Are North African Cities Polycentric or Monocentric? A Space-Time Urban Structure Analysis, Case Study of Algerian City Regions

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Despite the extensive work done on urban structure development dynamics around the world, and the issue being crucial for policy making in many fields, there is a drastic lack of research on the subject in North Africa. Therefore, this paper investigates the evolution of urban spatial structure of the 10 most populated Algerian city regions during the 2009-2019 time period. We use exploratory spatial data analysis (ESDA) techniques, and the fine-grained LandScan population dataset, in order to identify the population centers distribution. We then measure the degree of polycentricity and dispersion to establish the nature of the sampled city regions' urban structure. We consider the morphological definition of polycentricity; a more balanced population distribution between centers implies a higher degree of polycentricity, whereas larger population shares in the centers involve greater concentration. Our empirical results show that North African cities have a polycentric urban organization, as all the study cities have, at least two population centers. The polycentricity and dispersion measurements suggest that cities in North Africa tend to evolve towards decentralization and concentration (they tend to be more polycentric and less dispersed). Our findings shed light on the urban dynamics in North Africa, a region of the world where very little is known scientifically about this issue.

Key words: urban structure, urban development, polycentricity, dispersion, population center, Algeria

Malgré les nombreux travaux réalisés sur les dynamiques de développement des structures urbaines dans le monde, et le fait que cette question soit cruciale pour l'élaboration de politiques dans de nombreux domaines, il existe un manque flagrant de recherches sur le sujet en Afrique du Nord. Par conséquent, cet article étudie l'évolution de la structure spatiale urbaine des 10 régions urbaines les plus peuplées en Algérie, au cours de la période 2009-2019. Nous utilisons des techniques d'analyse exploratoire des données spatiales (ESDA) et les données de population LandScan, afin d'identifier la distribution des centres de population. Nous mesurons ensuite le degré de polycentralité et de dispersion afin de découvrir la nature de la structure

urbaine des régions étudiées. Nous considérons la définition morphologique de la polycentralité ; une distribution plus équilibrée de la population entre les centres, implique un degré de polycentralité plus élevé, alors qu'une plus grande part de la population dans les centres implique une plus grande concentration. Nos résultats empiriques montrent que les villes nord-africaines ont une organisation urbaine polycentrique, puisque toutes les villes étudiées ont, au moins, deux centres de population. Les mesures de policentralité et de dispersion suggèrent que les villes d'Afrique du Nord ont tendance à évoluer vers la décentralisation et la concentration (elles ont tendance à être plus polycentriques et moins dispersées). Nos résultats éclairent les dynamiques urbaines en Afrique du Nord, une région du monde où l'on sait très peu de choses sur la question.

Mots clés : structure urbaine, développement urbain, polycentralité, dispersion, centre de population, Algérie.

Introduction

During the last decades, urban spatial structure has encountered major changes around the world. The issue has sparked global interest in many fields, and much work has been done to illuminate the nature of the changes and investigate their origin (Anas et al. 1998; Musterd and Kloosterman 2001; Parr 2004). Starting from North America, in the early 1980s (Gordon et al. 1986; McDonald 1987; Giuliano and Small 1991; McMillen 2001; McMillen 2003; Lee 2007; Angel and Blei 2016), to Europe (Baumont et al. 2004; Burger and Meijers 2012; Vasanen 2012; Veneri 2013; Salvati and De Rosa 2014; Amiri et al. 2017; Taubenböck et al. 2017; Zambom et al. 2017). Research has also progressed in Latin America (Suárez and Delgado 2009; Fernandez-Maldonado et al. 2014; Aguilar and Hernandez 2016) and Australia (Moghadam et al. 2018), as well as Asia (Sorensen 2001; Sohn et al. 2010; Lee and Shin 2011; Huang et al. 2015; Liu and Wang 2016; Chen et al. 2017; Kim 2019; Yue et al. 2019; Liu et al. 2020; Wei et al 2020.). Thus, a growing body of empirical work has emerged to document the urban changes throughout the world; and polycentric urban structure seems to be the new prevailing organization for human settlements (Bertaud 2004).

