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Territorial health approach outputs of geo-governance of health facilities: case study of Batna, Algeria

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Abstract The city of Batna is currently experiencing major spatial disparities between the number of health facilities and their urban distribution. This situation has encouraged the re-evaluation of the functioning of the healthcare system and its spatial infrastructure deficit, especially regarding the proximity of healthcare facilities to the populations they cater to. This spatial deficit has resulted in a decrease in prevention program performance and the quality of healthcare. The aim of this paper is to measure the spatial healthcare inequalities in the city by quantifying the accessibility, delimiting the proximal service area, and detecting the distribution type based on a health-territory approach that integrates health dimension into a territorial master plan of the city using a geographic information system database developed for this purpose. The results confirm that accessibility is affected by the distribution of the health facilities as proposed by the urban master plan of the city. The proximity distances have increased, which provides an opportunity to maximise the service areas; however, it also creates a functional imbalance and overloads the health facilities.

Introduction

The Algerian health care system has been compared to those in the developed countries (Zehnati 2017) that have optimised the healthcare supply, made rapid adjustments in the face of ailments and transmitted diseases, and have invested money and resources in developing improved healthcare systems. In contrast, the Algerian system, characterized by a French colonial legacy (Chachoua 2014), has several structural problems, such as random distribution of health facilities with respect to population distribution, financial issues, and difficulty in adapting to new challenges; all these have a negative impact on its performance (Chachoua 2014; Bouyoucef barr 2015).

Despite the decentralisation of the national health system (NHS) and its public and private sector dualism (Oufriha 2006a) for improved adaption to local issues and quicker response to local diseases, several studies (Benachenhou et al. 2011; Bensafi and Djamel 2017) have affirmed that citizens are dissatisfied with the organization, quality, and efficiency of the public health care system. Even healthcare

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professionals are critical of the NHS (Chachoua 2014), even though it has very important investments (Oufriha 2006b), because of the lack of reliable data about patients, especially their educational and economic levels, which are major factors in measuring accessibility (Maron et al. 2019). These problems are related to sectoral inheritances and urban territorial issues, especially regarding the unavailability of land for the creation of new public health facilities (Bernia 2012; Billah and Fatiha 2014; Hayette 2017), Furthermore, the chosen mode of local development (Mohamed and Djamal 2018) and the master plan of planning and urban planning (PDAU[1]) affect the health services and health map orientations. Therefore, this situations requires coordination between various sectors (Louhi 2009) to resolve the complex sectoral problems in the local development plan of the city and to determine the best solutions via implementing a health territorial approach.

This paper aims to quantify and measure spatial healthcare inequality in the city of Batna by using a health territorial approach and the current health map, which is based on diverse demographic, economic, and social statistics and the epidemiological situation and has no association with the territorial elements of the city. Additionally, it focuses on the proximity of healthcare facilities in the city and uses geographic information system (GIS) analytical tools to quantify the spatial inequalities in healthcare access (Winchester and King 2018; Yin et al. 2018) and the manner in which this reflects on the actual health needs of the population.

Literature review

Medical geography

Medical geography is a sub-discipline of geography, and it focuses on the relationship between the environment, lifestyle, and health inequalities based on the distribution of a health infrastructure. The general geography is an important factor in the analysis of healthcare; it consists of two distinctive elements: geography of disease and geography of health care (Askari et al. 2016).

The geography of disease focuses on the spatial patterns of health and illness using many factors, including climate, microbes, exposures, culture, race/ethnicity, geography, and distribution of healthcare services. Susan Eliot (Elliott 2014) defined health geography as the study of the distribution, diffusion, determinants, and delivery associated with health and health systems in human populations. One unique aspect of examining health and health systems from a geographic perspective is the use of a spatial lens that allows for an investigation across a range of scales, from local (e.g., neighbourhood) to global.

GIS and health

GIS provides strong and dynamic techniques that allow the modelling and management of the geographic relationships that enable more informed decisions, improved functional performance, generation of more cost-effective citizen plans, evaluation of spatial details, and modification of information and maps (Meika 2010). In addition, GIS aids health geographers to utilise a range of methods (quantitative, qualitative, and spatial analysis) to answer the 'who gets what, where, and why' with respect to both illness and healthcare (Cromley and McLafferty 2011).

Public health is a growing field that is increasingly using GIS (Briney 2014) to map diseases and identify disparities in factors such as income and the availability of quality healthcare to determine where healthcare development should be focused, making GIS an important component in public health research. GIS provides analytical tools for health geography and epidemiological research wherein geography is important. For example, Higgs (2004) compared different approaches to measure access to health care services, and Apparicio et al. (2008) compared five approaches for conceptualising and measuring the geographical accessibility of services and facilities for residential areas. They found that measures of the geographical accessibility of urban health services may vary according to the selected distance type and aggregation method.

Several methods have been used to measure and quantify geographic accessibility to health facilities, either by measuring the distance from the nearest health facility (Lin et al. 2018; Lu et al. 2018; Nemet and Bailey 2000), using gravity models to study

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[1] Plan Directeur d'Aménagement et d'Urbanisme.

interactions between health facilities and other spatial factors (Pan et al. 2015; Shin and Lee 2018; Yang et al. 2006), or assessing economic accessibility, which measures the ability of people to pay for and/or find care that is compatible with their economic level (Jonsson et al. 2018; Maron et al. 2019; Swaminathan et al. 2019). It is possible to also measure accessibility using health proportions and ratios based on the health workforce, health service delivery, or any other health resource proposed by world health organisation (WHO 2010).

The measure of accessibility to health care was developed for use in advanced analyses and techniques such as the floating catchment area (FCA) method, the two-step FCA (2SFCA) method (Kiani et al. 2018; Luo and Wang 2003; McGrail and Humphreys 2014), and the adaptive floating catchment method (Matthews et al. 2019) or for approaches based on a third component such as the transport network (Zhang et al. 2018) or GPS data (Xia et al. 2019).

