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USING GIS TO DETECT SPATIAL INEQUALITY IN PRIMARY SCHOOLS IN AIN TOUTA

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Summary

The economic and social changes in Algerian society at the end of the 1980s and the beginning of the 1990s had a radical impact on the urban and regional dynamics and on population growth (besides rural migration) in the regional and urban networks, including cities like Ain Touta, which is considered the most prominent urban agglomeration in the region. Ain Touta was unable to keep up with development challenges, which has led to a deterioration of its education system and other public services. Moreover, the decision-makers of none of these sectors use modern technologies such as geographic information systems (GIS), spatial decision support systems (SDSS), smart cities, and E-government, which would enable them understanding the current issues from a geographical perspective, especially through measuring spatial inequality access to education services.

This paper uses a GIS approach to identify spatial inequality in primary schools and measure the distribution pattern using the nearest neighbour average method, vector distribution, hotspot, and service area analyses. These analyses can be help creating a functional access and disability map to improve the local school map.

The results obtained confirm the basic hypothesis, as it was found that the northern area of the city, which is the area were the immigrant population resides, is the least accessible to educational institutions. In consequence, other parts of the city have to bear the burden of supporting the northern area, and thus themselves become under-resourced.

Keywords

primary school • distribution pattern • GIS • inequality • accessibility • school map

1. Introduction

The public Algerian education system is free from the primary school level (elementary school) through to higher education at university. The government is responsible for providing educational facilities and infrastructure to all citizens. However, the most important is the equality of access to education, which has become one of the goals of sustainable development. Achieving this goal demands inclusive and equitable education that gives learning opportunities for all citizens throughout their lives (UNDP, 2018). Also, education is included in urban development funding programs [Million et al. 2016, Thomas Coelen and Million 2017] and national urban development policies to ensure good educational opportunities that improve the quality of life in cities. Further, educational investments in specific locations and areas can stabilise city quarters and neighbourhoods, so school buildings (facilities) can be considered as structural elements in many cities, settlements, communities and rural areas [Böhme and Flasche 2017]. Therefore, they became a geographic entity available in all territories and could be used in many related spatial studies and urban management [Makropoulos et al. 2003, Coutinho-Rodrigues et al. 2011, Chavare and Ubale 2013, Hashem et al. 2016; Badland and Pearce 2019, Kaczmarek 2019, Tadili and Fasly 2019]. However, it is still studied separately from the field of urban planning, so 'there is a lack of in-depth engagement with the relationships which are, however, said to be positive between educational measures and urban development' [Thomas Coelen and Million 2017]. The classical approach has also been based on the available land, so that the school buildings are located on the nearest plot of land, without taking into account the proximity and rentability of the school to the population.

Algerian law defines *primary education* as the first stage of the education system, thus, the age of pupils at this level ranges between 6 and 11 years. The adopted curriculum focuses on promoting foreign languages and informatics skills. Nevertheless, the improvement of education depends not only on its quality, but also on the equality of its spatial distribution, i.e. location of schools, access to educational facilities, and the distance to schools, which is technically known as a service area [Abraha 2019]. Consequently, this paper aims to identify the spatial inequality in the distribution of primary schools. Thus, it provides a tool for correcting spatial coverage and improving accessibility.