Despite rare cases, such as Dijon, France (Baumont et al. 2004), Beijing, China (Huang et al. 2015), and Kumasi, Ghana (Agyemang et al. 2019), the majority of the studies report a clear shift from monocentricity to polycentricity worldwide. This seems to be the case for cities and metropolises in both the Global North (Giuliano and Small 1991; Burger and Meijers; Vasanen 2012; Salvati and De Rosa 2014; Taubenböck et al. 2017) and a few investigated cities from the Global South (Fernandez-Maldonado et al. 2014; Liu and Wang 2016; Li et al. 2018). Cities are changing, and policy makers are trying to adapt their strategies to the new

urban trends (Angel and Blei 2016). Defining, whether an urban structure is monocentric or polycentric is decisive for policy making, all the more so since the urban structure strongly influences daily life.

Indeed, understanding the spatial structure of human agglomerations and their urban growth trajectories is a prerequisite for the formulation of effective policies. Urban spatial structure, defined as the "the spatial arrangement of land use in cities or metropolitan areas" (Chen et al. 2017) has a considerable influence on daily life in multiple fields, such as the economy and social equity (Meijers and Burger 2010; Zhang et al. 2017; Garcia-López and Moreno-Monroy 2018; Li and Liu 2018; Sun et al, 2019), transportation planning (Lin et al. 2015; Zhao et al. 2017; Kim 2019; Li et al. 2019; Jun 2020), health, epidemiology and risk management (Requia et al. 2018; Whitea et al. 2018), environmental monitoring (Chen et al. 2021) and much more. Despite the importance of the urban structure and its strong influence on many life fields, little is known about urban structure dynamics in the developing countries in general and African countries in particular.

Africa is one of the fastest urbanizing regions around the world, and its urban population is expected to represent 21% of the world's projected urban population in 2050 (UN 2014 World Urbanization Prospects), yet there are no studies that provide precise insight about African urban structures, with accurate measures, and quantitative data. With rare exceptions (Agyemang et al. 2019), most studies deal with the issue in a descriptive way, focusing more on the urbanization processes, such as in Dakar (Diop 2007) and Tunis (Oueslati-Hammami 2010).

In order to help fill this gap, this paper provides an exploratory analysis of the evolution of urban spatial structure of 10 city regions in Algeria, North Africa, during the time period 2009-2019, using LandScan dataset. We determine the distribution of the population within urban space, and measure polycentricity and dispersion to unravel the form and nature of the spatial changes occurring in North Africa. Section 2 describes our data and the methodologies used. Section 3 presents the analysis results. In Section 4, we discuss the findings and their implications, while Section 5 concludes, discussing limitations and further research agendas.

Data and Methods

Study Area and Data

The city regions that are sampled in this study are the ten most populated wilayas of the country. A wilaya in Algeria is a territorial public authority[1] that administrates areas of thousands of square kilometers (different urban plans and transportation plans are planned at this level). It is an administrative division of core urban districts and their

surrounding regions, which might contain urban districts (communes), towns, and/or other sub-divisions. A wilaya can be regarded as the equivalent to the prefectural or provincial level of some European countries' administrative division systems and can be considered as intra-city level/city regions. Drawing upon the 2008 census data, (the latest census available in Algeria), our analysis considers the ten most populated wilayas (city regions).

In order to identify the urban structure of Algerian cities and measure the polycentricity and dispersion throughout time, we use the LandScan™ High Resolution Global Population Dataset (2009-2019). The dataset was developed by the Oak Ridge National Laboratory, provides fine-grided population data (approximately 1 km×1 km), and has been used in recent studies on investigating urban spatial structures (Liu and Wang 2016; Li and Liu 2018; Li et al. 2019; Li 2020).

Despite the fact that the dataset might suffer from errors, which can occur in estimating grid cell population, it is extremely advantageous for our study context mainly for two reasons. First, statistical data on population in Algeria are aggregated at the communal level, whereas the LandScan dataset estimates population at a fine spatial level resolution (approximately 1 km×1 km grid cells), and thus enables more fine-grained identification of population centers, and measurement of polycentricity and dispersion; in addition, the analysis is not affected by the administrative boundaries. Second, the data is updated annually; it is convenient for both a real time urban structure identification and a temporal evolution investigation, noting that the latest census made in Algeria dates back to 2008, roughly 13 years ago.