The study area

Batna is strategically located in the eastern highlands of Algeria (Fig. 1). It is the sixth largest city in on the country (ONS 2011), and its geographical location has made it a hub with important crossroads connecting the country from every direction. Batna has experienced a strong but random urban dynamic (Chibani 2015) in terms of demography and space since its foundation in 1844, which has resulted in an imbalance in public services. This has affected the public health services and quality of life of over 299,698 inhabitants of the city (DPSB 2017).

Batna is located in a high-temperature zone ($+35\,^{\circ}$ C in summer) with moderate precipitation and a low slope (3–5%). These factors increase the vulnerability of the city to epidemics; Issam and Said (2017) indicated that 48.89% of the total area of Batna is highly vulnerable to cutaneous leishmaniasis, and Abdelhalim et al. (2016) found that vulnerability to typhoid fever in Batna is also high. To avoid this problem, the local health department must focus on the optimisation of public health in the city and increases the performance of prevention programs through healthcare proximity programs.

The study focuses on the urban space of Batna, excluding the metropolitan space and new urban extensions (Tazoult to the east of the city, Libmbiridi to the south, Fessdis to the north, and the new urban extension Hamla to the west) because of the unavailability of demographic census and health data. The study area has a total of 299,698 inhabitants that represent 3.05% of the total urban population in the country (ONS 2011). The city is divided into 315 small units that represent census tracts (DUAC 2012) (see Fig. 2). The distribution of the population is not homogeneous; however, the city can be divided into two major zones:

1. Height density zone: This zone is mostly comprised of level 5 and 6 buildings and collective housing constructed by the government as result of the New Urbanized Housing Zone (ZHUN[2]) to address the housing problems.
2. Low-density zone: This zone represents individual houses, majority are not a part of planned construction; these have no particular architectural style and they are of low quality. This area contains limited infrastructure and few public services.

Introduction to local healthcare facilities

The city of Batna has thirteen healthcare facilities and one hospital to ensure primary healthcare (Fig. 3). The hospital also provides proximity services because more than 48% of patients do not respect the graduation of care, even in cases of simple ailments that do not require hospitalisation (Nasereddine 2016a).

In 2007 the NHS was restructured to be more effective, cover a larger geographic area, and improve health service quality. The new structure classifies health facilities into four categories:

- Specialized health centres,
- Hospitals,
- Multi-service clinics, and
- Treatment rooms.
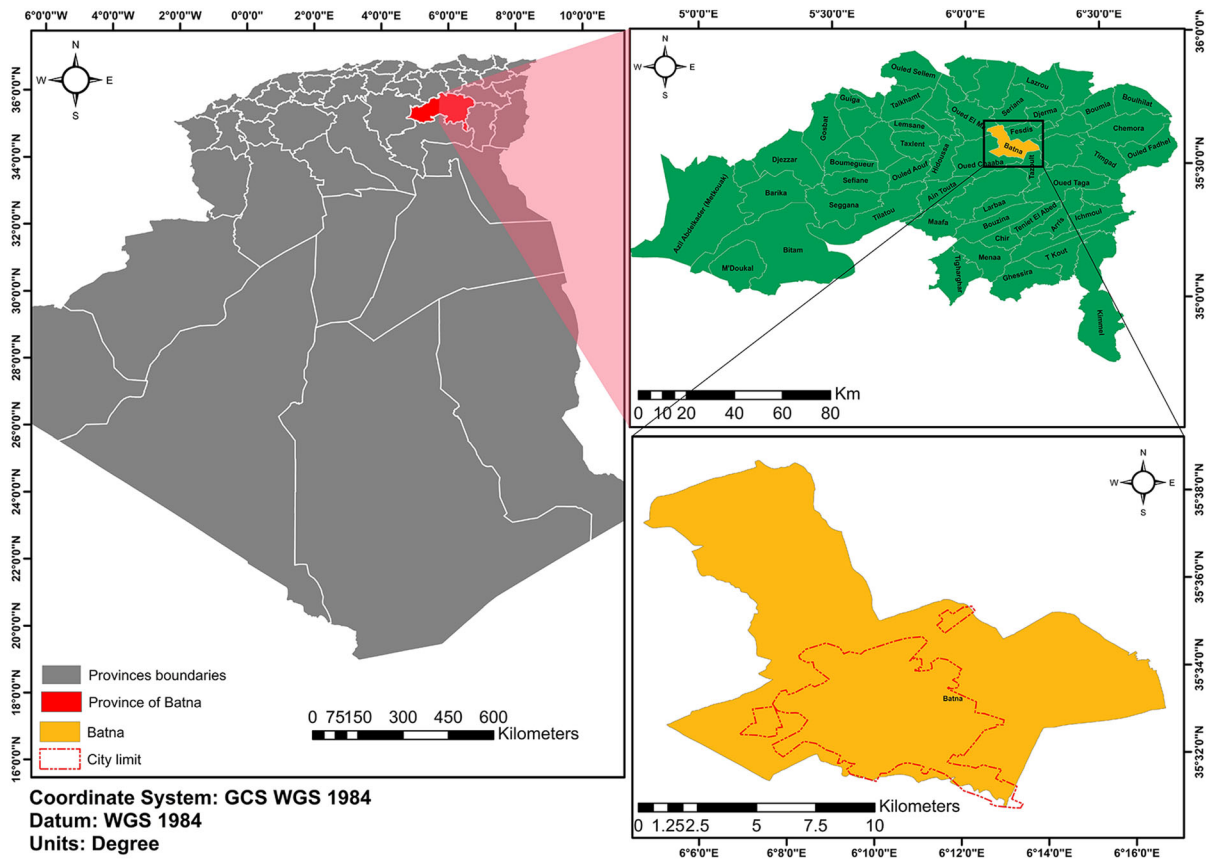
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[2] In French: Zone habitat urbanisé nouvel.