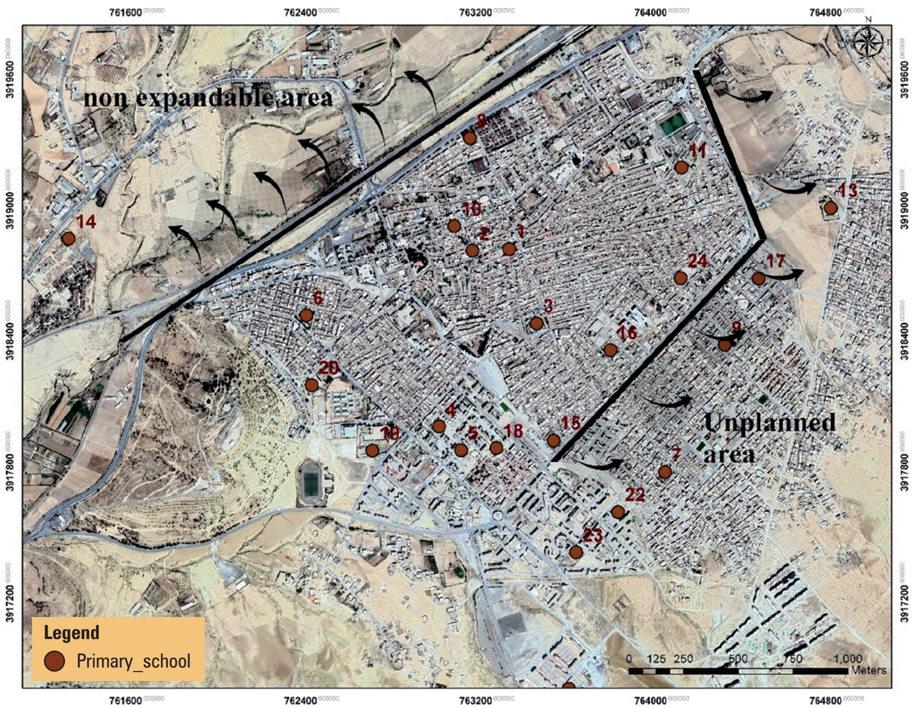
Education is one of the foundations of a nation, and it can be composed of several elements, including issues that require geographical approaches to address them. Therefore, the analysis of educational facilities could be considered as a key spatial indicator in the next generation of Algeria's Urban Master Plan (UMP). This UMP should identify the appropriate location of education facilities, their optimal spatial distribution, characteristics, and relationship with other urban land uses. The UMP also involves school mapping to guarantee competent and equitable distribution, especially during major reforms and significant growth periods [Ngigi et al. 2012]. This is essential to promote accessibility and equity of distribution, which allows to avoid over-localisation or over-concentration of schools in certain areas and creating deficits in others. School mapping is also important because it creates an environment conducive to universal education [Ekpoh 2018]. Therefore, primary school is a key element in the functioning of a neighbourhood, and determines the size of a neighbourhood (in generally, it should be less than 15 minutes or approximately a radius of 600 m).

This research paper aims to use GIS approach to assess the inequality of spatial distribution of schools based on geo-statistics analysis (i.e., distribution, hotspot, and ratios.).

2. Study area

The city of Ain Touta is the third most populated city in the province of Batna, with more than 100,000 inhabitants [DPSB 2017]. It is located in the south of Batna province, 450 km southeast of the capital, Algiers, between 6°7'and 6°13' east longitude and 35°34' and 35°31 north latitude. Situated between two mountain ranges, where most settlements are rural [La Direction Technique Chargée des Statistiques Régionales 2008, Office 2011], it is the only urban settlement in the area that provides good quality services (attraction pole).

The city is located at an intersection of several important roads, particularly the National Road number 03 (RN03), connecting Constantine and Biskra, and the National Road number 28 (RN28), linking M'sila and Batna city, as well as the Constantine-Biskra railway line, which extend its area of influence from local to regional. Ain Touta displays two types of urban development: an unplanned area in the southeast, and an area of essential services, which contains 24 primary schools, with six or twelve classrooms, and the average number of pupils per group ranging from 14 to 52. This situation, based on the spatial and functional deficit and the reorientation of pupils to the nearest one as a temporary organisation action, indicates the need for new schools.



Source: Authors' own study

Fig. 1. Ain Touta, geographic location, and primary schools' distribution

3. Methodology

GIS is one of the technologies that allows to solve many geographical problems quickly and efficiently, it supports analyses and provides a comprehensive framework and organisation of spatial, descriptive, and topological data. By combining spatial analysis with traditional database systems, it can be used in various domains, including crisis management that deals with natural or technological hazards, based on geographic approach [Cova 1999, Gunes and Kovel 2000, Johnson 2000, Schneider and Schauer 2006, Siddayao et al. 2014, Rimba et al. 2017], as well as healthcare and epidemiological studies [Akakba and Lahmar 2020, Cordes and Castro 2020].

The geostatistical analysis is one of the most important analyses in geography (and other subdisciplines). The main difference between classical statistics and geo-statistics is the assumption of a spatial dimension. The classical approach (statistics), according to Oxford Reference, is concerned with the collection, organization, analysis, interpretation, and presentation of data, whereas geostatistics is a statistical analysis of spatial or spatiotemporal phenomena, like dispersion, distribution, spatial correlation, etc. [Shekhar and Xiong 2017].

