of the city's population growth rate (Capozza and Helsley 1989).

Many land market analysis models exist, each more complex than the next with regard to the number and nature of parameters considered. Their level of complexity depends on the objective and defines the model's accuracy. The more accurate the model, the better it describes the situation and facilitates the simulation of future situations. Note that in many past and recent studies, the main goal has been predicting trends in future urban land prices. To do this, a variety of mathematical methods are used to analyze the spatial and, more notably, temporal variability of prices (Batty and Sik Kim 1992; Sampathkumar, Santhi, and Vanjinathan 2015). In this field, hedonic approaches combining different mathematical methods based on equally different variables are common (Hannonen 2008). Other goals may include the conservation of natural ecosystems at the territorial level (Philip M. Osano et al. 2011) or urban expansion planning aimed at more compact forms (Alain Bertaud 2015).

3. WHY A DIFFERENT APPROACH FOR AFRICAN CITIES?

Though relatively old, an important body of literature exists on modeling the dynamics of urban land markets in industrialized countries. Although the urbanization rates on this continent are the highest, and the future impacts are likely to be the greatest, few African cities have been the subject of such studies (Linard, Tatem, and Gilbert 2013). In order to fill this gap, our study begins with a discussion of the challenges of implementing studies on land markets in the African context.

3.1. Theoretical considerations.

Three essential questions can be raised at this level. The first concerns the complexity of tenure systems. In African cities, the coexistence of several land regimes has resulted in multiple parallel land markets with different land acquisition procedures, means for establishing property rights and ways of handling transactions (Durand-Lasserve and Le Roy 2012). Confusion amongst the different actors creates fundamental difficulties when it comes to regulating activities with regard to land. This in turn makes the logic of land use difficult to study, even if the mechanisms of the urban market - in the absence of clear regulations - tend to naturally produce land use based purely on criteria of profitability (Mundia and Murayama 2010). Land systems are complex, but then again urban systems

are complex on the whole, thus increasing the difficulty of understanding and predicting their dynamics (idem).

The second question concerns the behavior of economic agents and their level of information. This is due to archaic land market models whose basic general assumption is that developers seek to maximize economic profit, that buyers have a single objective (i.e. to find housing), based on which they seek the lot with the best features (Renard 1975). But in order to do this, they also need equitable access to information about land. In reality, however, people's objectives are not necessarily always the same; in other words, it is not always a question of making the greatest profit or finding the cheapest housing.

On the other hand, not only do economic agents not have the same degree of information relative to the land market, but it is also impossible to imagine that individuals have perfect knowledge of prices across the city when buying a lot (Renard 1975). In cities in developing countries and in sub-Saharan Africa in particular, the sectors are numerous and diverse, the markets are intertwined (Durand-Lasserve and Le Roy 2012) and knowledge of the offer is essentially informal. Land information networks range from word of mouth to television, family associations, posters in taxis and Internet ads.

The third question has to do with the reality of the urban economy in sub-Saharan Africa. Existing models are based on distance from the city center and on the assumption that most jobs are located there. However, in Lomé and Yaoundé, the majority of jobs are informal, and much of the economic activity (small businesses, crafts, etc.) is done in or near the place of residence (Fox, Senbet, and Simbanegavi 2016; Page and Shimeles 2015). This means that proximity to the city center is not necessarily a determining factor in city dwellers' residential choices. This variable should thus have a nuanced weight in relative to other variables such as the density of nearby activities and services, or distance to the nearest economic hub. With these considerations, others of a more practical nature also emerge.

3.2. Practical considerations

From a practical standpoint, the major challenge in studying land market dynamics is getting the necessary data. Quantitative studies on African cities often face issues when it comes to obtaining reliable, complete, up-to-date data on the urban space (Mundia and Murayama 2010). Land values in existing studies come either from databases of legally recorded transactions, which provide information on areas, prices, locations and other specific information on transactions, or from notarial or cadastral databases. However, such databases rarely exist. When they do, the values declared do not always reflect the reality due their official nature. Moreover, they are not sufficiently representative, as few transactions are legally registered, even within the registration service itself (Durand-Lasserve and Le Roy 2012). On the other hand, most cities have no comprehensive land register due to the drawbacks of the cadastral system in the African context and the rapidity of urban planning dynamics (Sietchiping, Permezel, and Ngomsi 2012). In this regard, Africa's urban population will at least triple within the next 40 years, with expected growth rates at roughly 2% and an increase of urban perimeters by a factor of 6 between 2000 and 2030 (Güneralp et al. 2017).