Fig. 1 The city of Batna: administrative and geographic locations
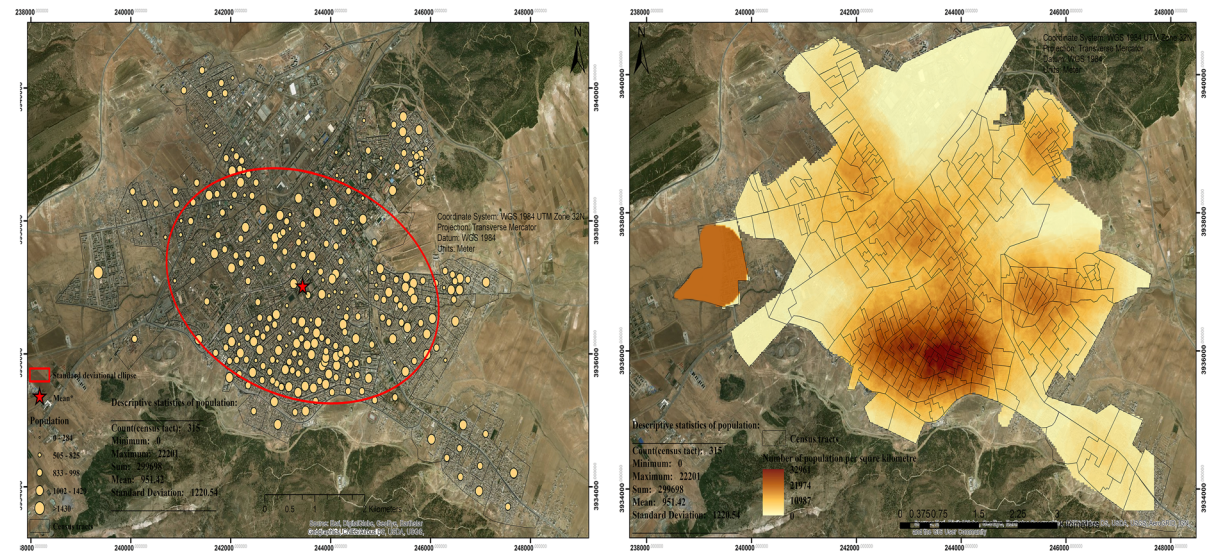

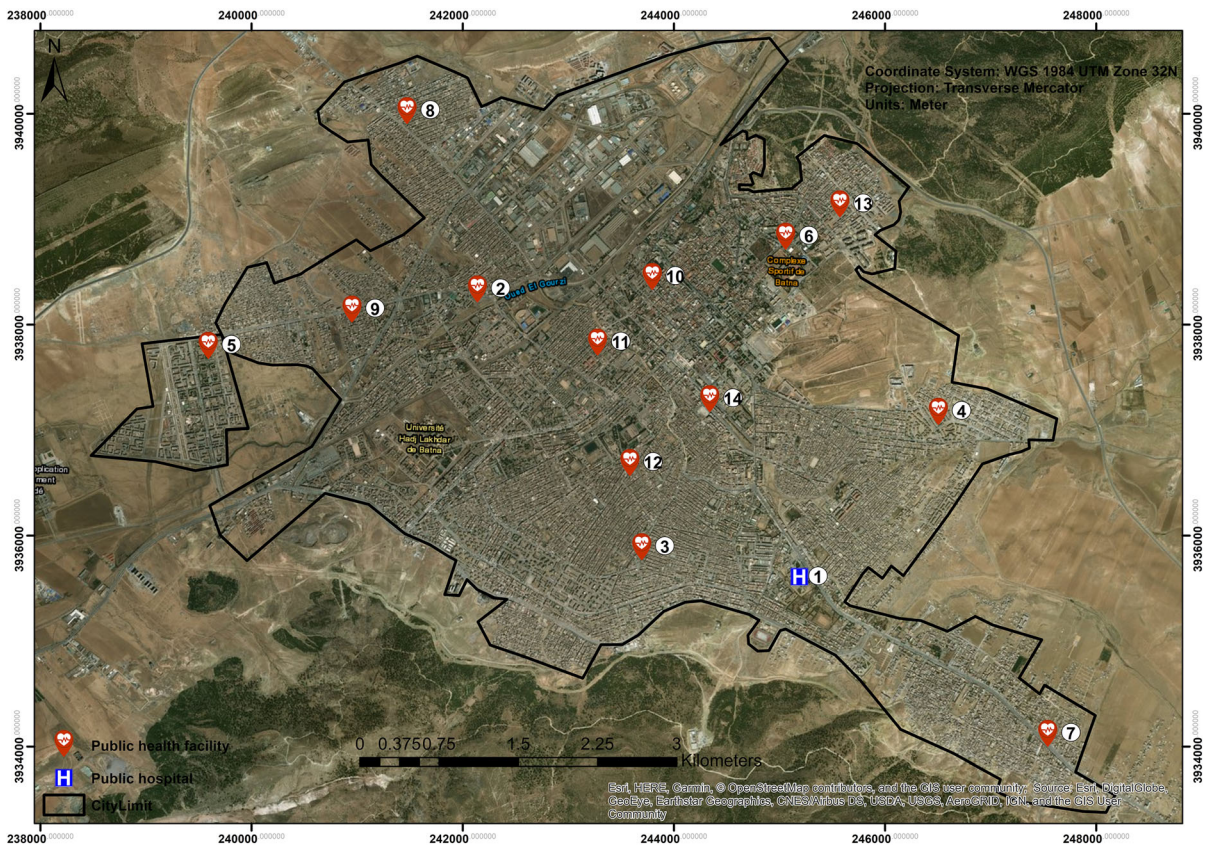**Fig. 2** Batna: the spatial distribution of the population

Fig. 3 Distribution of health facilities in Batna

Table 1 Classification of the local health facilities in Batna

ID	Category	Medical staff	Geographic service area
1	Hospital	Surgery, gynecology-obstetrics, internal medicine, general doctors, nurses, anaesthesiologists, and emergency	The city, metropolitan area
3, 4, 5, 6, 8	Multi-service clinic	Nurses, general doctors, dentists, laboratory staff, and specialist doctors (once a week)	Group of neighbourhoods, urban sectors
2, 7, 9, 10, 11, 12	Treatment room	Nurses, general doctors	Neighbourhoods

Every category covers a specific geographic area and has a specialised medical staff whose make-up depends on the category of health equipment and servicing population. The classification provides a functional and spatial healthcare hierarchy for a given territory (Table 1).