Subcenter Identification

In the literature, there are mainly two aspects considered in the identification of urban structure studies: the morphological dimension and the functional dimension (Burger and Meijers 2012; Vasanen 2012). The morphologically oriented studies identify the spatial distribution of centers and measure their importance (size) (Fernández-Maldonado et al. 2014; Moghadam et al. 2018). The functionally-based research aims to clarify the relationship dynamics between the urban centers based on flow analysis (Kim 2019; Wang et al. 2020; Wei et al., 2020) (see Fig. 1). The functional methods category can be based on commuting flows, mobility flows, goods, information or people flows, and requires important amounts of data. The data necessary for an urban structure identification based on functional approaches is hard to collect for big samples of cities, especially in the developing countries. This is why we have opted for morphology-based methods.

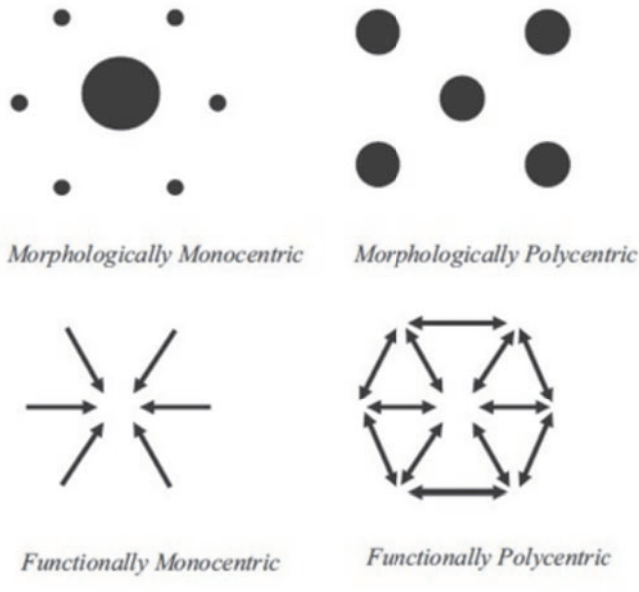


FIGURE 1
Morphological polycentricity and functional polycentricity (Burge and Meijers 2012)

Morphologically oriented research has a wide variety of methods; these can be grouped into four major categories. The first set of methods are the ones based on threshold (cut-off point). One example of this category is the widely used Guiliano and Small method (1991). The major shortcut of this kind of approach is the difficulty of establishing a pertinent threshold value, which requires local knowledge. Moreover, these cut-off points, if found appropriate for a case study, will not necessarily be pertinent for another case, which makes the method unsuitable for comparative studies. In order to overcome the arbitrary definition of the cut-off points, a second category of methods has been developed, density peaks-based methods (McDonald 1987; Craig and Ng 2001; Li et al. 2019). In this second category of approach, the threshold value is endogenously set. The third identification methods category is the residues-based approach, which can be parametric (McDonald and Prather, 1994) or non-parametric (McMillen 2001). This third group generally consists of two step-methods using locally weighed regression; first, a preselection of subcenter candidates is carried out. The second step then consists in measuring the magnitude of the effects of each subcenter on its surroundings; only those with significant influence on the urban structure are considered as subcenters (McMillen 2001; McMillen 2004). Both semi-parametric and non-parametric methods overcome the arbitrariness of a

cut-off setting. This represents a huge advantage in comparison with the first set of methods, but local knowledge is still necessary for both approaches for the interpretation of the results, which makes both categories of methods not suitable for comparative studies featuring an important number of samples. A more recent set of approaches comprises spatial cluster analysis and spatial econometrics-based methods (e.g., Moran's I index) (Baumont et al. 2004; Vasanen 2012) or the kernel density method (Leslie 2010). Since in this paper we proceed on the basis of a comparative analysis on both the temporal and spatial levels, we draw upon Vasanen (2012), Li and Liu (2018) and Li (2020) and adopt the Exploratory Spatial Data Analysis (ESDA), which is highly suitable for comparative studies.

