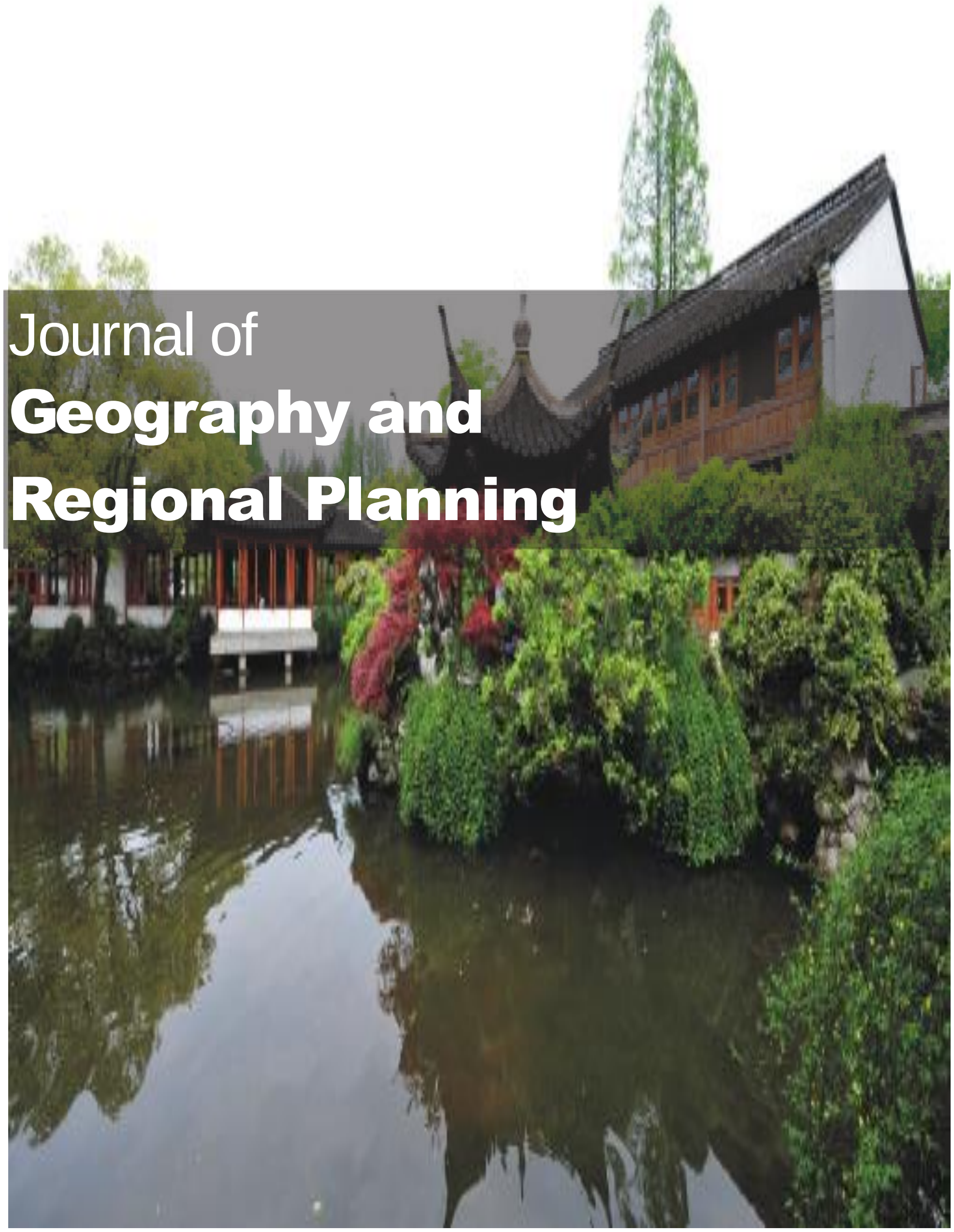

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Table of Content

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Full Length Research Paper

Why populations are not planets_ gravity and the limits of disease modeling by analogy

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Wellness depends on health and that, in turn, depends on the absence of disease. Analogous models based on physical laws have long been utilized by researchers to understand epidemic expansion in urban communities. Perhaps the most significant of this class is the gravity model in which population size is equated with planetary mass and distance between cities to that separating planets. While the model assumes homogeneity among different bodies, cities or planets, in epidemiology the likelihood of disease spread may depend on other heterogeneous, non-constant factors. The study used a public dataset of H1N1 Influenza in 2009 as the focus. A natural log regression was applied in an attempt to sort the relative importance of gravity model variables as predictors of influenza occurrence and diffusion. It was found that while the model population size serves as a general predictor of disease expansion that distance failed as an indicator of disease dynamics. Furthermore, findings from the study show that disease progression was irregular and not, as one might expect from the gravity model, consistent in space or over time. The study concludes that the gravity model may serve only as a coarse predictor of disease expansion over time. By extension, this raises similar questions about other models in which homogeneity between populations or network of populations is assumed.

Key words: Gravity model, H1N1influenza, regression, spatial epidemiology.

INTRODUCTION

In February, 2020, the Wellcome Trust (2020) called for a program of universal data sharing as COVID-19 expanded from a local to a regional epidemic and then became a global pandemic. In response, a series of publicly available, continuously updated “dashboards” providing real-time, continuously updated data on viral incidence were developed. These included both global surveillance programs like the Johns Hopkins University dashboard (https://coronavirus.jhu.edu/map.html) as well as more dedicated, national or provincial data sites, (for example, https://resources-covid19canada.hub.arcgis.com/). Whatever the scale or resolution all included maps of viral incidence as well as the underlying data used in their construction. The result has been an avalanche of data requiring analysis. To that end, various mathematical models have been available to researchers (Kraemer et al., 2019a). Some are based on analogies to physical laws including, in a partial list, the gravity model, another based on radiation diffusion (Simini et al., 2012), and, more recently, a third based on Ohm's 1827 law of electricity (Sallah et al., 2017). Others employ network analytics similar to those used in transportation studies. Finally, some analogize epidemic and pandemic dynamics through reference to natural phenomena like

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like ocean waves (Cliff and Haggett, 2006) and forest fires (Koch, 2016).

Irrespective of the precise methods of analysis, most are “share models” in which a specific product (a bacterium or virus) is shared between places (cities, counties, states, etc.) across a commuting or transportation network. All assume, as a class, a general pattern of transfer, constant and regular, that can be mathematically described based on one or another measure of population size and a system of interchange. Different models emphasize the networks (air, rail, or road) connecting population nodes which serve as data points joined at one or another scale (Kraemer et al., 2019b). What has become increasingly clear, during the current pandemic, is the failure of contemporary models to predict disease spread in a way that will permit regional health planners to anticipate an epidemic outbreak. Thus in the spring of 2020 most assumed Covid-19’s Alpha variant would expand from Michigan and Minnesota, where outbreaks were severe, and then progress across the mid-west. Instead, the disease barely spread to nearby Iowa or Ohio, dying out despite clear transportation and commuter ties. Similar discontinuities were observed in previous epidemics of, for example West Nile Virus (Koch and Denike, 2007) and 2009 H1N1 Influenza (Koch, 2021).

METHODOLOGY

As Cota et al. recently noted, the unprecedented volume of digital data now available requires we “revisit epidemic models, in particular those studying the geographical spread of pathogens leveraging the mobility of hosts” (Cota et al., 2021). Here we take up that challenge through a focus on the Gravity Model in part because its two variables, population or mass and distance between two bodies, are central to many later models. The hope is that the result will both explain the strengths or limits of the approach and, by extension our knowledge of disease modeling. The goal in all this is the ability to plan for epidemic events in specific health jurisdictions. Our approach is two-fold. First, the history of the model and the manner in which it remains widely used in epidemiology and other fields is reviewed. The ubiquity of its basic principles of mass and distance are then noted as characteristics in all share models. Following this we employ the model to consider the utility of its individual elements in a study of the first months of the 2009 Type-A influenza pandemic in the United States. This approach was limited to assure a useful and clear understanding of the merits of the individual components of the model. Alternately, variations of the model, or of different models, might have been applied to the same dataset. However, the question here is not whether one model may be better than another but rather the general structure of the attributes of most share models in which the implicit assumption is one of a homogeneous stability of disease transfer, spatially and temporally, between different nodes within a system. We end by nothing another fundamental limit to this class of models: Where heterogeneity exists, the transfer process and thus the predictive value of the model may break down (Hanes and Fotheringham, 1990). Increasingly, heterogeneity is seen at the local and regional level where specific congregate locations (assisted living and nursing homes, jails or prisons, manufacturing facilities, schools, etc.) create local ‘hot spots’ affecting the rate and intensity of disease expansion.

Gravity model: a history

Rooted in Newton's law of universal gravity, the gravity model is the oldest and best known of this class of models. Perhaps its best known applications are in economic (Anderson, 2010; Mele and Baistrocchi 2012) and transportation studies (Taaffe and Gauthier, 1973, Chapt. 3). It has also has seen heavy use in modern epidemiology and disease studies (Balcan et al., 2009). For epidemiologists, the focus has been upon disease transfer and subsequent expansion in presumably stable populations and across human travel and cargo networks (Kraemer et al., 2019b). Specific applications have included, in a partial list: the 2009 Type A H1N1 pandemic (Balcan et al., 2009; Viboud et al., 2006); Ebola in 2014 (Dudas et al., 2017), measles (Xia et al., 2004), and Zika virus. Importantly, the model’s use of both population size and relative distance, variously defined, are common elements of most models of disease dynamics. In its earliest formulation, Newton's Law described an attractive force between two bodies of different mass based on the distance separating them. Attraction was greatest between larger bodies closer to each other. This was, perhaps, the first expression of what Waldo Tobler famously called the First law of Geography: “Everything is related to everything else, but near things are more related than distant things (Tobler, 1970). In the nineteenth century Ravenstein (1885) used Newton’s law to formulate his "laws of migration" substituting the sum of two populations for that of two planetary masses to be divided by the Euclidian distance separating them. Zipf (1946) applied the model to urban population flows. In recent years, the basic algorithm has been used to analyze everything from cargo shipping patterns (Kaluza et al., 2010) to the inter-city volume of telephone traffic (Krings et al., 2009).

Over the years, a series of modifying additions have been required to fit the algorithm *ex post facto* to specific problems. Since Ziff, for example, a constant typically has been included as a multiplier. In transport analysis, a friction measure may be employed to reflect relative ease of travel in the divisor: Friction (and thus travel time) is greater between places joined by country roads than a highway, for example. In other applications, a population numerator may be modified to reflect general welfare or attractiveness; in retail analysis a numerator might reflect relative income levels to further distinguish populations.

Gravity model: limits

Various researchers have described a range of practical and theoretical model limits to the model's use. First, it lacks a firm theoretical rationale beyond the analogy to Newton's classical planetary formulation (Taaffe and Gauthier, 1973, 97-98). If it works, therefore, the question becomes how, and why. Second, as a deterministic algorithm it does not easily handle a range of observed variations at different scales of address over time. Third, its application may require a series of deterrence functions for it to be fitted successfully to this or that problem dataset (Simini et al., 2012). Fourth, neither its basic population product numerator nor a simple distance denominator are necessarily adequate, easily defined descriptors (Taaffe et al., 1996, 229). Finally, the model assumes homogeneity between population bodies of various sizes.