One of the domains of application of GIS is education Many papers and studies in this field (Ngigi et al. 2012, Kiani et al. 2018, Baser 2020, Ubogu 2020, AlQuhtani 2022, Jażdżewska et al. 2022) use it to solve geographical issues with education facilities. Therefore, we should highlight the distribution among the most common analysis methods as it gives us a better understanding of the spatial distribution pattern on which school planning decisions are based [Mashrur et al. 2015, Murad 2018, Murad et al. 2020, Al Quhtani 2022]. Generally, the analysis outputs will include the capacity of schools, spatial distribution, number of students and teachers, classrooms, and statistical reports within and between schools/districts.

In order to detect spatial inequality in a selected primary school in the city of Ain Touta, we used a GIS approach that provides several analysis methods. Using GIS, we modelled the school facilities as feature classes in the city geographic database to perform geostatistical, statistical, and network analyses that measure spatial inequalities. Therefore, developing this geodatabase aims to adopt a spatialisation tool for digital geographic information, and replace traditional maps and static plans. Moreover, this comprehensive database makes it possible to adjust the georeferencing of different plans, reducing graphic tolerance.

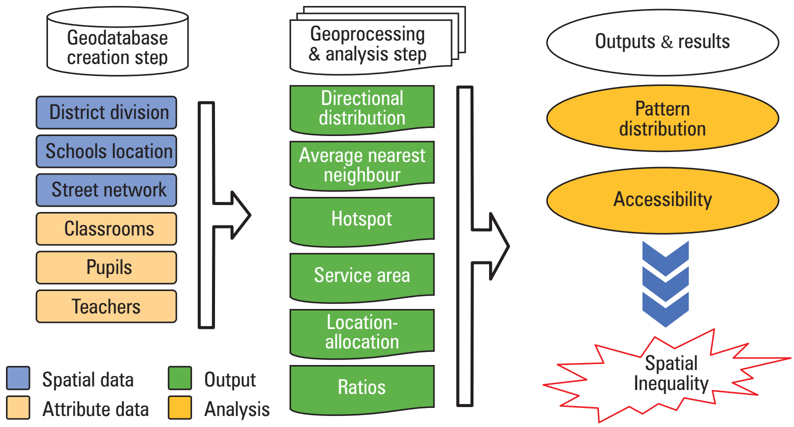
The first step in this research was to develop a geographical database that contains data related to the urban area and the educational service. This approach allows us to determine and measure spatial school inequalities in the urban area; it combines education service data (school facilities, ratios, and human resources) within the urban master plan (urban island, streets, buildings, land use, etc.). This approach relates the education sector to the interactions between component of an urban area.

In the second step, we determined the spatial inequalities of primary schools by measuring the following: distribution, pattern, geometric coverage of the service, deficit and surplus.

In the third step, in order to simplify the management of the education service from the geographical point of view, we solved the spatial inequality in the urban master plan, because it contains cadastral data that allow us to choose the most effective urban islands for the construction of new schools (see Fig. 2).

3.1. Spatial inequality assessment

School spatial inequality is the distribution of inequality of education services across city neighbourhoods, such as the pupil-teacher ratio, pupils/classrooms, and the distance to the school. In order to measure spatial inequality, we will use the following analyses (see Fig. 2).



Source: Authors' own study

Fig. 2. Measuring spatial inequality approach, inputs, geoprocessing tools and outputs

3.1.1. Distribution pattern

The Average Nearest Neighbour (ANN) index is one of the most widely used indices by geographers to measure the pattern of distribution in space. It is one of the few measures that depend on a 'quantitative' continuous scale. It is used to examine the overall distribution of schools within a study area based on the expected distance of each point from its nearest neighbours. The closer the value of the ANN index is to zero, the more it represents a clustered pattern, and the closer it is to 2.15, the more it represents a dispersed pattern; a value of 1 also indicates a random pattern [ESRI 2019].