In addition, the parameters often taken into account when analyzing these land values often include a large number of independent variables (e.g. proximity to local infrastructures and services, population density for each lot or block, soil quality, employment areas, legal status, etc.) that are

difficult to get accurate information on in African cities. Urban data issues also arise in terms of past data. As data is not systematically collected and archived, this automatically excludes the use of certain specific models that require an analysis of past trends. Such models would make it possible to perform simulations for past decades as well as for the future with relative accuracy. However, their performance largely depends on the quality and type of data available (Linard, Tatem, and Gilbert 2013).

Land values are thus little analyzed in urban Africa. A study carried out on the city of Accra showed links with six main parameters. These included: access variables (namely proximity to the city center), zoning, cultural determinants such as land tenure and the effect of ethnic groupings, date of sale, local services, and lot size (Asabere 1981). However, the database's main source was a housing and construction bank that focused mainly on properties whose purchase they had financed, and hence a certain bias. Nzau (2003) takes into account a larger number of parameters for Nairobi by adding independent variables such as population density, landscape view, topography, soil type and development potential, some of which are relatively subjective. On the other hand, the use of mixed pricing sources (ministry, real estate agents and experts, and advertisements in the press) is remarkably innovative.

4. DEVELOPING A CONTEXT-APPROPRIATE METHOD

4.1. Description of the method

In light of the aforementioned context, this study presents a simple method for building a database of land prices in major cities. The study focuses on actual prices from the field versus the official price grids that are sometimes available in the administrations of certain countries. This choice is in keeping with the primary objective of building a database that can serve as a basis for detailed spatial analyses of market dynamics.

Concretely, we propose a procedure based on the aggregation of expert opinions in four phases. To begin, the city must be divided the city into sufficiently small units in order to effectively analyze variations in values. It is possible to divide the territory in several ways. We chose the most feasible for the purposes of this study. Thus, the division into neighborhoods that exists in most cities is too broad and not precise enough. Division into lots, however, offers much greater accuracy, as the units are small enough to capture variations in values. However, this method has two major drawbacks. The first is that very few cities have complete maps of their lot divisions. The second is that estimating land value on a lot by lot basis for large cities would be extremely tedious. Therefore, the division should ideally be between these two scales.

Secondly, once the division method has been chosen, several groups of experts must be trained in order to estimate the average property values for all of the units of the division from the previous phase. The most suitable experts for such a study are real estate agents (also called real estate "lobbyists" in several cities). The latter are service providers that effectively act as intermediaries between indigenous landowners or resellers and potential buyers of building plots. These individuals thus have a front row view when it comes to land transactions in all sectors of the city. Moreover, they are more easily accessible, as they are generally aggregated into unions or workers' associations. The idea here is to gather these agents into small working groups in order for them to jointly determine ranges of land prices that are as close to the reality of each zone as possible. Ideally, at

least four or five groups are required in order to have credible estimates. For the actual estimate, the comparative value method, which consists of estimating property according to transactions involving comparable objects in the recent past is the easiest. This allows for an estimation of values that is true to the reality of the current market. Sales announcements in the press and on specialized websites can be good complementary sources for the database and verifying experts' estimates.
Third, the estimated values provided by the different expert groups must be combined in a in a simple manner. Fourth and finally, the data collected can be arranged and analyzed from a spatial standpoint using GIS software. This data approximates the reality on the ground more accurately than do the official price grids that exist in certain cities (see Table 1 for a comparison).

	Official prices	**Actual prices**
Theoretical considerations	Division is relatively approximate (often into districts). Zoning divisions not small enough for a detailed spatial analysis.	The subtlety of the division can be adjusted according to the objectives and means of the study.
	The goals are tax-oriented, which can bias values.	Experts are aware of the research goals and have no interest in skewing values.
	Only take into account the official land tenure system (registered buildings).	More accurately reflect the reality of the context because they include parameters that are difficult to measure, such as the marketing skills of the players handling the transactions.
Practical considerations	Databases sometimes exist but are often incomplete and not up-to-date.	Databases do not exist and would be difficult to update in a systematic way.
	Easy to follow changes over time if data is collected periodically and systematically.	Collection approach difficult to reproduce identically for several dates. Unreliable for past data.