In disease studies, the analog typically substitutes population size for planetary mass. But while the latter is a precisely quantifiable constant, urban populations are dynamic in nature. On any day commuter traffic may double the population of a large city, reducing that of smaller communities by an equal amount (Badger 2013). As importantly, urban boundaries by which populations are defined are elastic and often defined using different standards (Duncan et al., 1961). For example, the 2010 U.S. Census recorded the population of Santa Clara, CA, as 945,942 persons while its metropolitan population was reported as 1,781,642 persons. Disease incidence reported in the two different jurisdictions were 28 and 337 persons respectively in the first months of the 2009 H1N1 epidemic (Healthmap.org). Finally, as the center of a census-designated Combined Statistical Area (CSA) Santa Clara's population was over 8 million. The latter reflects, albeit loosely, what some describe as the appropriate analytic scale of a modern "megapopulation" defined by expansive, interurban exchange patterns (Nelson and Rae, 2016). Unfortunately, there is no agreement as to which urban definition is best suited to disease studies. Worse, it is typically unclear in disease-incidence datasets the urban definition (city, urban, metro, or regional) in which disease incidence is reported. Some appear indiscriminately to mix city, urban or metropolitan data in their reportage of an outbreak. For this study metropolitan census data was employed for the sake of consistency.

Finally, simple measures of Euclidian distance between urban places, however they are defined, may be insufficient as measures of interaction between population bodies. Distance also may be defined by density of air travel, cargo ship routes, or local commuter pathways in multi-scale urban networks (Balcan and Vespignani 2012). Various researchers have employed cell phone traffic (Exper et al., 2011) or currency circulation as measures of connectivity and distance between places.

Influenza 2009

In our consideration of the utility of the gravity model we employ a dataset describing the H1N1 Type-A influenza pandemic beginning in 2009 in Mexico City. While data on the current pandemic is extensive it is, unlike that of the earlier pandemic, constantly evolving. Furthermore, different regions have different systems of reportage and employ different standards of testing. This makes comparisons difficult. An avalanche of primary research papers using available data, over 17,559 articles published between January and June 20, 2020, has resulted in an unprecedented number of journal retractions of published articles (Yeo-Teh and Tang, 2020).

Data on the 2009 global pandemic, however, has been firmly established (CDC, 2009; Fraser et al., 2009). A novel Type-A (H1N1) influenza virus originating near Mexico City, data on its expansion was broadly reported by both formal (CDC, WHO, PAHO, etc.) and informal (news reports) sources (Brownstein et al. 2010). Despite early reports of high mortality, the case fatality ratio was approximately 0.4 percent (range: 0.3-1.8 percent). The reproduction number (R_o), the number of additional cases one case generates over the course of its infectious period, was 1.46, only slightly higher than that for seasonal flu, for the first wave of the pandemic ending in August, and 1.48 for the second wave (Biggerstaff et al. 2014). Finally, the incubation rate for this virus was between 2 and 10 days with a mean of six days with the infectious period for those affected determined as being between 4 and 7 days.

Data

A Harvard University-based research group, *Healthmap.org*, provides an automated capture network for formal (World Health Organization, the U.S. Centers for Disease Control, for example) and informal data on various infectious diseases (healthmap.org, 2018). The later, typically news stories, usually report the findings of the official organizations. In this syndromic capture system, each row entry includes a location (city, county, and/or country), its location (latitude and longitude) and a data source (typically a URL). For each the number of cases reported or suspected, is then included. Of healthmap.org's multi-year, influenza dataset (2008-2012), 28,866 entries referred to the first wave of the H1N1 global pandemic occurring between April 1 and August 31, 2009 in the United States. To streamline the database locations reporting only one or two "wild" cases" that did not trigger greater epidemic activity were excluded. Similarly excluded, to prevent double counting, were outbreaks reported in prisons, summer camps or schools located in cities or counties that also reported H1N1 influenza outbreaks. The result of this winnowing and consolidation was a set of 87 U.S. locations each with more than 10 confirmed cases in populations—city or county—over 250,000 persons in the first phase of the epidemic.

Based on this dataset, Figure 1 describes the general, spatial expansion of the pandemic in its first weeks. In the first six days of May, 2009, significant epidemic events began in Boston, New York, and Washington in the eastern U.S.; Los Angeles and adjacent San Bernardino County in Southern California; Sacramento in Northern California; Houston in Texas, and Seattle in the northwest. Of these sites only New York City reported confirmed cases in the last week of April, 2009 as the first wave of infection peaked in Mexico City.

Figure 1 Maps the May 2009 pattern of H1N1 Type-A influenza expansion in the continental United States during the first month of what became a national epidemic. All these mapped locations shared US Census-reported populations of greater than 3.8 million persons and a residential density of at least 1,150 persons per square kilometer (https://www.census.gov/quickfacts/). All were directly or indirectly connected to Mexico City by between two and 12 direct and at least sixty, one-stop indirect flights. Data on connections was observed for May 4, 2018 from the website *Expedia.com*. Because historical flight data was unavailable, the assumption was made that flight schedules between Mexico City and continental U.S. cities in 2018 reflected similar travel patterns during the earlier epidemic period.

In the second week new outbreaks were reported in San Diego, CA; Atlanta, GA; Detroit, MI; and Arapahoe County near Denver, CO. In addition, outbreaks in the Northern and Southern California areas expanded to nearby cities. In the third week, further outbreaks appeared in Miami, FL, Dallas, TX, New Orleans, LA, and along the northeast corridor. By the end of the fourth week, major outbreaks were reported in Chicago, IL, and Milwaukee, WI. In addition, smaller outbreaks were reported in an increasing number of smaller communities elsewhere across the United States. As the epidemic continued an every larger number of communities reported influenza cases; in larger cities a second wave of infection after August 29.

RESULTS

Analysis

Others have used two different distant measures in gravity-based simulation models of the 2009 influenza epidemic (Balcan et al., 2009). The first was a long-distance transfer function based on airline traffic data, the second used local or regional commuter flows. To these were added in both cases a power law function modifying distance parameters as well as proportionality constants for populations joined in a multiscale network. An attempt at redefining distance at two scales and with two travel modes in a stochastic model suffered from several limits.

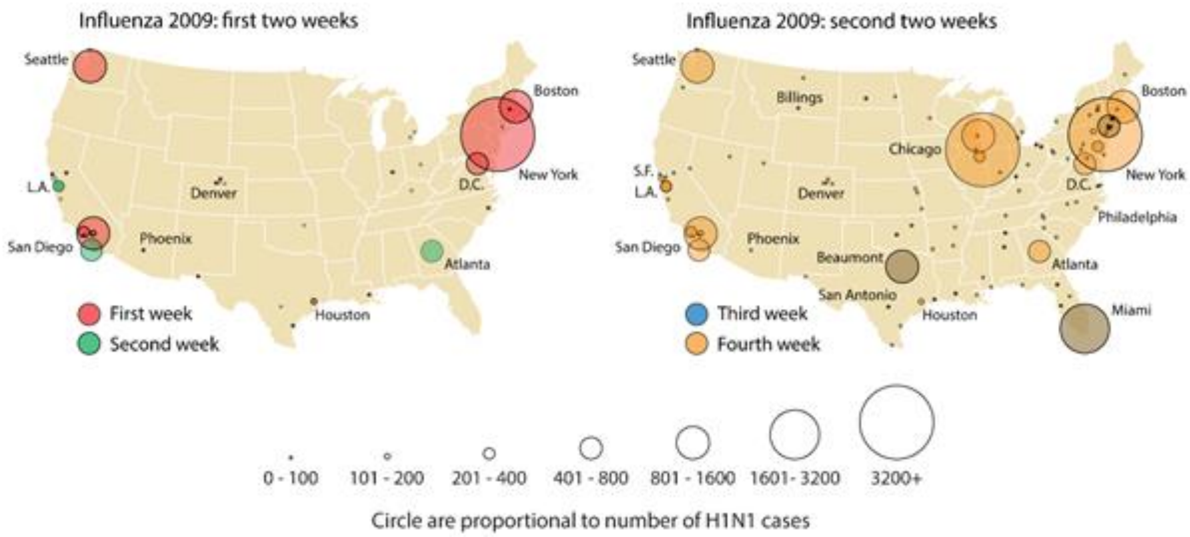

Figure 1. Pattern of H1N1 Type-A influenza expansion in the United States.

First, a focus on airline network travel data to major cities made difficult any clear understanding of semi-independent or independent transfer processes between primary centers (Boston, NYC, Washington, for example) and secondary locations (from New York City to Buffalo, NY, for example). Second, there was no acknowledgment of the different ways city populations are defined (were these local, metropolitan or regional population figures?). Third, there was no consideration of the potential for disease transfer by land travel across borders, especially in those states boarding Mexico where volumes of commuter and commercial exchange were likely to have been a source of viral transfer. To consider the utility of the gravity model we created a database of target city populations and their distance from Mexico City. As a first step, we then assessed a determination of fit by transforming the gravity model to a linear form and then calibrated its variables (population and distance) through a multivariate linear regression applying a natural logarithmic transformation

To test the applicability of a multifactorial regression in this program we applied a Durbin-Watson test resulting in a very robust 1.985 result, admirably close to the accepted benchmark for larger data sets. This indicated that autocorrelation (also called serial correlation), often a confounding issue in spatial analysis, was not a concern. The resulting normal distribution of residuals returned an Analysis of Variance very significant at the .000 level. Finally, Model R (.612) and the adjusted R Square of .375 were better than reasonable first approximations of viral transmission.

Figure 2 shows the high degree of concurrence between observed and expected cases resulting from a log natural linear regression based on the components of the gravity model. Cases were those reported by helathmap.org in the early weeks of the American epidemic. We then sought to test the effect of each independent variable on the pattern of disease transmission by fitting a linear regression line to a partial regression plot for each. If the model was to be useful, we reasoned, the variables would individually serve as at least partial explicators of disease transmission. The partial regression plots for the dependent variables revealed, however, that only metropolitan population was relevant independent. Distance from Mexico City was surprisingly irrelevant as a single explanatory element in the epidemic's progression. This can be seen in Figures 3a and 3b where regression lines were fitted to each of these variables. In the first, a R square fit of 0.375 indicated population size was a generally robust predictor of disease incidence. In contrast the slope of R2 linear slope of 2.835 E-4 in Figure 3b suggests distance from Mexico City was a largely inconsequential and thus confounding variable. That was critical if one assumes distance reflects a measure by which transfer occurs through population exchange. In Figure 3b high degree of concurrence is shown between population size and a natural log of cases while, in Figure 3a, no such relationship exists for distance of target cities from the origin spot of the epidemic.

Heterogeneity

Since Euclidian distance was an unreliable divisor we considered substituting air travel links between the origin site, Mexico City, and U.S. population centers. Others have reported major international cities receiving more than 1400 passengers from Mexico City during the earliest stages of the epidemic were at markedly increased

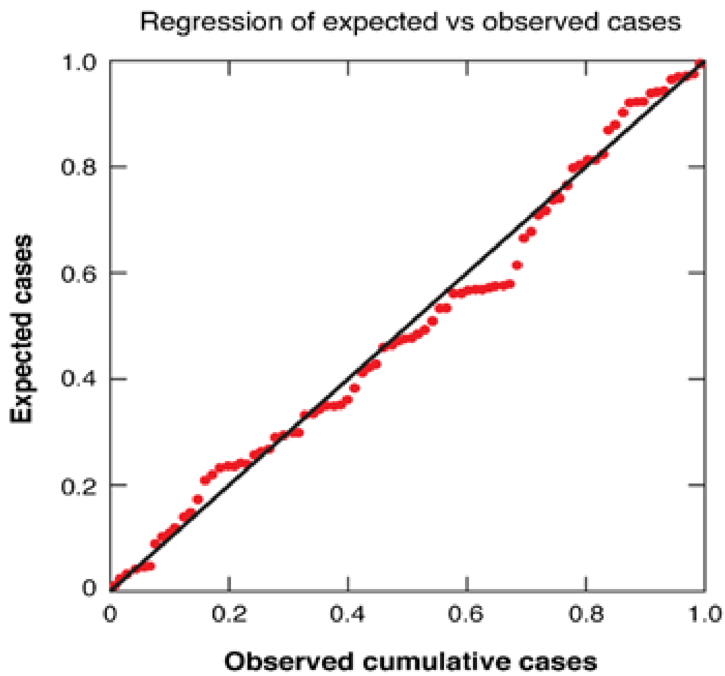

Figure 2. Degree of concurrence between observed and expected cases.