Methodological approach and tools

The health territorial approach using GIS allows us dynamically to determine and measure the spatial health inequalities in the city; it combines health function components (health facilities, health ratios, and human resources) in the urban master plan with the territory inputs (urban sectors, census tracts, road
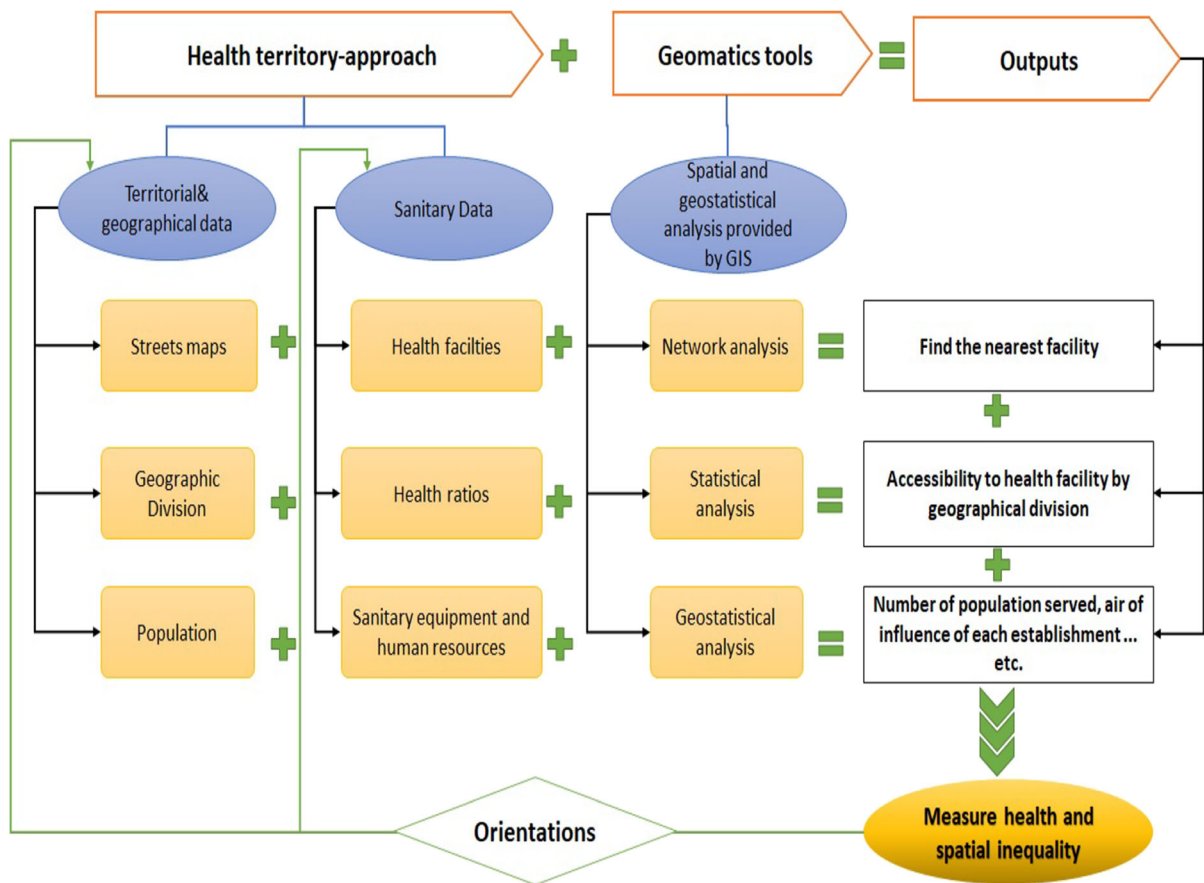
Fig. 4 The health territory approach, the inputs, tools and the outputs

access and transport, land use, etc.). This approach relates health sector and geographical space component interactions. By utilising GIS, we model the proximity of the local public health facilities in the city and territory inputs in a given geographic database to conduct spatial analyses including geo-statistical, statistical, and network analyses to measure spatial health inequalities (Fig. 4).

The proposed approach utilises territorial elements and health data, both are inputs for the spatial analysis tool, territory and health inputs are used for the spatial and geospatial GIS tools. After iterating all territorial element and the health data with the selected tools, the final result is the measure of spatial health inequality in Batna..

To study the spatial health inequality Batna, we selected the following criteria:

- Distribution: for detecting the spatial distribution of the health facilities, the city boundary was the

requested as a territory element, and the health centre locations were based on the health data.
- Geographic accessibility: the geographic division as the territory element and the health ratios as the sanitary data, they are the inputs for the GIS statistical analysis, and the output measures the accessibility to health facilities by geographic division.
- Service area: to determine the potential influence area and number of populations served by each health facility, the population count is the territory element, the health facility locations are the requested health data, and the output measures the populations served by each health institution, potential service area, etc.

The distribution

The nearest neighbour method determines the mode of spatial distribution of geographic features and statistically calculates the degree of feature grouping and dispersal.

> The result is obtained by measuring the distance between each centroid of entity and the centroid location of its nearest neighbor, and then averaging all these nearest neighbor distances, if the average distance is less than the average calculated for a hypothetical random distribution, the distribution of the analyzed entities is considered clustered. If the average distance is greater than that of the hypothetical random distribution, the entities are considered dispersed (Mitchel 2005).

The equation used to compute the nearest neighbour index are as follows (Esri 2019a):

$$A = \bar{D}o / \bar{D}o, \tag{1}$$

where $\bar{D}o$ is the mean distance observed between each feature and its nearest neighbour:

$$\bar{D}o = \sum_{1}^{n} di/n. \tag{2}$$

$\bar{D}E$ is the expected mean distance for the feature in a random pattern and is given by the following equation:

$$\bar{D}E = 0.5/\sqrt{n/A}, \tag{3}$$

where di is the distance between feature i and its closest neighbour, A is the area of the minimum enclosing rectangle around all features, and n is the total number of features.

Accessibility to health services

Health service accessibility is composed of three dimensions (Evans et al. 2013):

- Physical accessibility: the availability of services when the patient requests it.
- Economic accessibility: the ability of people to pay for services without financial difficulties.
- Acceptability.