Table 1. Comparison between official prices and actual prices for analyzing real estate market dynamics

4.2. Application of the method

a. Yaoundé and Lomé, similarities and differences

Located in the Center region, Yaoundé is the political and administrative capital of Cameroon. Administratively speaking, the city's perimeter corresponds to that of the department of Mfoundi, even if, in reality, the metropolitan area extends far beyond this. The Yaoundé Urban Community has the same perimeter and includes 7 district municipalities: Yaoundé 1, Yaoundé 2, Yaoundé 3, Yaoundé 4, Yaoundé 5, Yaoundé 6, and Yaoundé 7 (see Figure 1). Only the built area of the agglomeration area was considered within the scope of this research. The population of Yaoundé has risen from 90,000 inhabitants in 1952, to 1.8 million in 2005, to 2.9 million today. It is expected to reach roughly 3.5 million by 2030, with an average density 120 inhabitants per hectare (Ndock Ndock 2013).

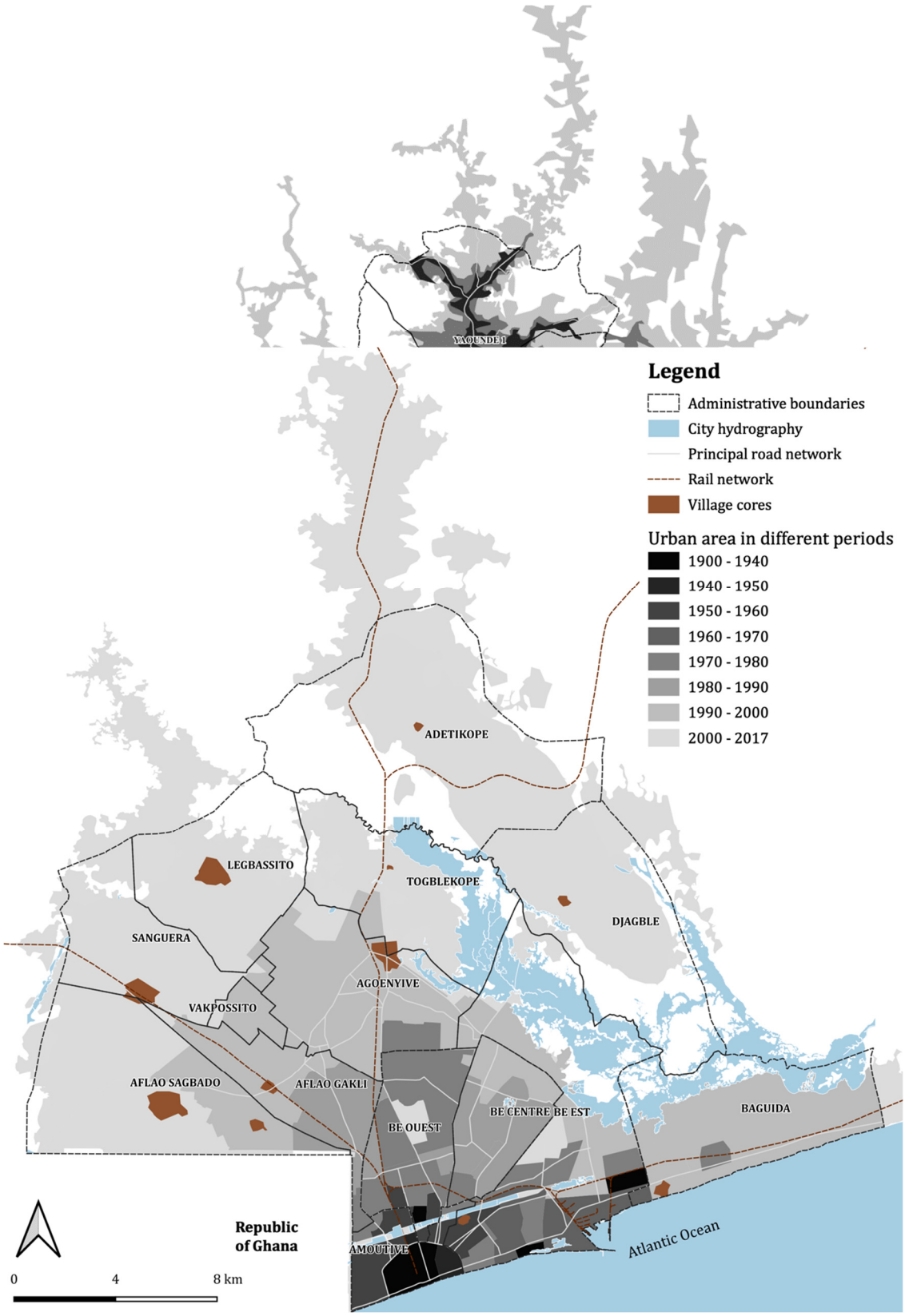

Fig. 2. Administrative limits and division of Grand Lomé.
Source: AGETUR-Togo, OpenStreetMap

Lomé, the capital of Togo, has a population of approximately 1.9 million for the entire agglomeration (Mawussi 2018). In 1981 there were 400,000 inhabitants, versus 865,000 in 1997 (Fiawumor 2016).