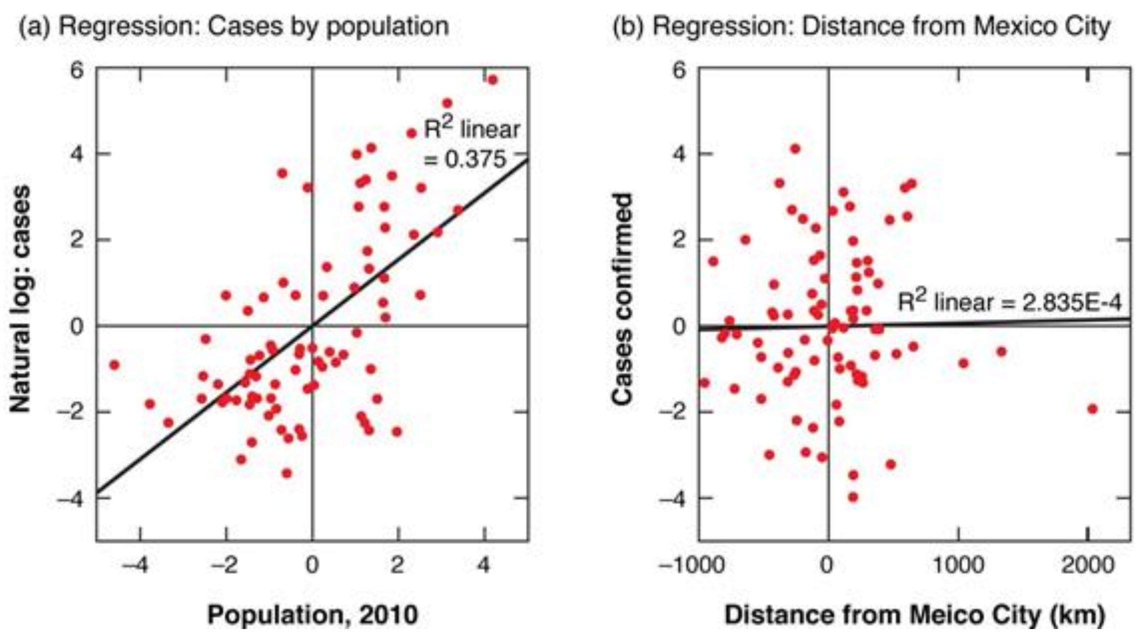

Figure 3. Regression: (a) cases by population; (b) distance from Mexico City.

risk of H1N1 transfer (Khan et al., 2009). Given an average Boeing 767 airplane at full capacity of 240 international passengers this would be six planes a day. Passenger volumes did not, however, serve as a simple distance substitute. In the first week in the US the number of direct flights from Mexico included: Boston, MA (2 Flights), Houston (11 flights), Los Angeles, (16 flights), New York City (12 flights), San Francisco/San Bernardino (11 flights), Seattle, WA **(**7 flights), and Washington, DC (3 flights). Significant but smaller cities with six or more direct flights daily first reported viral activity in the second week: Chicago, IL (6 flights), Atlanta, GA, (10 flights), and Dallas, TX (11 flights). And yet, Miami FL, (2010 pop. 5.56 million persons) did not report an early outbreak despite both relative geographic proximity and the frequency of direct flights from Mexico City (14). As the epidemic expanded, it included cities and towns with increasingly tenuous air connections either to Mexico City or principal U.S. foci (NYC, LA, etc.). Similarly, while urban population was a useful general predictor it was in itself insufficient to explain fully the pattern of disease expansion. For example, Boston, MA and Atlanta, GA are comparably sized, metropolitan cities. US Census data reported Boston's 2010 population as 692,600 persons and Atlanta's as 420,003 persons. Metropolitan populations reported were far higher, of course with 4,628,910 persons reported resident in metropolitan Boston and 6,020,964 in Atlanta. And yet, the outbreak began earlier in the former than the latter despite its far greater distance from Mexico City (3,670 miles vs. 1,792 miles).

Here the problem of heterogeneity among locations became critical. It is possible that the introduction of influenza to Boston resulted less from an influx of infected travelers from Mexico than commuting and travel volumes between it and New York City. Similarly, commuter travel volumes between New York City/Boston and Washington, DC. (Pop. 5.6 million in 2010), may better describe the latter's early epidemic onset than either travel volume from Mexico or metropolitan size alone**.** The early introduction of H1N1 influenza to Seattle, WA, with a city population in 2010 of 608,660 persons, is not easily explained with reference either to population size or the limited number of direct daily flights from Mexico. Airline intercourse with Los Angeles and San Francisco may have been a factor, however. But of greater importance may have been that May is the month in which many of Washington State's estimated 185,000 seasonal workers, primarily Mexican and Central American, arrive through Seattle to work in the state's agriculture industry. This would have increased the inflow of potentially infected if still asymptomatic persons who, working and living in a high density environment, likely would have accelerated viral activity.

In the same vein, the delay until the third week for a major outbreak in Miami, FL, seemed problematic. The frequency of daily flights from Mexico City, Miami's relative proximity to Mexico, and the presence of a large Latino population would have argued for an earlier and more virulent epidemic expansion**.** While its 2010 population was only 399,457 persons, that of Miami-Dade County was far higher (2,498,018 persons). However, South Florida's Spanish-speaking population is largely Puerto Rican and Cuban, not Mexican or Central American. It is therefore probable that direct flight passengers from Mexico used Miami not as a destination but a brief, first stop in travel to other locations.

DISCUSSION

What appears to have emerged was a kind of nested hierarchy (Balcan and Vespignani, 2012); in which H1N1 expansion began in a small set of international cities hosting frequent air travel from Mexico City. These cities became independent or semi-independent foci for epidemic expansion to secondary and then tertiary cities with few if any links to the origin site. This expansion occurred across secondary exchange networks among relatively proximate, and later, more distant metropolitan centers in the US. Population size appeared to be an at best coarse descriptor of attraction. The result was not one of a consistent attraction but one resulting, at least in part, from local characteristics and circumstances. These include, for example, the dynamic effect of commuting traffic on the size of a city population. For example, New York City's resident population doubles in size on a normal workday as suburban workers enter the city (Badger, 2013). The populations of commuters' home cities decreased by a similar amount. Population itself thus becomes a dynamic variable, not a constant. In addition, within each city the likelihood of viral expansion was dependent not only on size, and transmission by commuters or travelers, but the presence or absence of congregate locations (jails, manufacturing plants, schools, summer camps, military bases, etc.) in which once introduced a respiratory virus might spread. This was evident in a study of the 2009 H1N1-Type Influenza database employed in this study (Koch, 2020, 8) and, again, in the expansion of Covid-19 in 2020-2021. Thus, the national expansion of H1N1 influenza resulted from not one gravitational process but a series of distinct if related dynamics, including population and exchange patterns, involving a broad set of heterogeneous places. Perhaps the best analogy is hydrologic in which waterways are ordered in z hierarchical design frame in which data independence for each place is not assumed. Refining that observation and applying a hydrologic perspective to disease expansion will be the subject of a future report.

Conclusion

This is not to argue the gravity model should be abandoned. "Attraction" remains a powerful and useful concept. Care must be taken, however, in defining the populations of related urban populations employed in its calculations. Further, the nature of cargo, commuting, and other travel networks linking populations of different sizes and at different distances provides a complex mix of interactive volumes any (or all) of which may affect the date and rate of bacterial or viral introduction and potential expansion. One simply cannot assume that homogeneity exists among various populations at all scales, or that all places within a network are equal. Nor will a single measure of distance or connectivity (work flow, for example) necessarily serve as a simple measure. It is thus unlikely that a single algorithm will fully describe or predict disease expansion within a nation or at a different scale its individual regions. There is therefore an obvious need for further research both based on heterogeneity and the specifics of resident populations and the means by which this or other models, with different variables, might better serve to predict patterns of disease expansion. The next stage in this study for us will be to examine the manner in which this virus was transferred over time between primary foci, NYC, Boston, Los Angeles, and heterogeneous secondary exurban and suburban populations. The goal will be to more precisely define the appropriate scale of analysis as either urban, metropolitan or region, and to consider the extent to which local differences affected the rate of disease expansion and the severity of an epidemic event.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Public green spaces and management constraints in the Municipality of Seme-Podji South East of Benin

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An increasingly present component in urban architecture, public green spaces is an essential infrastructure that has various functions. The management of these spaces poses enormous difficulties after their establishment. The study has analyzed the uses and management of these spaces in the Municipality of Sèmè-Podji. It was carried out on the basis of a sample of 84 people made up of users and managers of green spaces, heads of neighborhoods or villages, heads of districts and officials of the Technical Services Department of the Town Hall. The thirty-three (33) green spaces still functional in the Municipality were visited. These are unevenly distributed between the districts and that of Agblangandan has the largest number (12). The density of green space in Sèmè-Podji was 0.132 green space/km^2 in 2018 against 0.02 in 2017, which remains low. Very frequented by young people (58.15%), the green spaces serve as places of leisure, rest, maintenance sports and are home to small shops. They are managed by the town hall, by local elected officials, or entrusted to individuals who, in return, pay royalties to the municipality. Poor infrastructure coverage and maintenance which generates visual and olfactory pollution according to 97.94 and 86.90% of the target population. Besides, the lacks of innovation in the activities offered to the public are the main constraints to the management of green spaces in the Municipality of Sèmè-Podji.

Key words: Sèmè-Podji, public green spaces, management, constraints.

INTRODUCTION

The concept of green space covers a wide variety of facilities. These can be public gardens, children's play areas, animal parks, and botanical gardens, walking circuits, fitness trails, sports stadiums and fields, family gardens, cemeteries (Muret et al., cited by Amireche, 2012:38). These spaces meet the needs of escape, isolation, relaxation, clean air for city dwellers, a growing attraction for nature. They are necessary for the city as a purifier of the atmosphere, a ventilator of the urban coating and essential for human life, through their beneficial influence on physical and moral health. However, during these decades, cities have developed by ignoring the nature that surrounds them.

More sustainable cities call for the development of public spaces (green spaces, public places, parks, etc.), the management of which is often part of an urban

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forestry program. These infrastructures can be a tool for structuring the urban area according to the density of vegetation and their attractive capacities (Marry and Delabarre, 2011:28). In addition, beyond the scientific issue, knowledge needs are formulated by land managers and planners for optimal and balanced management of green spaces (Pullin and Knigth, 2005:1993).

Several African cities have experienced uncontrolled demographic growth in recent decades and will house 60% of their country's populations in 2025 (UNFPA, cited by Tohozin and Dossou Guèdègbé, 2014:192). This strong human pressure coupled with space constraints is a major concern for these city managers, who are now looking for effective methods to offer city dwellers an ideal living environment while maintaining the city in its main functions (Osseni, 2013:75). This explains the proliferation of public spaces also called green spaces.

Since their creation, these public green spaces have always been privileged leisure places in the daily life of the populations; and are in very high demand. The innumerable activities undertaken in public green spaces include commerce, relaxation, celebration, meetings etc. A strong social unity is thus created within these places which takes into account all social categories and socio-cultural groups (Tchaou, 2014:7). This is indeed where one usually meets strangers, where one expects to meet mostly them (Monnet, 2012:201). Grafmeyer (2004:104), space is only public if it is open and accessible to everyone and is assigned to several functions and uses common to city dwellers. It is a space for meeting, exchange, communication and socialization in the image of the city.