Another aspect to consider for urban structure identification and center detection is attributes choice. Most empirical work focuses on a single attribute (Zhong et al. 2015), such as employment (Giuliano and Small 1991), or the physical built-up environment (Cai et al. 2017; Taubenböck et al. 2017). The attribute is the urban characteristic used as the centrality proxy and is chosen according to the context and goals of each research study. Although the majority of papers investigating urban structure focus on studying the spatial distribution of employment, an important number of papers consider population distribution within urban areas and city regions to detect urban centers (Salvati and De Rosa 2014; Liu and Wang 2016; Li and Liu 2018; Veneri 2018; Li et al., 2019; Li 2020). This attribute choice is of relevance in contexts where urban planning depends greatly on population concentration (Li and Liu 2018). In Algeria for instance, population distribution is a key planning parameter. The planning of infrastructures, public transportation, public services and land use is based on per capita quota. This is why we have opted for the population attribute in the present study.

This study identifies population subcenters using exploratory spatial data analysis techniques (ESDA) that have been used in recent studies (Vasanen 2012; Fan and Myint 2014; Li and Liu 2018; Li 2020). The ESDA-based approach sets uniform criteria for all the sampled cities and makes the results easily understood (Li 2020). For each city and each time period, we use the local Moran I index (Anselin 1995), one of the most commonly used local indicators of spatial autocorrelation (LISA) and spatial clustering technique, to detect local agglomerations of population grids. The method reveals grids that are statistically significant at the 95% confidence level of the local Moran I index, and sorts them into four categories: 1) High/high grids (HH): high density grids that are surrounded by high density grids; 2) Low/Low (LL) grids: low density grids surrounded by those with low density values; 3) High/low grids (HL): high density grids surrounded by low density grids; and 4) Low/High (LH) grids with low density surrounded by grids with high

density values (LH). First, only the HH category grids are selected as potential population centers. Those have a significant influence on their surrounding areas in comparison with HL grids and LH grids. Adjacent grids are then combined, as centers are considered continuous areas. Furthermore, small and insignificant clusters are filtered out from the selected centers. Minimum cut-offs for population size and area size are applied to ensure that the selected centers are of significance. Some papers set the minimum cut-off for a population center at 100,000 inhabitants for the population size, and 3km² for area size: centers should be of 3km² minimum size and contain at least 100,000 inhabitants (Liu and Wang 2016; Li and Liu 2018). Li (2020), on the other hand, lowers the threshold to 2km² for area size and a minimum of 50,000 inhabitants, as he examines the evolution of the urban structure over a period of years, and estimates that a lower cut-off is more relevant for analyzing results in earlier years and comparing them with the later ones. For this study, we consider that a subcenter should contain at least two grids (2km²) and contain at least 2% of the total city region's population at a given time period. This cut-off value is defined in order to make the center selection sensitive to local variations in each area and for each time period. This renders the results more comparable because it sets uniform criteria for all the cities throughout the entire study period.

For the choice of the appropriate spatial weight matrix, we draw upon previous studies, and the reverse of distance weight matrix has been selected, since it yields more robust LISA results than other matrixes (Li and Liu 2018; Li et al. 2019; Li 2020).

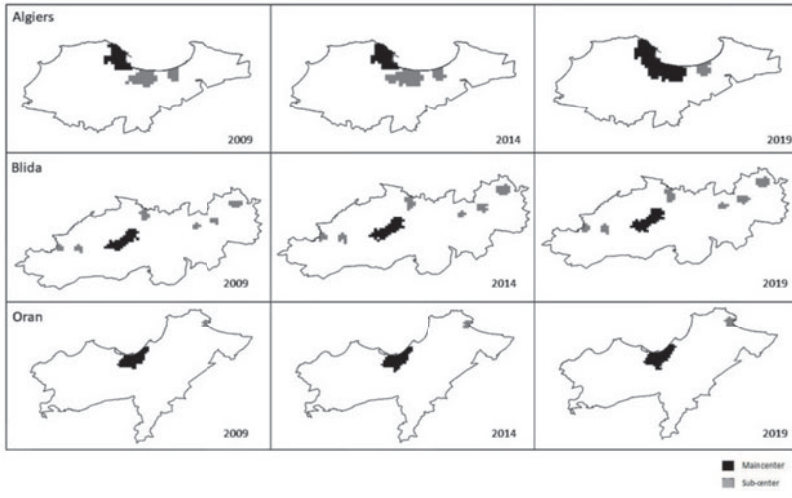
Polycentricity and Dispersion Measurement