Administratively, the municipality is subdivided into 5 arrondissements, whereas Greater Lomé also includes the Gulf prefecture with its 10 cantons (Amoutivé, Bè, Baguida, Agoè-Nyivé, Sanguéra, Togblékopé, Aflao-Gakli, Aflao-Sagbado, Légbassito and Vakpossito) and the neighboring canton of Adédikopé (see Figure 2). In Lomé, the agglomeration also extends beyond the municipal boundaries, with an average density of less than 80 inhabitants per hectare. The study area therefore includes the perimeter of the Gulf prefecture and the parts of the two neighboring cantons over which the urban area extends.

Rapid demographic growth in these two cities is raising issues of spatial growth similar to those in other cities in sub-Saharan Africa: horizontality, the marked sprawl of the urban fabric, and relatively low densities (Linard, Tatem, and Gilbert 2013; Mfoulou Olugu 2018; Olujimi 2009; Olvera, Plat, and Pochet 2003; Tewolde and Cabral 2011). Yaoundé measures 28 km from north to south and more than 18 km from east to west. The Lomé agglomeration stretches along the coast and nearly reaches the neighboring city of Aneho, roughly 30 kilometers away. The two cities also have in common the fact that they have similar land systems and were built molded by nearly identical colonial heritages and postcolonial laws, which laid the foundations for an unclear relationship between the State and customary communities.

Lomé, however, is a coastal city along a national border (that of Ghana in the west), whereas Yaoundé is an inland city that, theoretically, can continue to expand in all directions. Lomé is also the largest and by far most important city in the country from an economic, demographic and political standpoint, which is not the case for Yaoundé. It is also the smallest port city in the massive West African coastal conurbation that extends from Lagos to Abidjan.

We chose to study these two cities neither for their representativeness, nor to compare them, but rather to illustrate different contexts. Through these two cases, the text discusses the feasibility of the method as well as the potential for future developments.

b. Adapting the method to different contexts

The first phase consisted of choosing a division method for the two cities. In Lomé and Yaoundé, the most detailed division available is that of neighborhoods. Such divisions already exist; each city has approximately one hundred neighborhoods. Division by lot, however, does not exist. For a more detailed division, in Yaoundé we looked at the list of localities used a basis by for the land prices by the tax services. The localities here were denoted by notable landmarks such as public facilities (schools, markets and health centers for example), major intersections, main roads, well-known buildings, etc. The list included 347 points that we mapped and completed so as to cover the entire territory with the tightest mesh possible. In the end, the mesh contained 777 points, with a median distance of roughly 600 meters between neighboring points. In Lomé, in the absence of such a list, we used the division created for the 2010 RGPH. The goal was to have similar units of built density, to better balance out the work of the investigation teams. The 562 units in this division measured an average of 73 ha (with a median of 36.5 ha). The table below compares the three types of divisions envisaged (Table 2).

For the second phase, six groups of two to six experts were formed in both cities to estimate the average land values for the division units in Lomé, and for the localities (points) in Yaoundé, based on the current market. Ads from the main lot sale websites were used to supplement this data. Consistency among the various estimates and with the values obtained via the Internet ads were also checked for each division unit. The median was then calculated in the third step. Finally, the values were linked to the centroids of the division units in the case of Lomé and to the localities using QGIS 2.18, GIS software. Figures 3 and 4 represent the land values obtained in Lomé and Yaoundé respectively, represented here as Voronoi polygons.

	Division into neighborhoods	**Division/Zoning into lots**	**Realistic divisions**
-	Scale too large for spatial analyses	Only partially exists and is not up-to-date	Difficulty comparing cities
	The areas outside the administrative boundaries are not considered	Not realistic for pricing by expert groups or sales ads	Irregularity of polygon dimensions
+	Comparison between cities with similar divisions possible	Perfect scale for spatial analysis of property values	Sufficiently small scale; ease of estimating prices
		Easy comparison between cities	Division into localities corresponds to market practices

Table 2. Comparison of the three types of zoning envisaged, advantages and constraints