Despite the various benefits of green spaces, their establishment in the Municipality of Sèmè-Podji has not kept up with the evolution of the population and there is a spatial disparity in their distribution. Likewise, the quality of these spaces sometimes leaves much to be desired, thus testifying to inefficient management. The question that arises is therefore to know: what are the uses and management constraints of green spaces in the Municipality of Sèmè-Podji. Therefore, the objective of this study is to highlight some of the uses and management constraints of the said spaces in the Municipality.

MATERIALS AND METHODS

Presentation of the study area

Located between the parallels 6 º 22 'and 6 º 26' North latitude and the meridians 2 º 27 'and 2 º 42' East longitude, the Municipality of Sèmè-Podji is located in the County of Ouémé, in the South-East of the Republic of Benin on the Atlantic coast. It is bounded to the north by the city of Porto-Novo and the Aguégués, to the east by the Federal Republic of Nigeria, to the south by the Atlantic Ocean and to the west by the city of Cotonou (Figure 1).

The Municipality covers an area of 250 km2, which is about 0.19% of the area of the Republic of Benin, and includes the Districts of Agblangandan, Aholouyèmè, Djèrègbé, Ekpè, Tohouè, Sèmè-Podji. In total, it has fifty-five villages and city districts.

Materials

The material used consists of a topographic map of Porto-Novo from 1992. It comprises of sheets NB31XV2c and NB31XV4a at a scale of 1 / 50,000 with shape files and a cadastral plan at 1 / 10,000 from 2010. In addition, Garmin 76csx GPS (Global Positioning System) for taking the geographic coordinates of green spaces in the Municipality of Sèmè-Podji has been used.

Field survey method for a management mode of green spaces

An exploratory visit to the sites in the Municipality revealed that it has around fifty green spaces, of which only 33 are actually in use and under developed. The research focuses on the 33 spaces. A survey on the current management mode of green spaces was carried out among all the concerned stakeholders identified in order to be able to characterize them. A questionnaire is administered to collect information related to the uses and management of green spaces.

A random survey method made it possible to question a sample of fifty-five (55) users of green spaces. In addition, eighteen (18) Neighborhood / Village Heads, two (02) District Heads, seven (07) space managers and two (02) officers from the Technical Services Department of the Sèmè-Podji Town Hall were interviewed.

The examination of the survey sheets was done manually. Special codes have been assigned to each collected data in order to facilitate the groupings and analyses. The diagrams and curves were produced with the Excel spreadsheet to represent the quantitative data. The response rate by type of information was expressed by the following formula:

$$T = \frac{n \times 100}{N} \quad (1)$$

With: T = rate of responses given; n = number of responses obtained in relation to the information sought and N = number of people interviewed.

The density of the Municipality in green spaces is calculated according to the formula:

$$DEv = \frac{nEv}{Scom} \quad (2)$$

With: DEv = density of green spaces in the Municipality; nEv = number of green spaces in the Municipality (33); Scom = total area of the Municipality (250 Km2).

The results of the surveys largely contributed to identifying the weaknesses in the management mode of green spaces, then the sites' attractiveness and sustainability parameters.

RESULTS

The results of the study addressed three different aspects, namely: diversity and density of green spaces in the Municipality of Sèmè-Podji, use, and management of green spaces.

Diversity and density of green spaces in the Municipality of Sèmè-Podji

The green spaces in the Municipality of Sèmè-Podji are

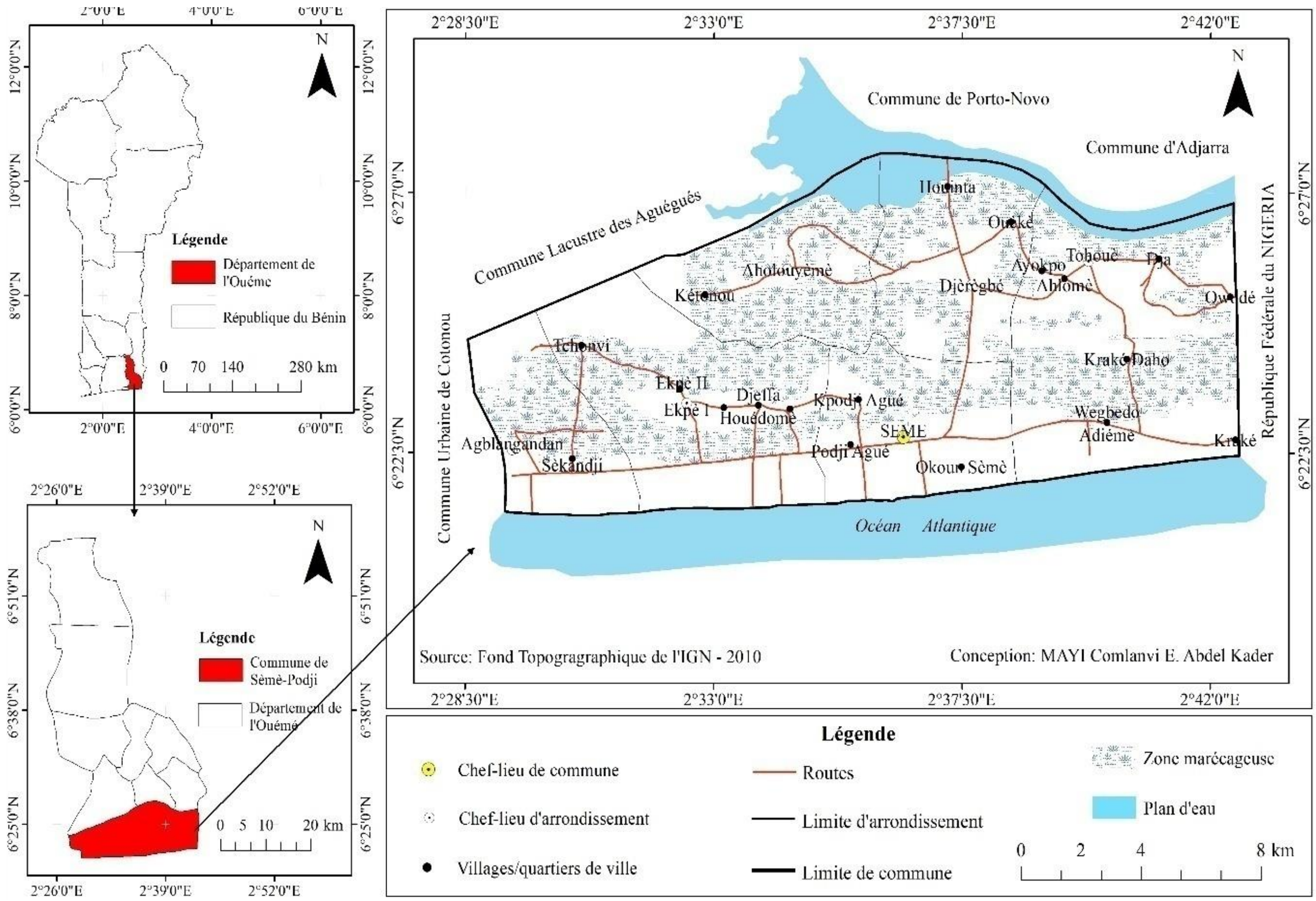

Figure 1. Geographical and administrative situation of the Municipality of Sèmè-Podji.

made up of Youth and Leisure Centers, developed junctions and war memorials. During the surveys, a total of thirty-three functional green spaces were identified in the Municipality and distributed as shown in Table 1.

The districts of the Municipality of Sèmè-Podji have a variable number of public green spaces. Agblangandan with a workforce of 12 mobilizes 36.36% of these spaces, followed by Ekpè (9 spaces, which are 27.27%). On the other hand, the districts of Aholouyèmè (03), Djèrègbé (04), Sèmè-Podji (03) and Tohouè (02) have less green spaces. There is an unequal spatial distribution of the green spaces within the district to which various historical, social, economic, political, recreational and cultural functions are linked. The entire population is also unable to enjoy the benefits of these infrastructures because of the disparity in their spatial distribution. In fact, not all neighborhoods have these spaces in each district. Figure 2 illustrates a spatialisation of some green spaces in the Municipality.

The density of green space in the Municipality of Sèmè-Podji is 0.132 green space / km2. The density also varies from one district to another depending on the number of space available and the area of the district. This low density is explained by the little investment in the development and management of green spaces despite the size of the population and the geographical and strategic position of the Municipality. The green spaces of the Municipality are used for various purposes by the population.

Use of public spaces in the Municipality of Sèmè-Podji

The green spaces of the Municipality do not all have the same configurations and functions. They are spaces of very high demand frequented by the population for various reasons.

Based on the survey, accessible to all, these spaces are frequented by all layers of the population; 58.15% are young people, 36.25% adults and 5.6% senior citizens. They come there for leisure (entertainment, events, games, meetings, etc.), rest, and take advantage of the space to learn lessons or to practice maintenance sports

Table 1. Distribution of public green spaces according to their functions by District in the Municipality of Sèmè-Podji.

District	Public green space	Function
	Sèkandji Youth and Leisure Center	Economic, political and recreational
	Lokokoukoumè public square	Political, recreational and cultural
	Houngakomè public square (Davatin)	Cultural and recreational
	Le Bélier junction	Economic and political
	Sèkandji junction	Economic and political
	Akpokpota	Cultural
	Kpakpakanmè	Cultural
	Kajacomè	Cultural and recreational
	Modokomè	Cultural
	Agbalilamè	Economic and cultural
	Gbakpodji	Cultural and economic
	Agblangandan	Cultural and economic
	Ginsame public square	Cultural, political and recreational
Aholouyèmè	Sokpanou	Cultural, political and recreational
	Aïtchémi-Honto	Cultural, political, recreational and economic
	Agbodamè public square	Cultural
Djèrègbé	Gbehonmè Entertainment Room	Cultural, political and recreational
	Hontogbo public square of Awanou	Cultural, political and recreational
	Djèho	Cultural
	PK 10 junction	Cultural and recreational
	Ekpè youth center	Economical and recreational
	Zangbétô-vadji	Political and economic
	Ekpè station	Social and economic
Ekpè	Djeffa station	Social and economic
	PK 18 or Road Junction	Social
	Fâ-Flé Sagbohanton	Cultural, political and recreational
	Ekpè Youth Center (Agangbo 2)	Cultural, political and recreational
	Kanhonou	Cultural, political and recreational
	Sèmè-Podji Youth and Leisure Center	Cultural, political, recreational and economic
Sèmè-Podji	Memorial	Historical, political, social and recreational
	Sèmè-Podji junction	Economic et social
Tohouè	Kraké Daho public square	Cultural, political and recreational
	Zanhôde Tohouè public square	Cultural

Source: Fieldwork, March 2018.

Some go there to carry on small businesses. These spaces therefore represent places of entertainment, development and socialization for the population of the Municipality and elsewhere. Based on the survey, most of the users (85.45%) are residents of the Municipality and the remaining, in transit to other neighboring Municipalities or the Federal Republic of Nigeria. The pictures on Plate 1a and b show some uses of green spaces.

Green spaces, beyond their recreational functions and apart from the fact that they offer an ideal setting for rest (Figure 2) are also used for gatherings of public interest such as population censuses (Figure 1).

The choice of frequented space depends on several factors such as distance, the quality of the setting and what you can or want to do there. In terms of period, afternoons, weekends and public holidays are the preferred times of attendance. The crowd is less in the morning, or even zero in some places. The green spaces of the Municipality have different management modes.

Figure 2. Spatial distribution of public green spaces in the Municipality of Sèmè-Podji.

Management of green spaces in the Municipality of Sèmè-Podji

Patrimony of the Municipality, green spaces is managed with difficulties, the main links of which are presented here.