Having identified population centers of all the study urban regions, we then use two indicators to measure the urban spatial structure (polycentricity and dispersion) and identify the main spatial trends for the sampled cities (Figure 3).

We measure polycentricity from a morphological perspective (Meijers and Burger 2010): this means that a city region is considered more polycentric if its population distribution is more balanced, and it is deemed less dispersed and more concentrated if a higher share of the population is living in its urban centers. We do so drawing upon Li and Liu's approach (2018), developed based on Green's approach (2007). The morphological definition of subcenters is based on two aspects: the subcenter population sizes and their distances to the main center.[2] Thus, the polycentricity measurement is defined as follows:

$$P = \frac{\delta obs}{\delta max} = 1 - \frac{\sqrt{\frac{\sum_{i=1}^{n}(x_i d_i - \bar{x}\bar{d})^2}{n}}}{\frac{x_{\max} d\max}{2}}$$

FIGURE 2
The evolution of the spatial structure of the sampled city regions

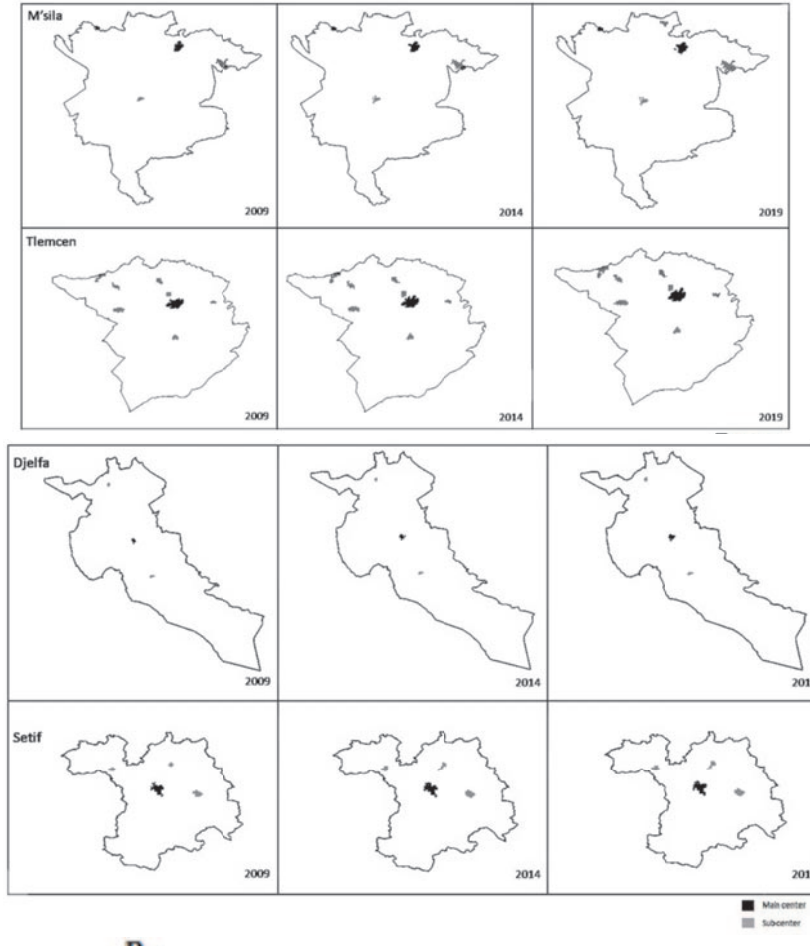


P is the degree of polycentricity of a given city region; σ_{obs} represents the standard deviation of an individual center's importance within a city; σ_{max} indicates the standard deviation of 'importance' in a hypothetical two-center city, where one is the main center with the maximum observed importance and the second has an importance equal to zero. We follow Li and Liu's approach (2018) that considers both the size of the subcenter (x_i) and its distance to the main center (d_i);thus the product ($x_i d_i$) represents the importance of a population subcenter; $x_{max} d_{max}$ define the importance of the main center in a city region; is the average importance of all individual centers, where D represents the degree of dispersion of a city region; P_c and P_T represent the population living in urban subcenters and the total population of a city region respectively.