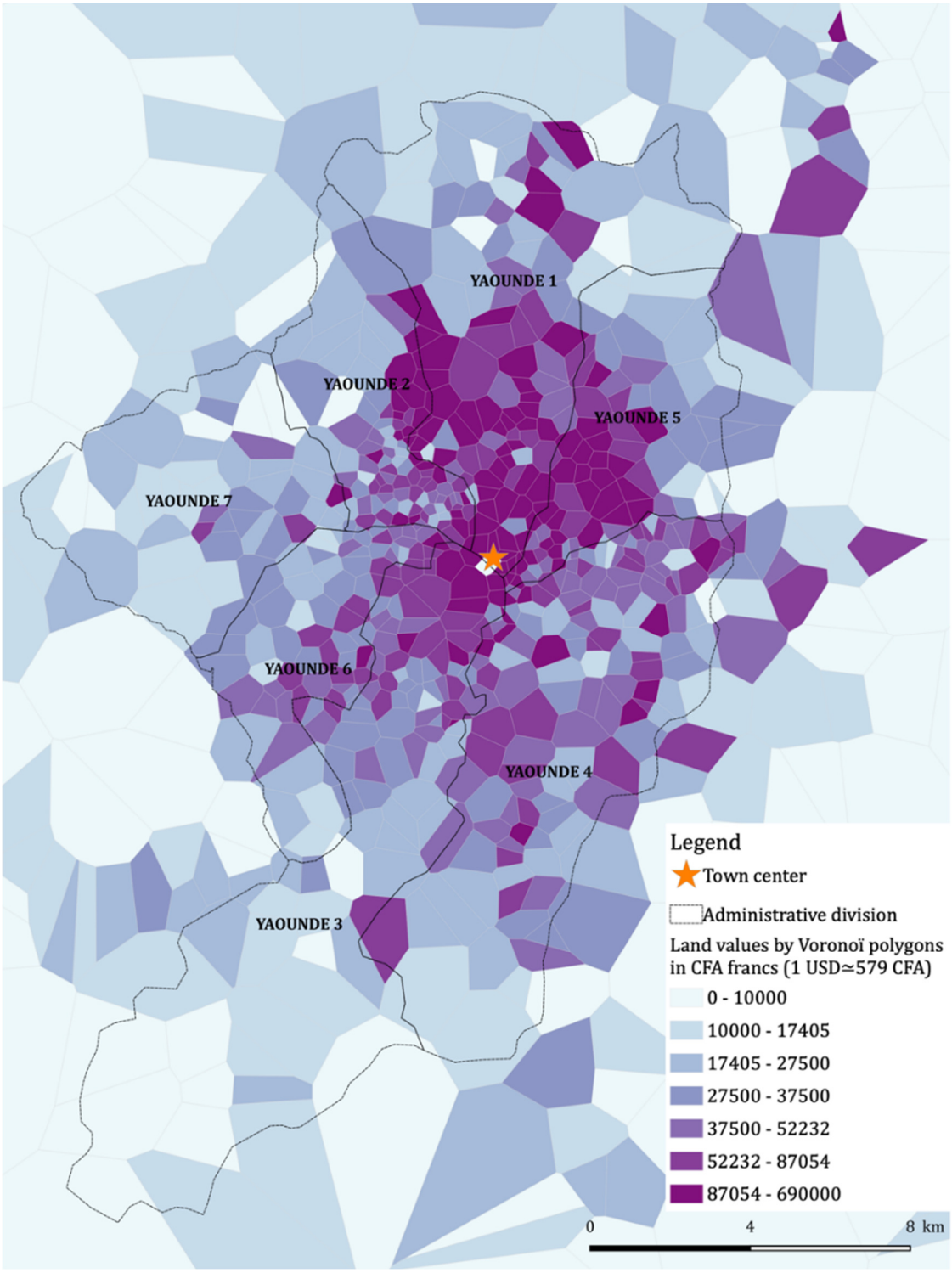

Fig. 3. Land unit prices in Yaoundé in FCFA per m²
(Representation method: quantile, 7 equal categories of figures)