Several studies on Algeria (Bouledroua 2010; Nasereddine 2016b) show that the main determinant of healthcare accessibility is the distance travelled by the care seeker; prejudices about the quality of healthcare is the secondary factor, so the accessibility in the Algerian case refer to two factors: geographical and functional, we chose to use two methods to measure health accessibility: by distance (Apparicio et al. 2008) using immediate proximity analysis and functional accessibility using WHO ratios.

Proximity analysis

Proximity is a component of accessibility, and its main spatial goal is to provide the greatest number of possible services to citizens. This is done by computing the distance between a location and the closest facility (Esri 2019b). In this study, the distances between the local health facility locations and census tract centroids are calculated. Thus, this analysis assumes that residents of each census tracts are equidistant from the nearest facility (see Fig. 6). This method helps to find the distance travelled by the population within the census tracts using the Near tool. This GIS tool calculates the distance between the census tracts centroid and the closest health facility and in the same time calculate the additional proximity information of the input features and the closest feature in another layer or feature class (Esri 2019b; "Near—Help | ArcGIS for Desktop" 2019).

Functional accessibility

We also measured accessibility to health services using a functional ratio based on the infrastructure, framework, and human resources in the health sector, and we chose the criteria of distribution of health facilities for each 10,000 people living in the same geographical area (the urban sector in our study). This functional ratio has been defined by WHO (2010) and was calculated using the following equation:

$$i = 10000 * \left(\frac{s}{p}\right), \tag{4}$$

where i is the value of the ratio, p is the total population in a specific unit (urban area), and s is the total number of health facilities in a specific unit (urban area).

The proximal service area

To determine the potential influence area, an analysis network was used to detect the closest facility to the population. This analysis was based on the actual travel path between a health facility and care recipient. By determining the service area with a network analysis, we can find the proximal service areas for each health facility.

There are different methods for defining the proximal service area such as of Garnick et al. (1987) method or the analogy method (Erickson and Finkler 1985), but proximal methods are preferable (Guerrero and Kao 2013; Okabe et al. 2008; Peipins et al. 2013) because they are geographic approaches and can be implemented using GIS. The proposed

approaches group the residents who sharing the same (closest) facility and function on the following assumptions: (1) every local health facility only serves the local residents and (2) the population prefers to access the nearest facility. According to these rules, residents who share the same nearest facility are grouped together (Xiong and Luo 2017).

Results

The dispersed distribution

The results of the average nearest neighbour analysis illustrate that the distribution is dispersed with an average distance of 1241 m from each institution to
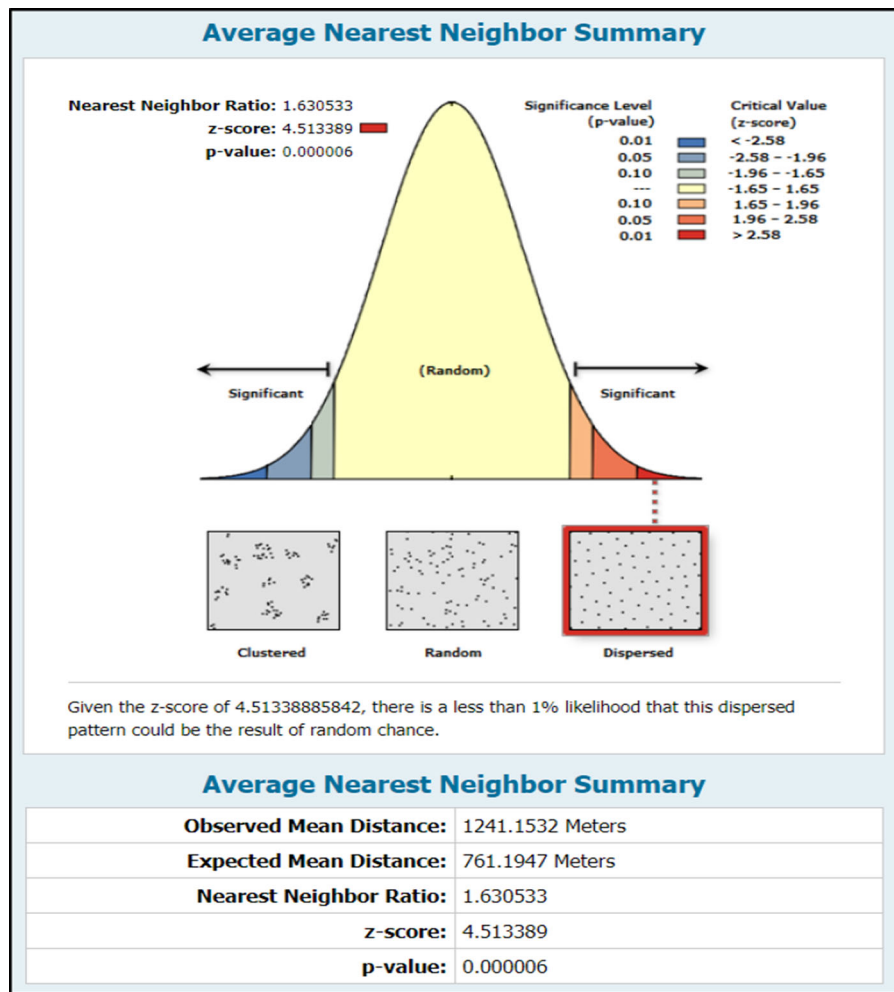

Fig. 5 The output of the average nearest neighbour analysis

its nearest neighbour with a score of ANN=1.63 (see Fig. 5).

The distribution of health facilities is dispersed, which helps maximise the service area to cover the entire city, and based on the z-score of z=4.5133, there is a less than 1% likelihood that this dispersed pattern was the result of random chance because our approach denotes a statistically significant relationship' between territory element and health service. This distribution is impacted by the availability of land both inside and outside of the city, which helps to create a new health facility in suburban areas (Fig. 3).