Management modes of green spaces

Since the advent of decentralization and the adoption of Law No. 97-029 of January 15, 1999, on the organization of Municipalities in the Republic of Benin, local authorities have the power to manage the resources at their municipalities themselves. This is the case, for example, with green spaces which, in the Municipality of Sèmè-Podji, are placed under the authority of the Municipality. However, their management also falls within the prerogatives of the Water and Forests Inspectorate. In practice, the Town Hall has opted for delegated management of all or part of certain spaces by entrusting them to individuals or to privates who have fitted them out. It is the case for example of CIM-BENIN for the Le Bélier junction and Sèkandji, and Houdégbé for the PK 10 junction.

In the case of delegated management, the new manager develops and operates the space, assumes responsibility for the maintenance and pays a monthly fee

Plate 1a. Population in Lokokoukoume square for a census.

Plate 1b. A young man resting on a bench.

of around 30,000 F CFA to the Town Hall. The rentals of youth houses or centers for meetings, ceremonies and others generate income as do commercial activities (bar, catering, cafeteria and shop, etc.) carried out by

Plate 2a. Rubbish littering the ground.

individuals in these spaces.

When the space is directly managed by the Town Hall, a manager is appointed. This is the case with animation rooms, youth houses and centers. For neighborhood public squares, they are managed by the neighborhood chiefs assisted by the council of elders and young people.

According to the municipal authorities, the resources collected are reinvested in the development of the Municipality. However, the management of green spaces in the Municipality is not without challenges.

Difficulties in managing green spaces in the Municipality of Sèmè-Podji

Apart from the non-qualification of managers if they exist, the main constraints to the management of green spaces in the Municipality of Sèmè-Podji are the poor infrastructure coverage, the numerous failures in the maintenance of these spaces and the lack of innovation in the activities offered to the public.

Poor infrastructure coverage

Different infrastructures are essential for the viability of green spaces. These include, depending on the case, benches, lighting equipment and hygiene and sanitation infrastructure (garbage cans, runoff drainage pipes and urinals).

According to 88.09% of respondents, green spaces lack enough benches to accommodate users. They estimate (at 53.57%) that these spaces are poorly lit and not at all lit according to 26.19%. Indeed, the few solar street lights erected by the Municipality on certain spaces have been vandalized and are not replaced. The poor coverage or even the absence of lighting infrastructure forces the population not to visit green spaces beyond a certain time in the evening due to insecurity.

None of the green spaces in the Municipality have garbage cans and only seven (7) out of the thirty-three (33) have urinals, although this is not always necessary as is the case with junctions. Based on the survey, the runoff drainage pipes are non-existent.

All these shortcomings testify to the lack of awareness of the importance of green spaces for the well-being of populations in a rapidly expanding urban environment.

Nuisances in green spaces

The lack of maintenance and especially the resulting insalubrity is one of the main problems facing the green spaces of the Municipality. Due to the lack of sanitation infrastructure (garbage cans, urinals, water drainage pipes) and staff dedicated to maintenance, on the one hand, and inappropriate behavior by users, on the other, the green spaces of the Municipality present an unsanitary appearance (Plate 2a and b).

Plate 2b. Akpokpota green space on the memorial of Sèmè-Podji flooded with water.

Plates 2a and b show respectively the unsanitary conditions of the Sèmè-Podji Memorial and Akpokpota Green Spaces, which are considered cultural spaces.

One of the direct consequences of poor waste management is the visual and odor pollutions. According to 97.94% of the survey respondents, visual pollution is the result of the degradation of the physical environment through the presence, among other things, of waste of various types. This form of pollution denatures the space where cleanliness should normally reign. The unsanitary conditions caused by garbage are manifested by the presence of spontaneous piles of garbage and herbs gathered here and there which become open-air dumps and which keep multiplying. On these dumps, one can observe papers of various origin, dead leaves, and plastic bags sometimes containing remains of food, drinks or water, rotten fruits, and broken bottles. So, many heterogeneous objects that should not be found in such spaces.

Another type pollution is criticized by 86.90% of the targets stems from the presence of decomposing waste on the perimeter or near green spaces, as well as the lack of sanitation infrastructure, especially urinals; which leads users to urinate all over the green spaces. The presence of waste attracts insects (flies, cockroaches) and animals (rats, mice, etc.) and can harbor pathogenic germs and parasites. As they putrefy, they give off bad odors that indispose and vitiate the atmosphere. Odor pollution is especially repugnant in intense heat. Under these conditions, users can no longer breathe well.

According to 67.86% of users interviewed, poor maintenance is the determining factor in limiting their visits to the spaces. In fact, the unsanitary space no longer meets the expectations of a population in search of healthy places to breathe fresh air, relax or play maintenance sports. It is therefore essential to properly manage the environment in order to improve the living environment and protect oneself from nuisance and disease.

Lack of diversification in the activities offered to the public

One of the strengths of green spaces in creating more attractiveness is that they can offer various fun and educational activities to populations. In the Municipality of Sèmè-Podji, this is not the case. Most of the green spaces managed by privates are exclusively transformed into refreshments or restauration places. Apart from youth houses or centers which host some cultural activities, no initiative has been taken to create attractiveness in these places. Worse, on weekends, these spaces are occupied for festive events, which prevent some users from having access to them. This phenomenon is also decried by all the respondents. This is why 69.05% of users want these spaces to offer a variety of activities to the public.

DISCUSSION

Urban development requires the establishment of a certain number of infrastructures (health, education, social, leisure, etc.). Green spaces are part of leisure infrastructure and therefore occupy an important place. Every man at a given time needs rest, distraction, and leisure. Green spaces to some extent meet these needs.

Quantitatively, the Municipality of Sèmè-Podji has more green space than the city of Porto-Novo, where 13 green spaces are identified by Tohozin and Dossou Guèdègbé (2014:195), but less than Cotonou with its 70 spaces.

The present study and several other authors have shown the disparities in the spatial distribution of green spaces in the different Municipalities.

As explained by Tonde (1994:28), through its definition, the role assigned to a green space is very important. This explains its high attendance. It must contribute to improving the living environment of the populations. As a result, green space necessarily has the following characteristics: recreational, health, educational, social, cultural and economic, contrarily to what Deverin-Kouanda (1990:7) believed that green spaces must contribute to limiting the effect of the desertification rather than establishing recreational spaces, of walking, because going for a walk in the square is a Parisian not a Ouagalese culture. This conception excludes the other functions of green space and, in other words, for the latter author, frequenting green spaces is more a Western than African behavior.

While this may be true at some point, the fact remains that conceptions change and these spaces now feature in all urban development plans (Somadjago and Suka, 2018:268). As it has been demonstrated, green space allows people to find an ideal and healthy and clean place to rest. In addition, it contributes to the awakening of the conscience of the populations for a better management and the safeguard of the environment. Also, it promotes the closeness and the contact between people coming from various horizons. An adequate framework for the organization of various events (music, exhibitions, recreation, education, etc.), the green space also promotes the development of business activities that create jobs and generate income. For these reasons, the development of a green space is necessary because it helps to solve problems of employment, but it still has to be well managed.

In Benin, the law on decentralization confers on the Municipalities a certain prerogative in the management of the territory and its components and therefore green spaces. This management mode does not differ fundamentally from that described by Osseni et al. (2015: 153) in Porto-Novo in Benin where it is the forest inspectorate, the Town Hall, NGOs and the population that intervenes in the management of green spaces. The management model in force in Benin presents certain differences with that of Lomé in Togo where a fairly large number of actors are responsible for their management (Polorigni, 2012:58; Somadjago and Suka, 2018:271). It also differs from that of Kinshasa where green spaces are managed concurrently by four different ministries (Ngur-Ikone, 2010:16).

In Sèmè-Podji, the local authorities have delegated part of their prerogatives over green spaces to private entities made up of legal and natural persons. These private entities pay a monthly fee and use the spaces for their economic purposes. The green space must be maintained on a regular basis to continue to provide a healthy environment for populations. It must also offer a multitude of activities to its users and have certain infrastructures essential to its viability. These criteria are far from being adopted or implemented in the Municipality because of shortfalls at all levels (infrastructural, sanitation and innovation). These findings are similar to those of Amontcha, Djego, Lougbegnon and Sinsin (2017:85) in Nokoue, Hounsou (2018: 42) in Sèmè-Podji in Benin and Bouge (2009:56) in Tourangelle in France. Indeed, the findings show that the maintenance gives more consideration to the refreshments installed on the perimeter of the spaces rather than the infrastructures (benches, lighting, plants, etc.), the sanitation, or the adequacy which the users expect. Within this context, it is first and foremost the responsibility of the municipality to rethink the development of green spaces and to effectively invest in them accordingly, with reference to the municipal development plan.

Conclusion

The Municipality of Sèmè-Podji has long neglected public spaces in its development process in favor of the uncontrolled expansion of buildings. Most of the spaces in the Municipality are functional but do not always meet the expectations of the population who frequent them for entertainment, rest and other activities such as shopping. The management of green spaces faces many challenges which must be addressed to avoid losing them, as they are being less and less visited and neglected by the population. In the face of rampant population growth and urbanization, the municipalities must become effectively involved in the restoration and development of new green spaces to provide an adequate leisure environment for their respective and healthy populations.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Quantitative and qualitative assessment of urban green spaces in Boussaada City, Algeria using remote sensing techniques

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A central issue for the Algerian city, in the dry environment, is awareness of the establishment and preservation of particular green spaces within the framework of sustainability. The overall goal of this study is to concentrate on the issues of green space provision in the city of Boussaada. Boussaada is a complex and fragile city with a rich history, archeological and natural diversity, and is under tremendous anthropogenic stress. The city of Boussaada has long had issues with the availability of green areas, a situation that is attributed, among other things, to a flawed urban design that places a premium on the environment. We attempted to define the quantity of green spaces in the city and quantify their richness through this study. The qualitative and quantitative study was carried out with the help of the normalized difference vegetation index (NDVI) and qualitative analysis and more specifically the species of trees in the new town of Boussaada.

Key words: Green spaces, Boussaada, Natural Heritage, normalized difference vegetation index (NDVI), the species of trees.

INTRODUCTION

Public green spaces are the main islands of high-surface nature in the urban fabric. Maintained to varying degrees, they can house a relatively large number of plant species, planted and/or spontaneous, and thus potentially represent an important pole in maintaining biodiversity (animal and plant) in an urban context (Philippe, 2007). Maintaining this diversity has been recognized as a major environmental issue and priority at both the international and local levels (Philippe, 2007). Green areas have a positive effect on the quality of life of residents in urban areas (Porcherie et al., 2021), through their benefits on health (Faure et al., 2019), social cohesion and the environment (Dehimi and Hadjab, 2019). Green areas represent a natural heritage by creating an urban landscape which can reinforce people's sense of belonging and identity and protect vulnerable areas (Minzhanova et al., 2021).

Trees and plants, as important components of the earth system, are helping to regulate urban conditions and to reduce urban heat on the island by creating a cool effect through oxygen, carbon dioxide absorption, solar ray's minimisation and interception, shadow creation and

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radiation absorption (Gherraz and Alkama, 2020). The progressive degradation and weakening of natural elements from a physical and chemical point of view can lead to instability and fragility of structures associated with such landscapes, and is responsible to a higher degree, for the vulnerability of natural ecosystems (Cocean, 2020). In terms of quantity and quality, Algerian cities have several green space issues. Law No. 07-06 of 25 Rabie Ethani 1428 corresponding to 13 May 2007 proposes a standard of 6.8 m2 per habitant, but that standard was never respected and green spaces do not have priority for city development in order to define rules on management, protection and development in a sustainable development context.