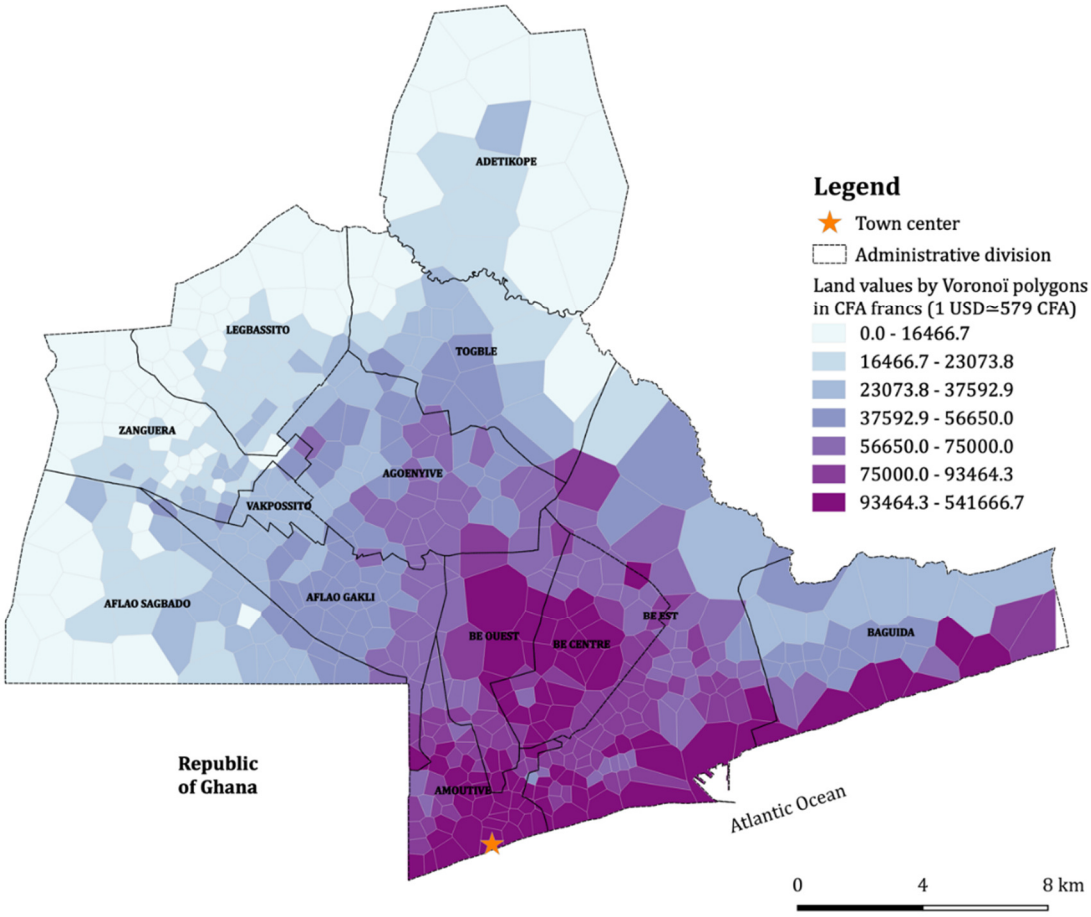

Fig. 4 – Land unit prices in Lomé in FCFA per m²
(Representation method: quantile, 7 equal categories of figures)

c. Spatial analysis of land values in Lomé and Yaoundé

Once data regarding prices had been collected, we then proceeded with the analysis variables (independent variables). According to the literature and for reasons of feasibility, five variables were chosen: 1) distance from the city center, 2) density of the road network, 3) building density, 4) distance from the nearest school infrastructure, and finally, 5) distance from the nearest health facility. We were unable to include the density of economic activities, a variable that would have been more adapted to the context than the distance to the city center, as the data available was not complete or sufficiently robust, as explained above. The data concerning these variables was extracted from the OpenStreetMap platform using the OSMnx tool, and the calculations and analyses were done using the Python 3.7 programming language and the GeoPandas library.

We began by normalizing the data. While land prices were not normalized, the data for the variables was normalized for the sake of comparability using the Min-Max scaling function. We then chose the statistical model to apply. Two models are typically used in the literature: the negative exponential function (see equation 1) and the inverse power function (see equation (2)).

$$model\ 1: \rho(r) \simeq e^{-r} \quad (1);$$

$$model\ 2: \rho(r) \simeq r^{-\alpha} \quad (2);$$

Where $\rho(r)$ is the land price in a zone at a distance r from the city center and α a scale exponent.

After testing the two functions, we selected the second (model 2) as it provided better results. This was in keeping with previous studies showing that it better corresponds to the morphological characteristics of contemporary cities (Batty and Sik Kim 1992). The graphical representation of the logarithms for the two cities allows us to observe heavy tail probability laws (see Figures 5 and 6 opposite).