Accessibility

Accessibility was measured both geographically and functionally. Geographically, the distance between the local health facilities and the census tract centroids was calculated. Thus, this analysis assumes that residents of each census tracts are equidistant to the nearest facility. The results (Fig. 6) indicate that the citizens living in the southwest portion of the city travel the longest distance (1700 m) to reach the closest health facility, while for people living in the city periphery, the health services are closer.

To obtain more accurate results regarding the travel distances, the previous results are grouped into five distance categories according to the distance to the closest facility (Fig. 7): less than 100 m, 100–300 m, 300–600 m, 600–800 m, and over 800 m.

The optimal walkable distance is under 600 m, and we found that 69.9% of the population in the city resides within this distance to health facilities. A distance of 600–800 m is also acceptable (in most cases), but a travel distance above 800 m requires using a transport line or vehicle.

Regarding the functional accessibility, the results confirm that the urban master plan affects city health service availability. Thus, new neighbourhoods in the city suburbs have sufficient health accessibility compared to those in the centre of the city because of land availability, which allows for the development of new service facilities in the suburbs (Fig. 8).
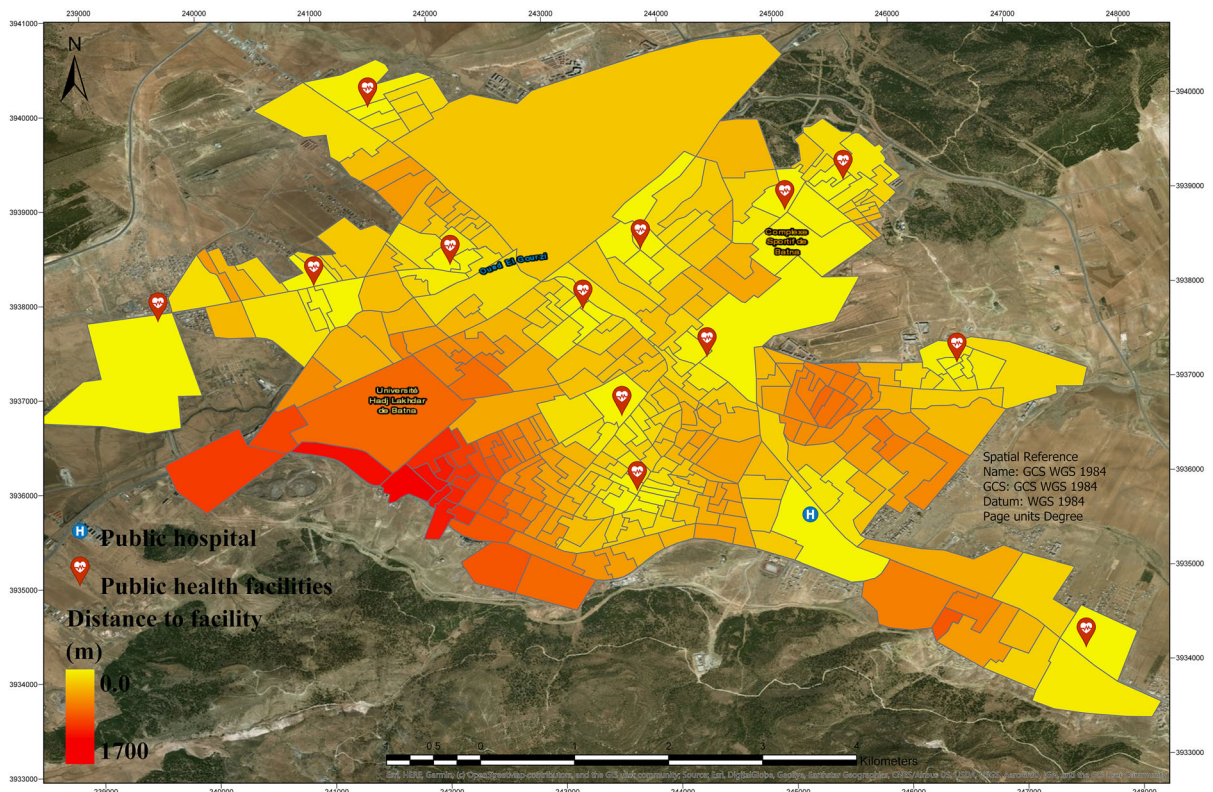