Several studies state that the Algerian city also performs poorly in terms of the preservation of its natural heritage, urban forestry and preservation of biodiversity. The situation has occurred as a result of expanding urbanization, which has led to a lack of available space, land pressure, and a strong influence of minerals on the vegetation. Higher management of town and property of urban development and due to inadequate designing, accelerated urban growth, and a substantial loss of inexperienced areas have resulted in the mobilization of quantitative and qualitative strategies by proposing approaches to call support. Special detection will facilitate decision-makers and planners to perceive factors and changes within the use of vegetation cover so as to require effective and helpful measures (Shahabi et al., 2012). In recent decades, several vegetation index types have been developed to facilitate vegetation detection in relation to other soil cover types (Roy, 2008) such as the normalized difference vegetation index (NDVI).

We have targeted the city of Boussaada by a quantitative and qualitative examination of green space. This city has an associate degree of exceptional tourism and heritage potential, and has a full-fledged accelerated urban growth. The study attempts to bring an improved data on the issues associated with their development, by completing an identification of those areas within the city of Boussaada so as to answer these queries that pass through the assembly to map the vegetation of Boussaada town from the employment of a vegetation index applied to an image with medium resolution MODIS. The study also examines tree species as well as how it fits into the region's climate by knowing their properties. The importance of this research lies in identifying the highlights of the green spaces and their various benefits in cities with semi-arid climates, while showing the importance of focusing on the qualitative side of them through restoring the green spaces in residential neighborhoods in particular and the city in general. The study will also focus on the necessity of selecting of trees species that are suitable for climate data, while also paying attention to the oases, which represent an excellent natural heritage. In this context, two questions were asked: quantitatively, is the amount of green space in Boussaada city enough? Qualitatively, are tree species compatible with the region's climate?

BACKGROUND

There is a lot of research on the topic of quantitative analysis of green spaces in many cities around the world, but very few studies have analyzed the quality of green space on arid cities especially species adapted to this climate. This research is based on several sources, but mainly on research that is complementary and quite convergent. It is in this favorable general climate that we see a very marked increase in the number of research carried out on the subject, particularly the work of the Dialog-Citizens Committee (Report of the Table on Ecological Areas in 2008) which has presented a very clear categorization of green spaces, a categorization based on several criteria: geographical location, accessibility, size and vocation. The first category corresponds to islands of greenery. They are "green spaces of limited size, natural or fitted out, intended for greening or for connecting two spaces and which can be used for relaxation". This category includes street trees, municipal flower boxes, floral structures, roofs and plant walls, urban wasteland or even areas of spontaneous vegetation. The second category corresponds to recreational areas. These are "demarcated and regulated green spaces, more or less large, for recreational, sport or leisure activities" such as municipal parks, community gardens, playgrounds, areas for skiing, hiking or sports grounds are included in this category. The third and last category corresponds to ecological areas. Green spaces are, according to Bonhomme (2012), geographically defined, accessible to citizens in whole or in part according to protection needs, which are regulated and managed in a sustainable way in order to achieve objectives of preservation and maintenance of biodiversity and its related developments respecting the natural character of the sector and are harmonized with it. "This category includes protected areas, buffer zones, ecological corridors, etc.

Several researchers claim that urban vegetation makes the urban environment healthier and that it regulates climate variations and provide a favorable environment for the development of biodiversity according to Manusset (2012). Local availability of green space has been associated with a wide range of health benefits (Richardson et al., 2013). The presence of green spaces brings several benefits to the inhabitants. The physical and psychological balance of the city dwellers often compromised by the urban environment, foster exchanges, contacts and social encounters, especially a young people squares and recreational areas (Flouri et al., 2014). This strengthens the bonds of the society, the green space is a space to get fresh air and to engage in fun and recreational activities and to make the city pleasant to live. Donadieu Pierre always follows the same logic, and explains: "The plant is not only a regulator in the city, it is also a social mediator, that is to say, what the identity and quality of the city is, what makes the agglomeration appropriate or appropriable by the inhabitants" (Donadieu, 1996).

Green spaces also have an impact on the public's perception of safety and sense of security. Some authors suggest that "the presence of trees improves the control of outdoor spaces and the supervision of children in disadvantaged urban environments" (Vergriete and Labrecque, 2007). They play a significant role in arid and semi-arid cities (this is the case of our study), where rainfall is low/irregular and the actions of winds are remarkable and harmful (Gherraz and Alkama, 2020). Researchers have proven that vegetation is the best filter-exchange screen for wind erosion control, soil surface maintenance and particle retention (Wolfe and Nickling, 1993). Green spaces also play a thermoregulatory role, they allow to fight against the effects of heat islands and the creation of cool beds in arid areas (Shiflett et al., 2017). This cooling of the ambient temperature is due both to the shade provided by trees and to evapotranspiration (François, 2010) and large parks where residential neighborhoods with extensive vegetation can produce air temperature reductions as much as 10°C (Boudjellal, 2009). When planning for species trees that may face future climatic scenarios that are anticipated to be warmer and drier, information on seasonal adjustment of species will be useful (Iverson et al., 2019). Some research studies have discovered selected tree and shrub species should be suitable to the future climate, to the context and to the needs of the urban environment

Relation between urban heat and oasis effect in arid and semi-arid urban environments

A group of researchers in a paper titled Green infrastructure performance in arid and semi-arid urban environments (2021), survey more than 9 studies and they all confirmed the relationship the oasis effect and cooling effect, that vegetation reduced temperatures in the surrounding area, especially from larger shade trees. Shade trees perform particularly well vis-à-vis other vegetation like grass as an urban heat mitigation strategy when water use is taken into account. For arid environments, where water is limited, there may be a real tradeoff between vegetation benefits and irrigation requirements (Meerow et al., 2021). In a study, Shiflett et al. (2017) confirms that taller trees with a blocking sunlight showed the greatest air temperature difference (mean of 4°C at 0.1 m height) compared with bare soil. The difference was mostly pronounced around midday (mean of 6.9°C) and lowest in the late afternoon (2°C). Plots with shorter trees and grass were only consistently cooler than bare soil in the middle of the day (an average of 4.6°C for short trees and 4.1 for grass). Feyisa et al. (2014) confirmed that the cooling benefit provided by trees varied by species and by characteristics (size, shape, and vegetation), but overall they calculated an air temperature drop of 0.2°C for every percent increase in overall tree canopy cover. Parks with more tree canopy cover and larger areas had a more powerful cooling impact that lasted beyond the park's limits (Meerow et al., 2021). As a result of the foregoing, it can be concluded that vegetation plays a significant role in cooling the urban environment, this effect varying depending on the kind, density and length of trees.

METHODOLOGY

Our study is based on several sources, but mainly on research that is complementary and quite convergent. It is in this favorable general climate that we see a very significant increase of research in Algeria (books, memoirs and theses, article) on the subject in at hand. The first step is to investigate in the theoretical field by a bibliographic search and a reading of various works, whether paper, online, CD-ROM or database, book, theses, official journal, journals, articles, periodicals, encyclopedia, dictionaries, websites, on the subject studied "green spaces". The second stage consists of a set of direct observations, which are taken in the field in order to obtain objective information that can be categorized and analyzed statistically. The quantitative spatial analysis was performed using the normalized difference vegetation index (NDVI). Normalized Vegetation Index (NDVI: Normalized Difference Vegetation Index) is based on an empirical approach based on experimental data (Baghiani, 2006). The calculation of this index is mainly based on reflectance differences found in different spectral bands and on the variability of reflectance within the same spectral band, which reflect surfaces of different natures. NDVI is the most commonly used vegetation index for satellite image analysis. Thanks to the strong reflectance in the near infrared chlorophyll, this index effectively detects the green status of plants. Vegetation indices are widely used, on the one hand, to identify and monitor vegetation dynamics, but also to estimate certain biophysical parameters characteristic of plant cutlery, such as biomass, leaf area index, active photosynthetic radiation fraction. It takes values between -1 (water) and 1 (intense vegetation) and is calculated using the NIR (near infrared) and R (red) bands, according to the following formula.

$$NDVI = (NIR - R) / (NIR + R)$$

IR=infrared pixel values ; **R**= pixel values of the red band.

It is enough to raise the population figure by age group and to assign it the category of green space that corresponds to the needs assessed by the grid of norms and also offer is to be related to the real demand of the inhabitants.

PRESENTATION OF THE CITY

The city of Boussaada

The city of Boussaada is the first oasis found in Algeria. It is located in the south-east of northern Algeria and 250km from Algiers and covers an area of 225 km². It is considered a real crossroads between the Mediterranean

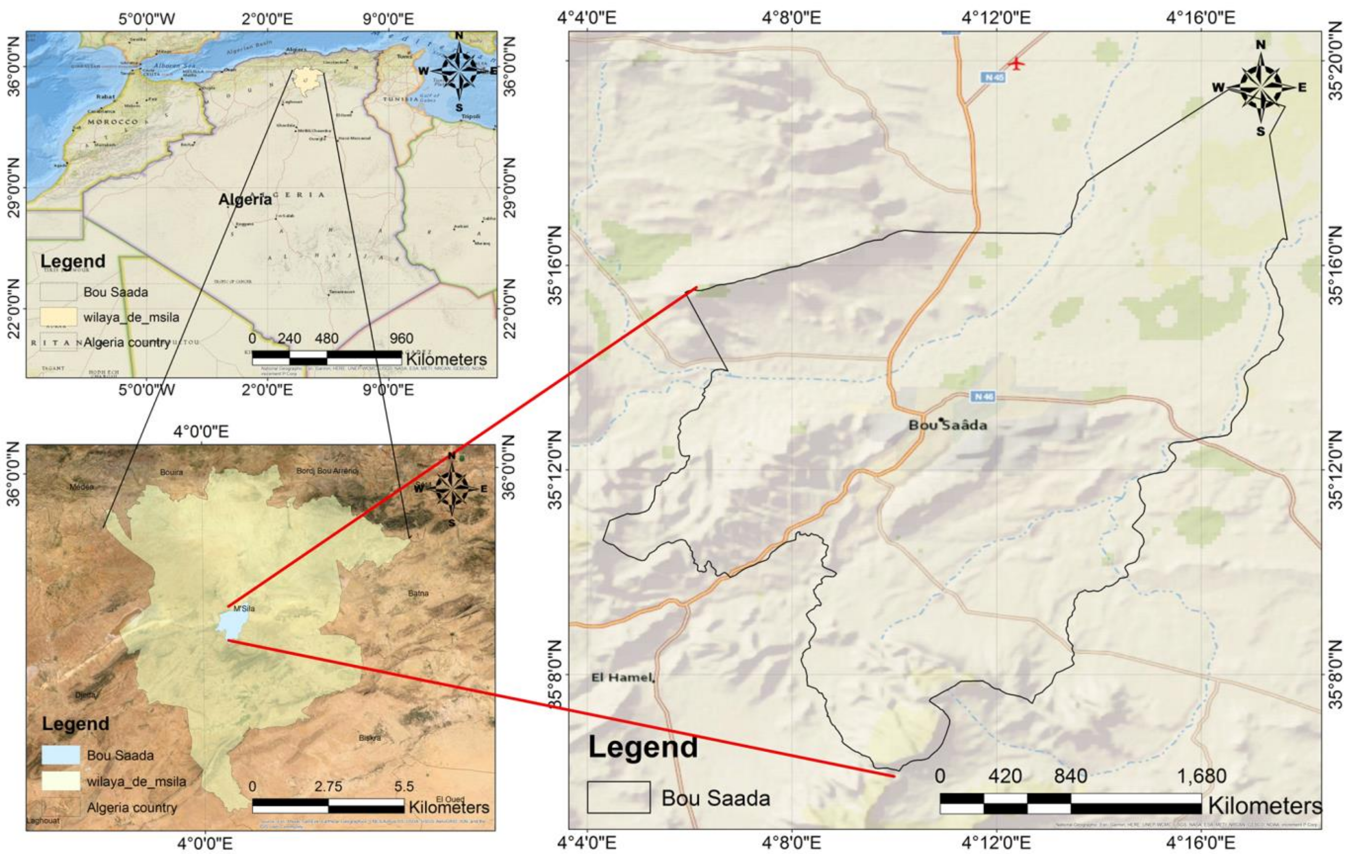

Figure 1. The location of the city of Boussaada.

and the Sahara. Locally, the capital of the Daira de Boussaada is located south of the Wilaya of M'sila (Figure 1).