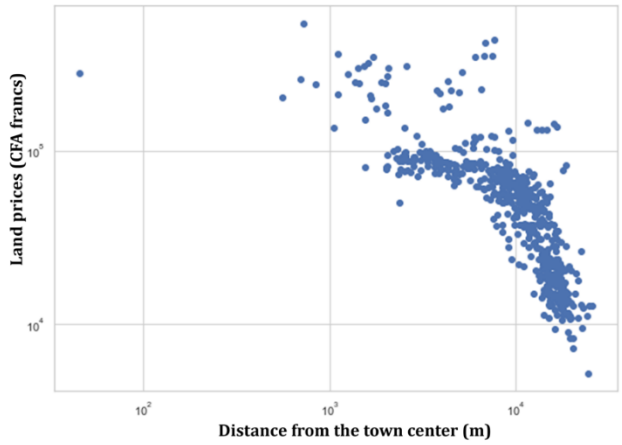

Fig. 5. Distribution of probabilities of prices according to distance from the city center in Yaoundé

Fig. 6. Distribution of probabilities of prices according to distance from the city center in Lomé

In light of these observations, we decided to do linear regressions in order to analyze prices according to our independent variables (see equation (3)).

$$\text{Log}\,\rho \simeq \text{Log}(r^{-\alpha})$$
$$\simeq -\alpha.\,\text{Log}(r) \quad (3)$$

Once the calculations had been made, we observed a moderate relationship with the parameters considered, which means the variables effectively impacted land prices the way we expected them to. The greater the distance from the city center, nearest school or nearest health facility, the greater the decrease in prices, whereas density of buildings and road networks impacted prices positively, i.e. prices increased with these two parameters.

Variables	Yaoundé	Lomé
Distance to the center	-0,440	-0,438
Density of roads	-0,020	-0,017
Building density	0,091	0,049
Distance to the nearest school	-0,026	-0,126
Distance to the nearest hospital	-0,077	-0,162

Table 3 – Standardized coefficients of the different variables

In Yaoundé: Overall, the coefficient of determination R^2 was 0.53 (this coefficient can vary from 0 to 1). However, the variables had different weights. For instance, the distance from the center parameter weighed five times more than building density, and six times more than the distance from

the nearest hospital parameter. Overall, these three variables proved to be the most important. The other two – the density of the road network and distance from a school – were less decisive (respectively 4.5 and 3.5 times less than the building density variable).

In Lomé: R^2 had a value of 0.54 for all of the independent variables. As in Yaoundé, the variables had different weights for the dependent variable, which was price. The distance to the city center parameter was roughly three times more important than that of distance to the nearest hospital or school. Building and road network density had very little weight.

For both cities, the principle observation was the predominant weight of the distance from the city center. The distance from the nearest school and/or health facility ranked second. The building density parameter had a similar weight to the aforementioned variables in Yaoundé, but was much less important in Lomé (80 inhabitants per hectare, compared to 120 in Yaoundé). This is probably due to the fact that Lomé is relatively less dense. Other factors may also explain some of the differences observed, notably Lomé's proximity to the Ghanan border which significantly influences the territorial dynamics of the entire agglomeration, the presence of the sea (which increases prices on the coast) and the fact that the road network in Lomé were better distributed over the urban territory according to our observations. The figure below shows the relative weight of variables other than distance from the city center in the two cities (figure 7).

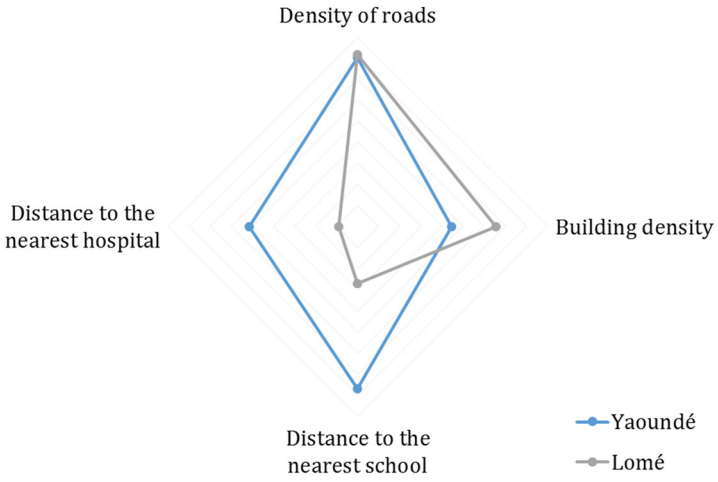

Fig. 7. Relative weight of the different secondary variables on land values

In the two cities, we observe that the density of the road network is significantly less important than the other variables. This shows that accessibility therefore does not seem to be a determining factor in land values as is the case in most cities in developed countries (Xu and Yang 2019; Li 2018; Yang et al. 2019). This result could be explained by the fact that the level of public transport infrastructure and services in general is low in our two cities. They have neither a sufficiently developed network, nor public transport of a sufficiently large capacity to make a significant difference between zones of different accessibility. In addition to this, the low weight of the accessibility variable could also be explained by the fact that the majority of mobility is provided by individual means of transport (personal motorcycles or mototaxis, walking) or of low capacity (collective taxis), and these means are capable of operating even in the absence of improved roads (Kemajou et al. 2019; Diaz Olvera et

al. 2016; Olvera et al. 2012). Despite this, pedestrian accessibility could have been a determining variable in itself, if we were in very high density cities, and which provided good walking conditions (Higgins, Nel, and Bruyns 2019).