Fig. 6 Distances to facilities based on census tracts

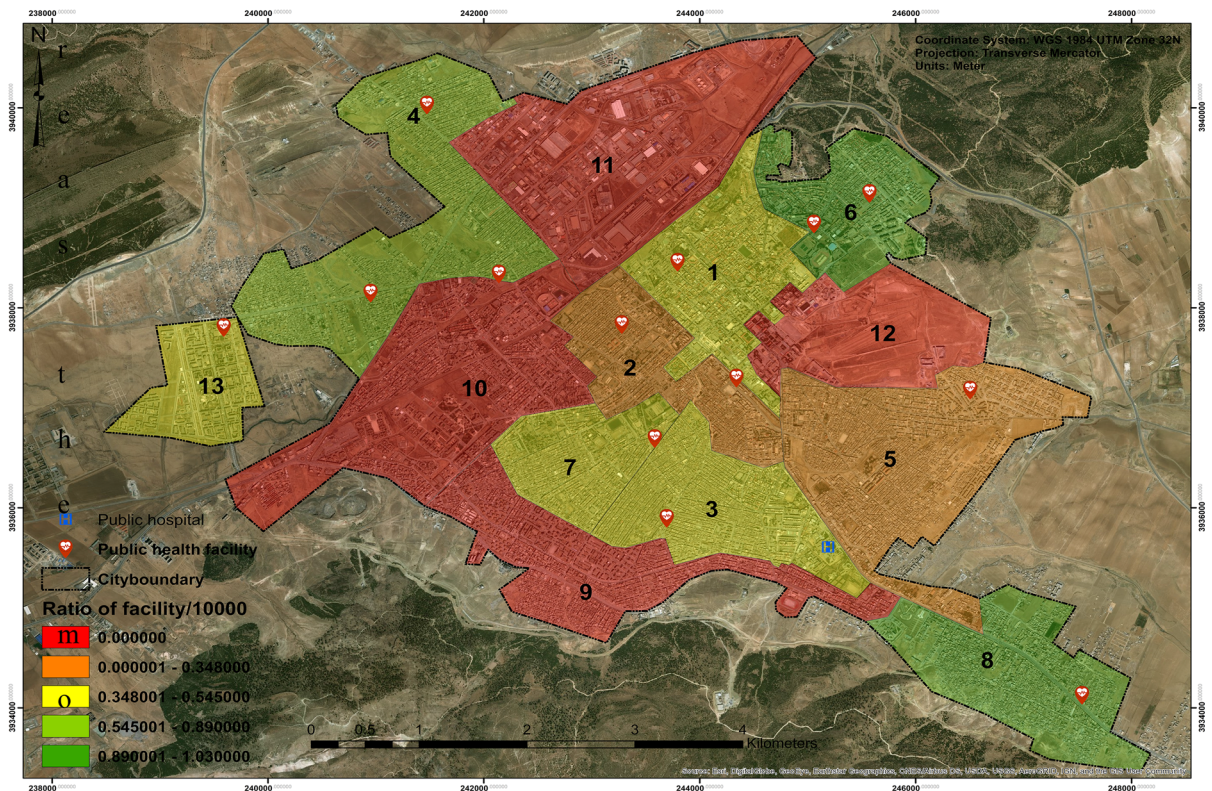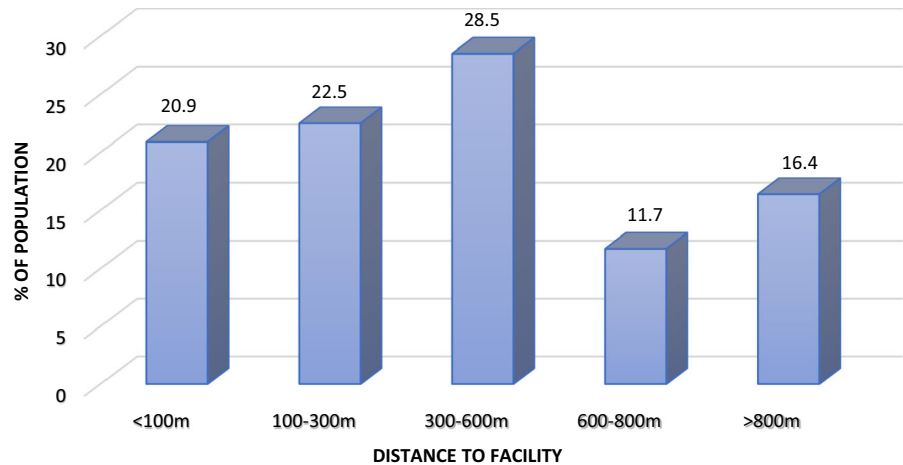**Fig. 7** Distances to the nearest facility

Fig. 8 Ratio of the number of facilities per 10,000 people based on the urban sector

The functional accessibility results confirmed our main hypotheses that space elements are a major factor in healthcare service, especially the availability of land and the urbanisation dynamic. We can explain the relationship between land availability and population as a parameter to health accessibility as follows:

- Sectors 9, 10, 11, and 12 have the lowest health facilities per 10,000 people ratios, (equal to zero) (Table 2) in the city because those sectors do not have any health facilities. Sector 11 is industrial area that was first built outside of the city, but as a result the urbanisation, it became a part of city.

Table 2 Ratio of facilities per 10,000 people ratios for each sector

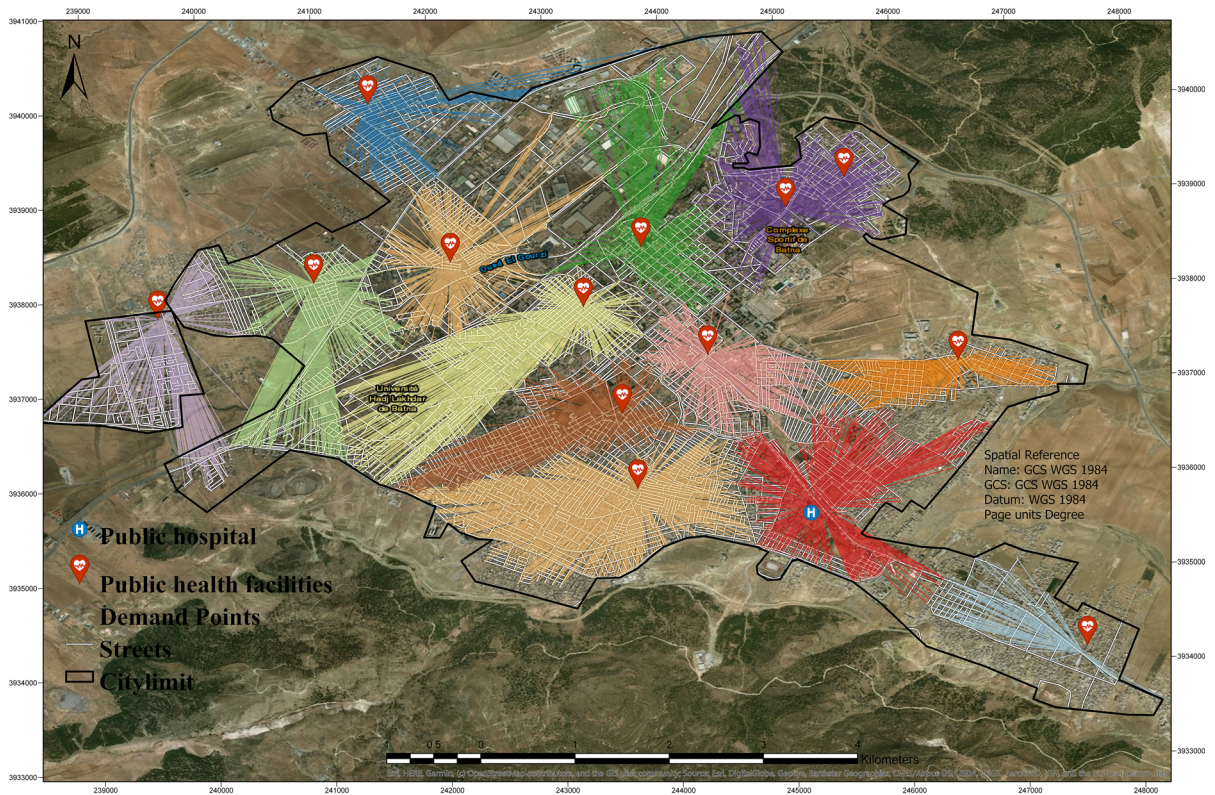| Urban sector ID	Health facilities	Population	Health facilities per 10,000 people
1	1	18,344	0.545
2	2	28,712	0.348
3	2	45,488	0.44
4	3	33,854	0.89
5	1	44,375	0.23
6	2	20,420	0.979
7	1	19,997	0.4
8	1	9685	1.03
9	0	34,784	0
10	0	21,838	0
11	0	0	0
12	0	0	0
13	1	22,201	0.45