The higher the values of P and D, the more polycentric and dispersed a city region is. Accordingly, the degree of monocentricity and concentration can also be measured (one minus the respective degree of polycentricity and dispersion).

Results

As mentioned earlier, in order to identify the urban structure of the population distribution throughout the ten most populated Algerian city regions, we have employed the two-step method developed by Li (2020) and Li and Liu (2018), based on the work of Green (2007) and Liu and Wang (2016), using the LandScan data set. Fig. 2 shows the evolution of the population centers of the concerned city regions. The results found



$$D = 1 - \frac{P_C}{P_T}$$

show that all of the top populated city regions have more than one center, which means that they clearly have a polycentric structure.

The population center numbers range from 2 to 8 centers per city region through the period of study (as shown in Table 1), with an average number of centers that went from 4.2 in 2009 to 4.5 in 2019; three city regions (wilayas) saw their center number increase, while the capital city region center number decreased by one, since the CBD has expanded to contain the surrounding secondary center. We do not report any center's location changes or declassification. The proportion of the largest center ranges from 5.98% to 61.49% in 2009 and from 6.16% to 58.63% in 2019,

TABLE 1
Changes in numbers of population centers and the population share of the most important center

City region (listed from the most populated to the least)	Number of centers		Share of population of the most important center	
	2009	2019	2009	2019
Algiers	3	2	22.47%	22.78%
Setif	4	4	15.63%	15.84%
Oran	2	2	61.49%	58.63%
Djelfa	3	3	19.09%	19.16%
Batna	5	5	25.33%	25.42%
Tizi Ouzou	3	5	5.98%	6.16%
Chelef	3	4	14.62%	16.28%
Blida	7	7	29.41%	31.20%
M'sila	4	5	14.65%	14.16%
Telemcen	8	8	23.57%	23.63%

with averages from 23.22% to 23.32% respectively.

The polycentricity and dispersion value results for the year 2009 and 2019 are shown in Table 2. The polycentricity values were between 0.33 and 0.98 in 2009, with an average equal to 0.73; in 2019 the values ranged from 0.38 to 0.99, with an average value of 0.78. Dispersion calculation results extend from 0.35 as a minimum value in 2009 to a maximum value equal to 0.89, with an average value of 0.60. In 2019, the results are from 0.38 to 0.84, with an average value of 0.58. Fig. 3 shows the evolution of polycentricity and dispersion values across the years. The slightly increasing values of P indicate an overall tendency towards polycentricity, while the overall decreasing values of D indicate a general tendency towards concentration.

The results of the temporal evolution show that there is an overall clear tendency towards polycentricity and concentration in population distribution.

According to Fig. 4, we can divide the urban structure of the sampled city regions (wilayas) into two main categories: monocentric-dispersed urban structure (4 of 10 city regions came under this category) and polycentric-compact urban structure (4 of 10 came under this category as well). We also note a strong consistency in the urban structure classification, as eight of ten city regions stayed under the same urban structure type.

Discussion

The main goal of this paper was to find out whether north African cities tend to follow the polycentric urban organization trend observed in most of the Global North's urban systems, as well as in major cities in the Global South (Bertaud 2004; Fernandez-Maldonado et al. 2014; Le

TABLE 2
Polycentricity and dispersion values of the sampled city regions, 2009-2019

City region	2009		2019	
	Polycentricity	Dispersion	Polycentricity	Dispersion
Algiers	0,66	0,53	0,99	0,53
Setif	0,71	0,71	0,71	0,71
Oran	0,98	0,35	0,98	0,38
Djelfa	0,61	0,62	0,60	0,62
Batna	0,76	0,56	0,77	0,56
Tizi Ouzou	0,72	0,89	0,76	0,85
Chelef	0,83	0,75	0,87	0,71
Blida	0,92	0,46	0,93	0,41
M'sila	0,33	0,64	0,38	0,61
Telemcen	0,82	0,47	0,85	0,46