The results also showed that the weight of proximity to socio-collective infrastructure is different in the two cities. It is more significant in Lomé than in Yaoundé. This state of affairs could partly be explained by the fact that coverage of socio-collective facilities is less sparse in Lomé, even if it is generally lacking in both cities. In Yaoundé, greater involvement of the private sector makes it possible to reduce the shortcomings of public services in terms of schools for example, through powerful public-private partnerships, to the point where a majority share of the agglomeration's school infrastructure in the agglomeration belongs to the private sector (Patrinos, Barrera Osorio, and Guáqueta 2009, 48; Clarke and Perrot 2012). Here, therefore, less defective coverage could lead to less dependence of property values in relation to this variable.

4.3. Discussion of the method

One of the major challenges of urban studies in sub-Saharan Africa is acquiring reliable data. The method presented in this article allowed for quick and simple collection of the data used as the basis for analyzing property values in two large agglomerations. This is an important methodological contribution in the urban sub-Saharan African context.

However, certain limitations should be taken into account when assessing the results. The first is having chosen the land market as related to the official land registration system (i.e. the experts' estimates are based on the unit prices of lots to which at least one official document is tied). This creates a bias because this virtually excludes the unregistered land market. On the other hand, only considering markets tied to unofficial regimes would exclude city centers and peri-central areas where, depending on the city, a greater or lesser portion of the titled land is located. It is therefore necessary to devise ways of collecting and rendering comparable the land values of different markets, or on a lot by lot basis.

The second point is inherent to the data collection process itself, and reliance on the advice of experts chosen at random. Data reliability was optimized by enlisting as many experts as possible, then checking the consistency and differences in their estimates, and finally combining them using the median rather than the average. Furthermore, while the method can be easily reproduced for several time series analyses to measure future development - a great advantage - relying on experts' memories for data regarding the past would be more difficult, were the ultimate goal to analyze data from a more distant past.

The third point is the use of Voronoi polygons. As the points are not evenly distributed over the territory, the resulting polygons' sizes vary. This limited the type of variables that could be introduced into the model, notably topography (average slopes) and soil type, which can have a significant weight in certain cities. To limit this bias with regard to the variables chosen for this study, we tried to obtain the tightest possible mesh in the collection phase, and then excluded a certain

number of polygons whose areas were too large in the analysis phase. The methodological limits thus discussed constitute avenues for future work on the topic.

5. CONCLUSIONS: POTENTIAL APPLICATIONS OF THE RESEARCH

Ultimately, the aim of this study is to better understand urban planning and management policies in sub-Saharan African cities. In this sense, the potential applications of the method presented are numerous. For instance, it could help in determining land values in order to better manage cities' spatial growth. This could notably be done by anticipating the dynamics of expansion, by studying land market trends, and by developing transportation infrastructure and urban services intelligently, which would help in increasing the compactness of the urban fabric and in preserving natural, agricultural and/or landscaped areas.

The method could also prove useful in terms of measuring the spatial impact of certain laws, policies and/or programs relating to land and urban planning (e.g. the recent law on co-ownership of buildings in Cameroon (law n ° 2010-022), the newly adopted land and state code in Togo (law n ° 2018-005) which introduces important adjustments to land practices, or large road infrastructure programs). Analyzing the land market can help in better monitoring the implementation of such laws and programs. Finally, this method could be of use in better understanding the increase in land value to finance urban management through custom-designed fiscal mechanisms in accordance with the reality of the context. This last point would contribute to greater transparency in managing urban land in sub-Saharan Africa.

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9. KEY TERMS AND DEFINITIONS

Data collection: Implementation of different techniques to obtain information relating to a specific urban issue. It feeds the analyses framework designed to answer a research question or assessing a given situation.

Land market: Set of all transactions such as purchase, rental, sale, exchange, or farming contract, relating to land properties in a given territory. It is structured by the dynamics of land values, legislation and the socio-cultural framework.

Spatial model: A simplified representation of a material or immaterial geographic reality. It could help build an overall understanding, more or less schematic, of the spatiality of a given phenomenon.