The town of Boussaada is located in the south of the Wilaya of M'sila (Figure 2). The city of Boussaada is surrounded at the: North, by the commune Ouled sidi brahim and south-east by the commune Oultem and Hamel; North-East, by the municipality of Maarif; and East, by the municipality of Houamed and west by the municipality of Tamsa.

Climate

Climate is a very important factor in urban studies and any planner needs to know the climate data of the city where he intends to build (the temperature and humidity regime of the air, the regime and the nature of the precipitation, the sunshine, the regime and the nature of the winds during the annual cycle). Boussaada belongs to a semi-arid (Figure 2) zone according to the map of the bioclimatic stages below, between temperate and tropical climates, characterized by a drought thus winter, spring and autumn precipitation that are rare and irregular the average being 178.95 mm per year (this data recorded at the weather station of Ain Diss and the agency of theresources in water in the period 1971-2012).

The city is located at the edge of a high plateau and deserts, therefore a very hot climate in summer with a very strong and intensive solar brightness, variations of temperatures between day and night are between 4 and 8°C; winters are cold, temperatures can go down below zero degrees Celsius. In order to better define the characteristics of the climate of the city of Boussaada (external conditions), it is useful to refer to monthly weather data collected at the weather station of Ain Diss over the period 1971-2012. Figure 3 shows the Ombrothermic Diagram of the city of Boussaada based on monthly average rainfall and thermal data over a period of 41 years. (1971-2012). Figure 3 shows that the dry season extends from mid-May to late August.

Climate data

The territory of the city of Boussaada is a varied but overlapping territory, characterized by ecological elements, very varied landscapes, complex and fragile subject to strong anthropogenic pressures "The wadi, the mountain and the dunes have therefore imposed it where

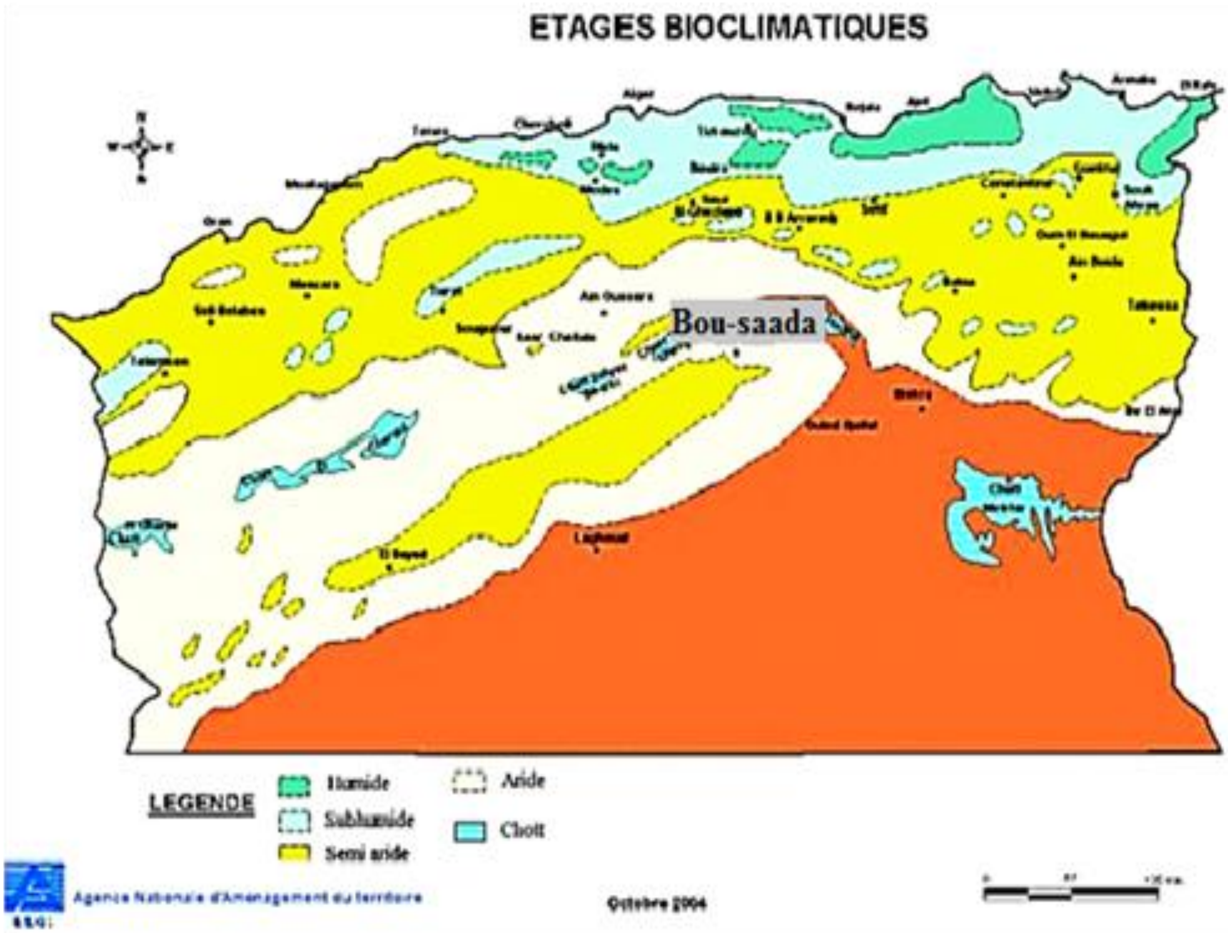

Figure 2. Bioclimatic stage of Boussaada.

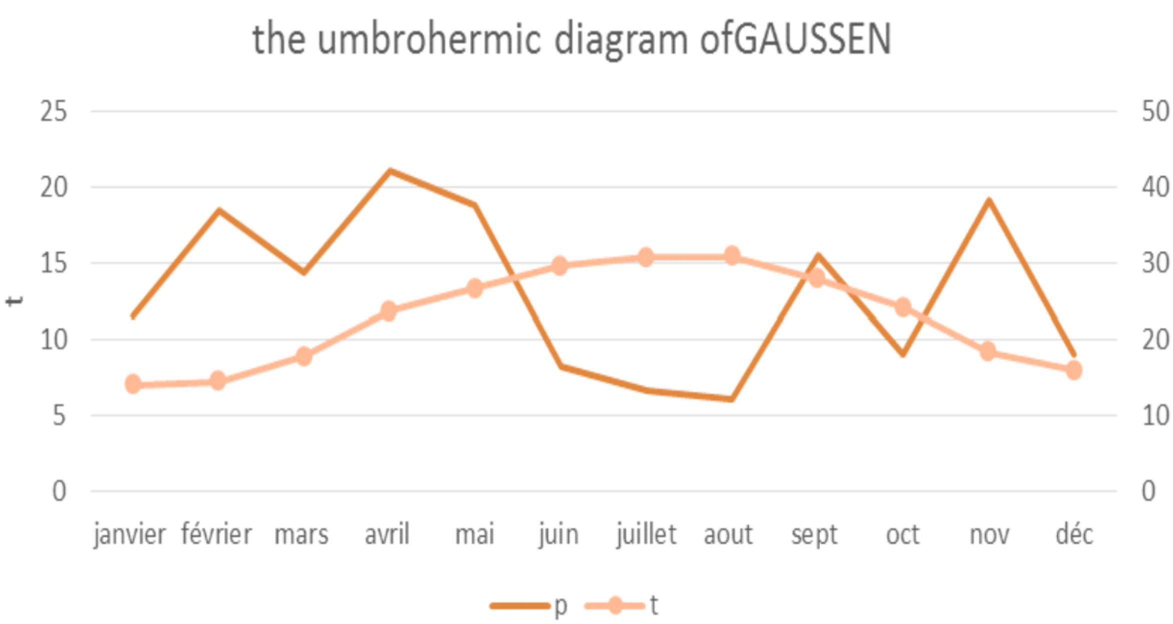

Figure 3. The umbrohermic diagram of GAUSSEN.
Source: Authors.

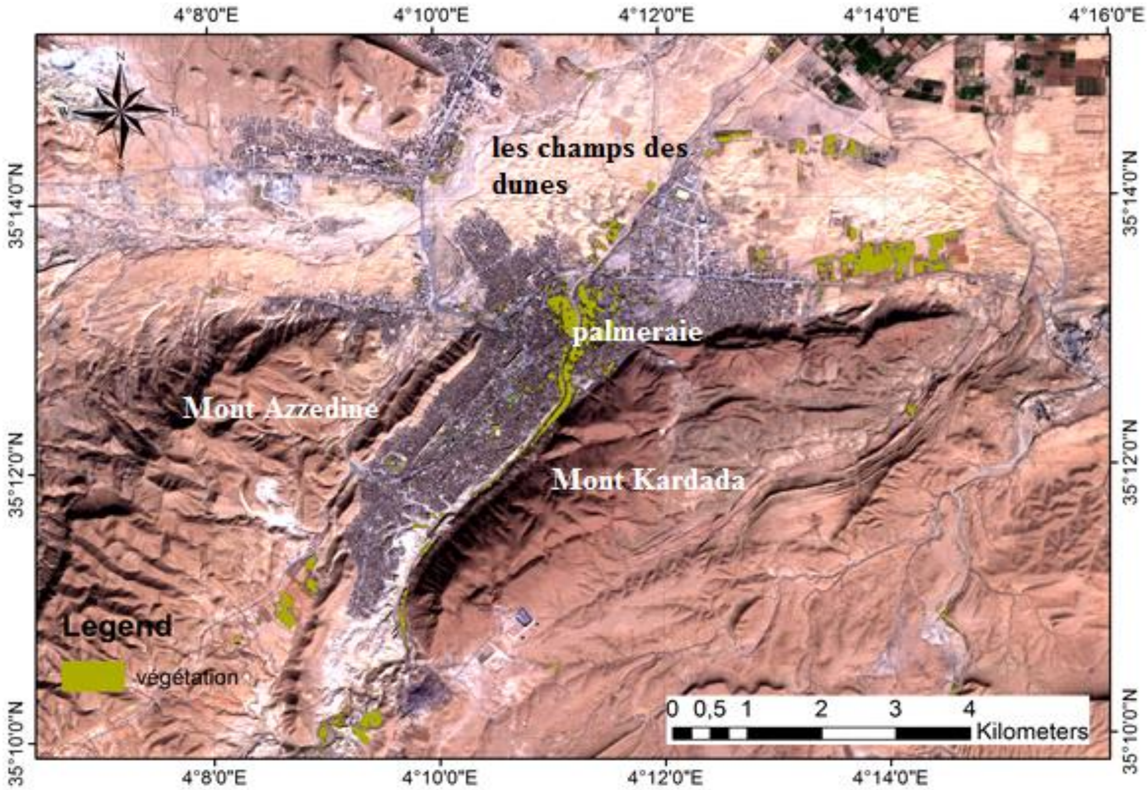

Figure 4. Vegetation in Boussaada city.

it is, in gradient towards the palm grove (Nacib, 1986).