Boennec 2014; Liu and Wang 2016), or if they join a minority of monocentric urban structures (Baumont et al. 2004; Huang et al. 2015; Agyemang et al. 2019). Our findings indicate a clear polycentric urban organization of all the city regions in the case study, as all of them have at least two population centers. The study results corroborate the scientific claims of a global polycentric urban development trend (Bertaud 2004; García López and Muñiz 2010). Indeed, to date very little has been scientifically known about the urban dynamics in developing countries in general and in North Africa more specifically.

We objectively define the urban structure for the ten most populated

FIGURE 3
The evolution of the degrees of polycentricity and dispersion throughout the years

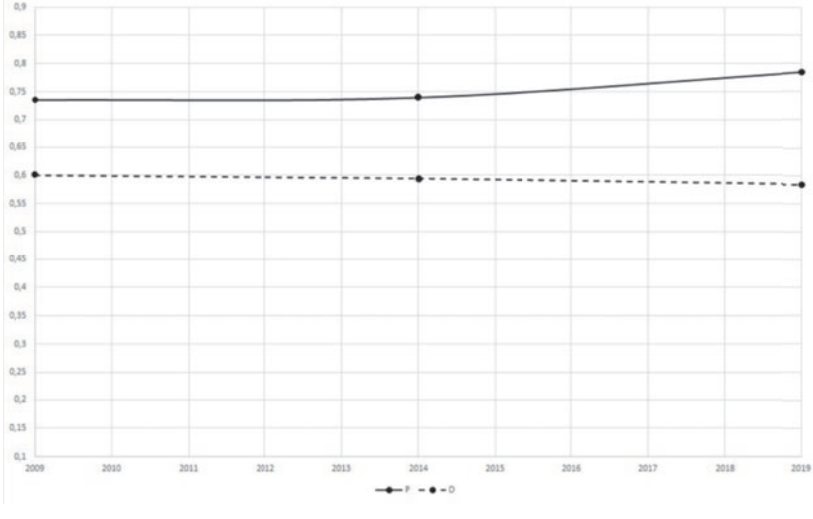
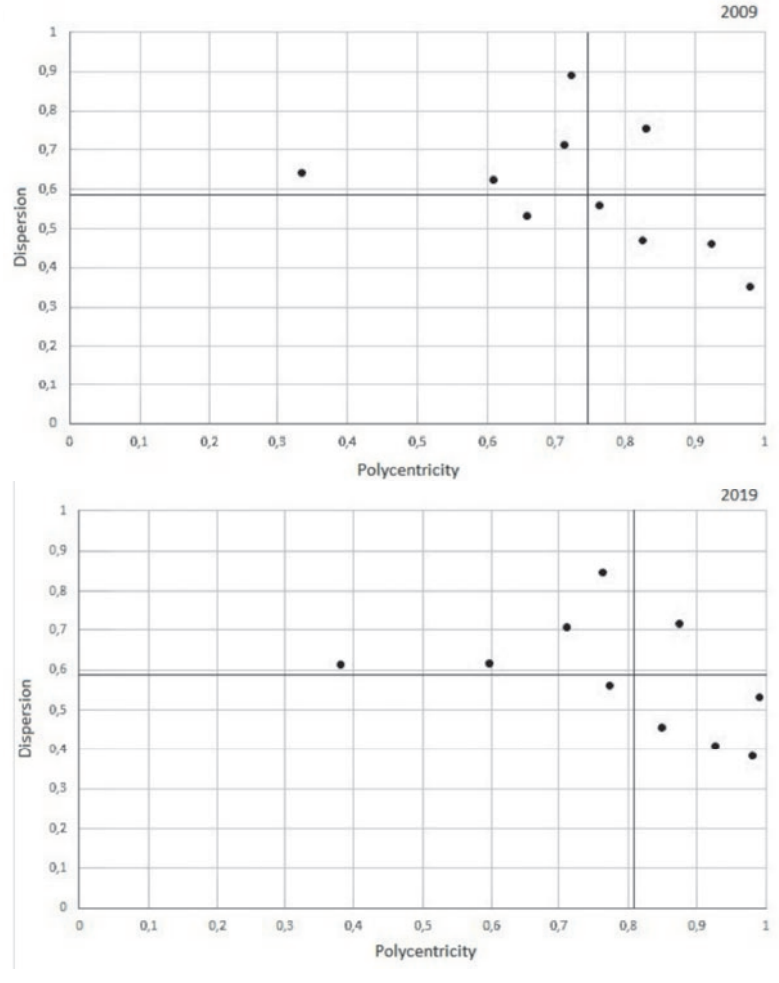