Fig. 9 Service area based on the location–allocation method

- The ratios of Sectors 1, 2, 3, 5, and 7 can be classified as medium ratios with 1–2 facilities per sector. These sectors are the most densely populated ones in the city (Fig. 2); hence, the ratio is affected by the population size (Table 2).

Fig. 10 Potential population served by each facility
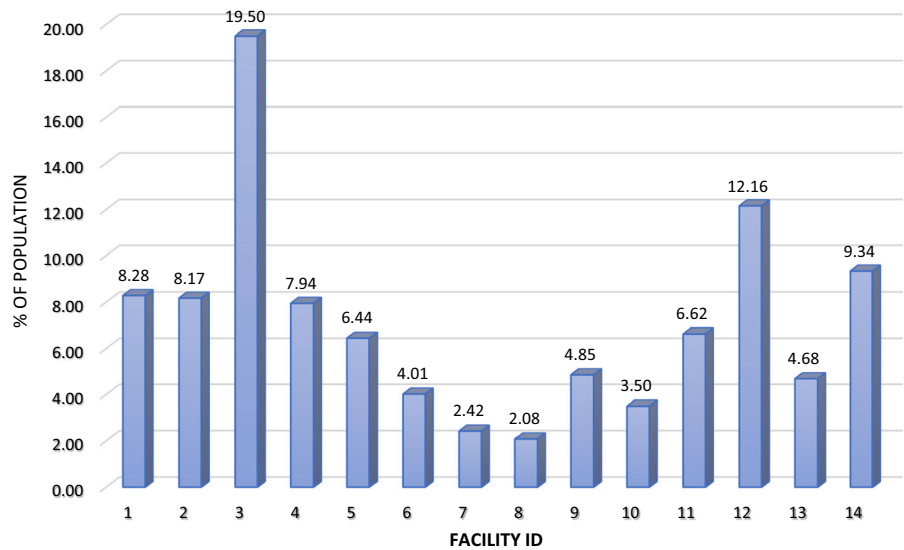
- The remaining sectors (4, 6, 8, and 13) are the suburban areas of Batna. The land in these sectors is available, and the population is limited and less dense compared to the other parts of the city, making those areas the most accessible.

Delimiting the service area based on the location–allocation method

Based on the city road network, we calculated the distance between each resident and the health facilities using the location–allocations method which selects the best health facility to serve the greatest demand (Fig. 9).

From the previous result, we then calculated the population served by each institution (Fig. 10).

As shown in Fig. 10, the imbalance in the distribution of the work effort between health facilities affects their quality, which is based on three causes: distribution of health facilities in the city, distribution of health facilities with respect to population density, and distance to the closest facility.

Discussion

Using territorial parameters such as population distribution, geographical division, and PDAU guidance to measure the space health inequality demonstrates that the distribution of healthcare compared to the population is random, which results in a functional imbalance. For example, Establishment 3 serves 19.50% of the population of the city compared to Establishment 8, which covers only 2.078% of the total population.

Regarding accessibility, the peripheries (suburb area) of the city are more accessible than the city centre, which is rare for an Algerian city (most public services in Algerian cities are found in city centres for historical reasons). This is because the land in the city centre is unavailable, which led to new public services in the PDAU being located outside of the urban area where land is available. This mode of distribution increases the proximity distance to 1200 m but provides an opportunity to service the entire city.

There is an imbalance between the health facilities due to their locations in relation to the population distribution. To avoid this problem, residents must be oriented toward the next nearest establishment(s) in some cases to help reduce the load of the other establishments to improve performance and quality of care.

Conclusion

The results of this study highlight a major imbalance in health services in Batna that is due to the absence of the health sector and all its elements in the territorial approach. Therefore, it is necessary to

integrate health services into the territorial method to obtain the most suitable sites for providing sufficient health services.

The health territorial approach allows us to create new health equipment that is based on scientific criteria because the urban policy (creating public services, housing, transportation, etc.) is random and does not consider the needs of the population (or any known criteria). In the studied case in Algeria, proposing new equipment is based on a pre-treated equipment grid[3] that is the standard for every city in the country. By using this approach, information is transferred via a two-way flow between the health sector to the regional field as directives and orientations, and from the territory of the city to the health sector as a territory project, meaning that the data is updated quickly and frequently. This illustrates the functional deficits or surpluses according to the region and neighbourhood within the city, thus directing new projects towards areas that suffer from a deficit in health services. The workforces in regions with a surplus can be redistributed to the areas that suffer from deficiencies in the workforce.

To succeed with this approach, periodic statistics must be provided on population, educational level, economic level, current health of patients, quality of health care provided, and efficiency of health services. The NHS currently has faces several issues including unavailability of data. A census is conducted every 10 years and some local departments have their own data collected every year or every 5 years; however, it may not be accurate and may only cover population, housing, and economic data.

In summary, the detection of spatial and functional inequities in the local healthcare system of the city of Batna is done using the territorial parameters of population distribution, geographical divisions, and PDAU suggestions. The spatial inequities can serve as the guidelines for PDAU revisions, and the indices and the orientations can be utilised to optimise the health map of the city.

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[3] La Grille théorique des equipement.

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