DISCUSSION

Outstanding green spaces in the city of Boussaada

The small green spaces in Boussaada city, represent 2.0796 hectares, or 0.036% of the total area of the municipality, making the ratio of square meters of green spaces to the number of inhabitants in the municipality of Boussaada (The municipality of Boussaada extends over 111 km² and it encompasses 16042 9 inhabitants according to DPSB 2017), the result is 0.01 m² per capita, a figure much lower than the 10 m² per capita recommended by the World Health Organization (Bougé 2009). One observation is clear; the green spaces in the city of Boussaada are shrinking and today represent only a small part of the total area of the city

Calculation of the normalized difference vegetation index (NDVI)

The green space affected by the analysis is dark green in Figure 4. This spatial analysis tool, combined with a database treatment, enabled the NDVI index to be calculated. This value of NDVI is done by dividing the surface of the green space in the city of Boussaada (0,78km²) by the total surface of the city (23 km²), which gives 0.33. Pixels with an NDVI value of < 0.2 are included in a "surface without vegetation cover" mask. This NDVI value is in the range 0.2 to 0.65, so it corresponds to partially vegetated surfaces. The vegetation in the town of Boussaada is unevenly distributed over the whole city (Figure 1), several large spots are located in the city center such as the palm grove and trees of alignment and 3 gardens. Based on the value of the category surface in Table 1, it was noticeable that the majority of urban spaces were consumed by the building compared to other spaces such as green spaces. According to the visual comparison of the NDVI, there is a very uneven distribution of green spaces in the urban space of the city of Boussaada, where the highest rate of green spaces is located in the central districts and urbanization is already significant. This is the disparity between the center and the periphery. Beyond that, it seems useful to us to emphasize that the phenomenon of disparity in the city of Boussaada has several scales, starting with the absence of green spaces and the differentiation of physical and geographical conditions, arriving at a minimal socio-economic situation characterized by a high concentration of low-income households. Under the silence of the local authorities, two phenomena have evolved over time in the city of Boussaada: desertification and siltation (Figure 5) due to increased pressure from populations on already

Table 1. Percentage of green spaces.

Categories of urban spaces	Built-up surface		The surface of green spaces		Free surfaces		Empty communal surfaces
Surface de milieu urbain	**Surface Km**	**Surface %**	**Surface Km²**	**Surface %**	**Surface Km²**	**Surface %**	88 km²
	12.73	55.34	0.78	3.39	9.49	41.25	
Total urban area	23 km²						
Total communal area	111 km²						

Figure 5. the silting of the town of Boussaada.

fragile natural resources to meet their basic needs such as construction on sandy land that increases sand mobilization. Vegetation is considered a soil protector by decreasing wind speed, fixing and restoring the land.

Quality of green space in new city of Bousaada

In the late 1970s, in order to meet the pressing needs of the urbanization of the city of Boussaada, an important Urban Habitat Area New (UHAN) was built in the south of the city, located on nearly 5 km north of Boussaada. In 1993, the latter constituted a new urban pole. It is commonly called the "new city". It covers an area of 115 ha. The UHAN Boussaada suffers from lack of infrastructure and green spaces "a less well-served space" as shown in the map (Figure 6), with a syncopated rhythm that only has a dominant function (housing) "dormitory cities".

Tree species

Selecting appropriate trees for urban and suburban areas depends on a number of factors; it should bind fine particles, ability to adapt to climate change, and improvement of the urban landscape (Sjöman et al., 2018). Trees in Boussaada city, with a semi-arid climate, must be able to endure the drought and heat that exit in this area, in addition, well-placed trees can provide shade and reduce the heat felt due to global warming (Figures 7 to 10). Field observation revealed the presence of 3 tree species array of trees in the area sampled in this study.

1. *Nerium oleander* is an ornamental species of high aesthetic value, grown in arid and semi-arid regions because of its drought tolerance, which is also considered as relatively resistant to salt.
2. *Eucalyptus* is a highly adaptable tree, often fast-growing trees that vary greatly in adult size, flower color,

Figure 6. Green space in the urban habitat area new.

Figure 7. Genus :Nerium L/species : Nerium oleander.

Figure 8. Eucalyptus.

leaf shape.

3. *Casuarina equisetifolia* is very similar to a conifer. It is a very beautiful and resistant tree that grows in both sandy and poor soils, and also produces very small flowers.

In spite of adaptation of tree species with urban climate in the study area, the diversity of the trees was poor and the facilities of the green spaces are rudimentary. They should be improved on in order to encourage users to frequent them.

The palm grove: fragmented green elements

The palm grove has long played an important and beneficial role in the city of Boussaada at the same time, historical, social and economic, as a friendly space, creator of landscape and refreshments in short (Encyclopedie consulted 22/12/2015). The palm grove is a great collective heritage (Figure 11), but the inhabitants do not have the information available on the palm grove

Figure 9. Casuarina equisetifolia.

Figure 10. poor quality of design /lack of accessibility and conviviality.

state which does not allow building their perceptions as well as the problems of degradation and deforestation. The palm grove of Boussaada covers 120 h and had more than 30,000 palm trees and other crops (vines, fig trees, cognassier, apricot trees, etc.), it presented a real source of labor for 857 employees in agricultural activity, so we can say that the population of Boussaada lived more on agriculture than from crafts. The palm grove offered other benefits, it also supplied fruits and vegetables for barter with other products, it also offered a raw material (wood especially) for the construction of buildings (arches, beams). Figure 12 shows the reduction of the surface of the palm grove in favor of urbanization, three very negative phenomena have been observed: decline in favor of urbanization: the transformation and deforestation of palm trees in this case we call it "Beast of the palm grove"; "disinterest of the population": the links between the inhabitants of Boussaada have become close in a way "a detachment of the inhabitants to its palm grove"; the palm grove becomes fragile and weak in terms of use and productivity.

RESULTS

The territory of the city of Boussaada is characterized by ecological elements, very varied landscapes, complex and fragile subject to strong anthropogenic pressures. El Maader is an agricultural land located 8 km from Boussaada, it contains a wide range of fruits and vegetables. Ecological continuity has become a central issue due to the acceleration of urbanization in the city of Boussaada. The quantity of green spaces in the city of Bousaada is unrelated to the particular situation of the cities, which is the size of the city and the number of inhabitants. There are two distinct areas: one in the city center with a concentration of gardens and tree-lined arterial roads with monospecific plantings, and the other on the outskirts with few arterial roads, gardens, and tree-lined yards. This disparity can be explained by historical facts as well as the current urban environment's organization between the center and the outskirts and heterogeneous distribution of tree types in different neighborhoods. The administrative centre has benefited from the planting and maintenance of trees to combat wind and erosion, to provide shade and to beautify the city. Also, the floristic inventory reveals 3 species belonging to the sites studied, which constitutes a low diversity of the tree flora of the city of Boussaada. 5 additional species were observed outside the selected sites. A clear observation: the green spaces in the city of Boussaada are shrinking and today represent only a small part of the total area of the city.

Few trees on the public domain and some trees on the private domain bring greenery to the public space. Green spaces in the city of Boussaada are rare and often in very poor condition. The lack of supervision of urbanization and legislation remains weak, scattered and fragmented and exacerbates these problems. We also note that the quality of the design of these green spaces did not meet the needs of the users who use them. The decline of the vegetation in the palm grove is mainly due to the change of the way of life including the new technologies which have pushed the peasants to leave the palm grove and move to other profitable and advantageous sectors, in addition, the remote level of local/national tourism and the lack of recreational activities or the reduced accessibility due to privatization of the land. The detachment of the inhabitants to their palm grove has several signs, among the most striking is the proliferation of waste within the palm grove, the inhabitants who have thrown the waste illegally do not have sufficient culture and knowledge. Like this case, associations, mosques and schools must transmit and enrich culture by giving everyone access to knowledge, that is to say, to cultural, intellectual and natural heritage.

Figure 11. Palm grove.

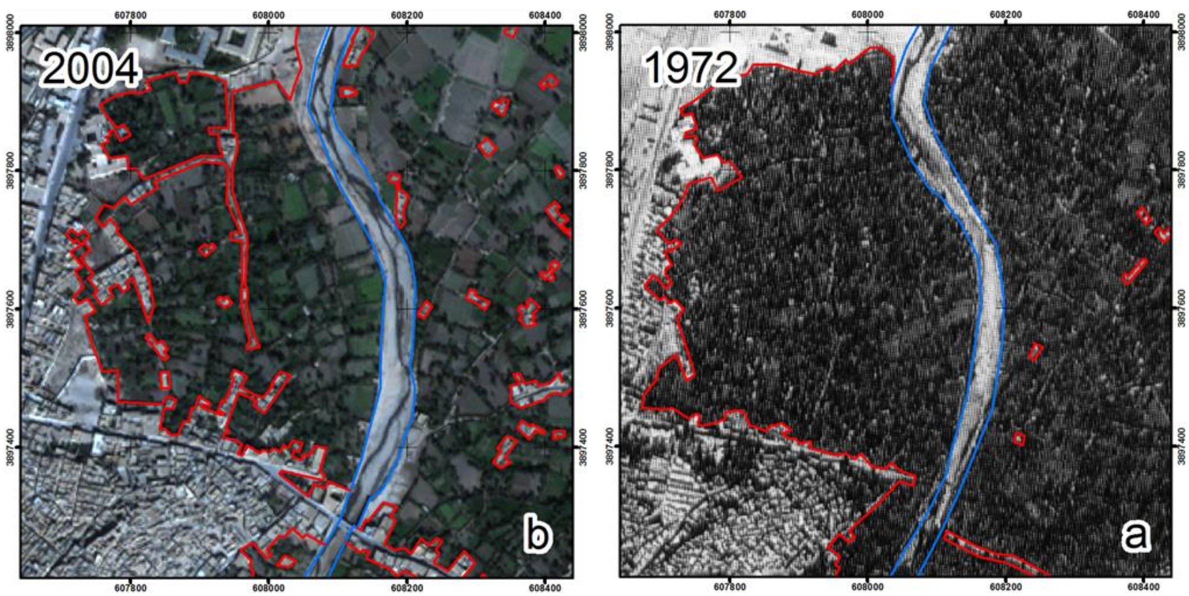

Figure 12. Decrease in green space in the palm grove.

CONCLUSION

Through this research, we have shown the importance of vegetation on the formation of microclimate, by its ability to reduce the impact of sun rays and winds, as well as its effect of cooling the air by the action of evapotranspiration and the reduction of heat pressure during the summer period. Green spaces also have an aesthetic and decorative, hygienic and sanitary role and a social and educational role (Fadel et al., 2016). Among the indicators used to compare the vegetation situation in the city of Bousaasa is the ratio of square meters of green spaces and the normalized difference vegetation index (NDVI). It is important to note that the normalized difference vegetation index (NDVI) is an effective tool for improving the quantity of green spaces and its distribution throughout the urban area. We have shown that through the quantitative research of green spaces, the city of Boussaada has nearly 0.1 m^2 of green spaces per capita and with a proportion not exceeding 3.5% of the city's surface; that is to say, it is poor compared to the national standard which is about 10 m^2/inhabitant. It should be noted that this small presence of green spaces does not allow the preservation of the natural heritage (the palm grove). It is therefore necessary to think about creating and developing new green spaces in the city and restoring the palm grove to its rare value. This requires a systematic mapping of land skills and the creation of an urban forest. It also seems essential to restore the palm grove to its rare value, to make cartography. The development of green spaces in the city of Boussaada requires the identification and knowledge of tree species. The diversity of use or functions of trees is ensured thanks to the adaptation of planted species to ecological, climatic and landscape conditions. The study thus highlights the importance of urban forestry. In the case of the city of Boussaada, taller trees with a closed canopy can provide a cooling benefit like acacia tree with a big ability to thrive under hard conditions. The consideration of the quality and quantity of green spaces in urban planning instruments must be strengthened and based on a much more qualitative approach and on a real urban forestry (care, treatment, silviculture); that seeks to maintain a healthy environment and an aesthetic and clean image of the city. As we have shown in the course of this research, the land use plans of Boussaada city should control the Algerian urban space, protect the existing natural heritage, in this case the oasis, and create and promote green spaces in the future.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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