FIGURE 4
Scatterplot of the degree of polycentricity and dispersion in 2009 and 2019



city regions in Algeria, North Africa, using quantitative methods that have worked well for similar political contexts (Liu and Wang 2016; Li and Liu 2018: Li 2020). Our findings constitute an important source of information for effective spatial policy making. Most of the centers are small towns and nearby villages that have developed into population polarizing centers. This is similar to what has been observed in Europe (García López and Muñiz 2006). This resemblance may be due to the influence of the historical urban legacy of the colonial period.[3] We also noted that some centers originated from post-colonial urban policies aiming at decentralization. The political factor of polycentricity is similar to the Chinese context (Li and Wang 2016). Just as in the PRC, the

Algerian government has a strong influence on the urban development trajectories of cities. Another resemblance with the Chinese findings is the general tendency towards concentration and decentralization (Li 2020). Li (2020) reports that these results differ from the North American context and are mainly due to the strong governmental interference in the urban scene, a trait that is shared between the North African context and is predominant in the People's Republic of China.

Conclusion

In this paper, a descriptive analysis of the evolution of urban spatial structure of the 10 most populated Algerian city regions during the period 2009-2019 has been presented. The main purpose was to document the trends of urban dynamics in North Africa, a part of the world where very little is known about the issue, as well as to provide crucial insight for policy making. To establish the distribution of the population centers, we drew upon the methods of Li (2020) and Li and Liu (2018) and used exploratory spatial data analysis techniques and fine-grained LandScan population data. We then measured the urban spatial structure from the perspective of polycentricity and dispersion. The results show a clear polycentric organization in the sampled city regions, which is different from findings in sub-Saharan Africa (Agyemang et al. 2019) in Kumasi, Ghana. North African cities are thus rather similar to the Global North cities (Lee 2007; Burger and Meijers 2012; Zambom et al. 2017), Latin American cities and Chinese cities (Fernandez-Maldonado et al. 2014; Liu and Wang, 2016). As for the polycentricity and dispersion measurement results, they show a general tendency towards decentralization and concentration in population distribution. These results are the same as those obtained by similar research in China (Li 2020).

Shedding such new light on the polycentric nature of the urban structure in North Africa is just a beginning in empirical research, for there is still much to be done in this field. First, future research could investigate the urban structure from an economic point of view, considering employment distribution and business centers, and then compare the results with those obtained in this paper (i.e., a comparison between emitting centers – the population centers - and the polarizing centers - economic centers). This can provide important insights for transportation planners and land use projections. Second, we are yet to find out whether the polycentricity is mainly morphological in North African urban settlements or functional as well. It would also be interesting to dig beneath the influence that the polycentric urban structure might have on daily life in this section of the globe. For instance, does it have environmental and social benefits (EC 1999) or does it generate more inequalities and urban problems in general (García López and Moreno-Monroy 2018)? Although the subject has

been intensively investigated in other places in the world, for the African context the issue is still largely underexplored and much is yet to be done.

Notes

1 Loi no 90-09 du 7 avril 1990, relative à l'organisation territoriale du pays, sur www.joradp.dz, Journal officiel algérien no 90-15, 11 avril 1990, p. 434.
2 The larger a subcenter's population size is and the farther away it is from the main center, the more important it is.
3 Algeria was a French colony (1830-1962).

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