The Average Nearest Neighbour ratio is given as:

$$\mathrm{ANN} = \frac{\overline{Do}}{\overline{De}}$$

Where $\overline{Do}$ is the observed mean distance between each feature and its nearest neighbour:

$$\overline{Do} = \frac{\sum_{i=1}^{n} di}{n}$$

And $\overline{De}$ is the expected mean distance for the features given in a random pattern:

$$\overline{De} = \frac{0.5}{\sqrt{\frac{n}{A}}}$$

where:

- di – equals the distance between feature i and its nearest neighbouring feature;
- n – corresponds to the total number of features
- A – is the area of a minimum enclosing rectangle around all features.

3.1.2. Spatial distribution of deficit and surplus

Using the Hotspot analysis tool analysis allows us to locate areas of high density of schools (hotspots) and thus identify the places with a deficit in the city's educational service. The intensity of demand for educational services is calculated by the ratio of students to teachers or the number of pupils in the classroom. So, the ratio is a functional index proposed by international academic community, such as the number of students per group and pupil/teacher ratio [UNESCO 2009].

The Hotspot analysis tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots); it creates a new output feature class with a z-score, p-value, and confidence level bin (Gi Bin) for each feature in the input Feature Class. A high Z score and a small *P*-value for a feature indicate a significant hot spot. A low negative Z score and a small *P*-value indicate a significant cold spot [ArcGIS Pro Help 2022].

The Getis-Ord local statistic is given as:

$$G_i = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \overline{X} \sum_{j=1}^{n} w_{i,j}}{s\sqrt{\frac{n \sum_{j=1}^{n} w^2_{i,j-\left(\sum_{j=1}^{n} w_{i,j}\right)^2}}{n-1}}}$$

where:

- X_j – is the attributed value for feature *j*,
- $W_{i,j}$ – is the spatial weight between feature *I* and *j*,
- n – is equal to the total number of features and:

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_{j-2\left(\overline{X}\right)^2}}{n}}$$

The G_i statistic is a *z*-score, so no further calculations are required.

The G_i statistic returned for each feature in the dataset is a *z*-score. For statistically significant positive *z*-scores, the larger the *z*-score is, the more intense the clustering of high values (hot spot). For statistically significant negative *z*-scores, the smaller the *z*-score is, the more intense the clustering of low values (cold spot) [ArcGIS Pro Help 2022].

3.1.3 Spatial distribution of educational services

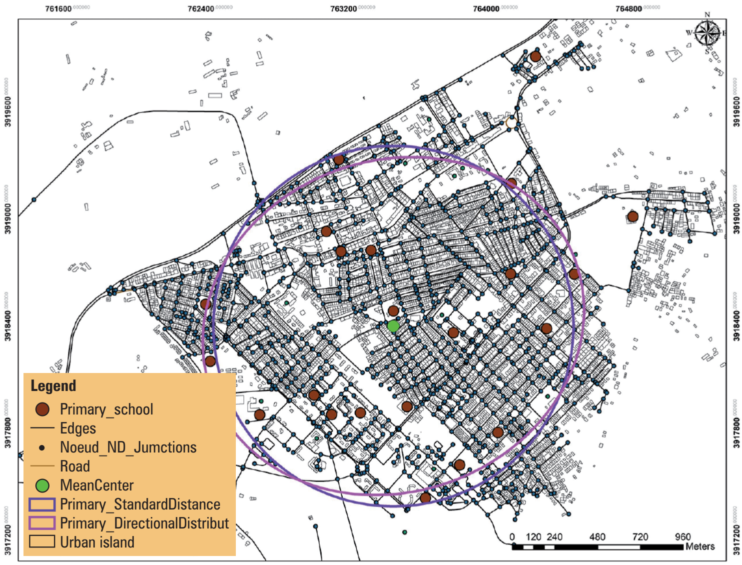
Service areas are mapped using network analysis, a method popular in many studies. The application of this analysis is explained in detail in the following references [Garnick et al. 1987, Higgs 2004, Chen and Jia 2019]. Using this tool, the analysis allows us to model, simulate, optimize and visualize the area of influence, define the educational institution (such as primary school) as a central point, and specify a maximum travel distance or time that a pupil can reasonably be expected to travel. The tool then calculates the area that falls within the service area. The following diagram summarizes the stages of the transition from the classical approach to the geomatics approach.

4. Results and discussion

There is geographical and functional inequality, which is addressed by many different methods and approaches. However, we propose to measure spatial inequality using ANN and service area. Functional deficit is also measured by hotspots and ratios.

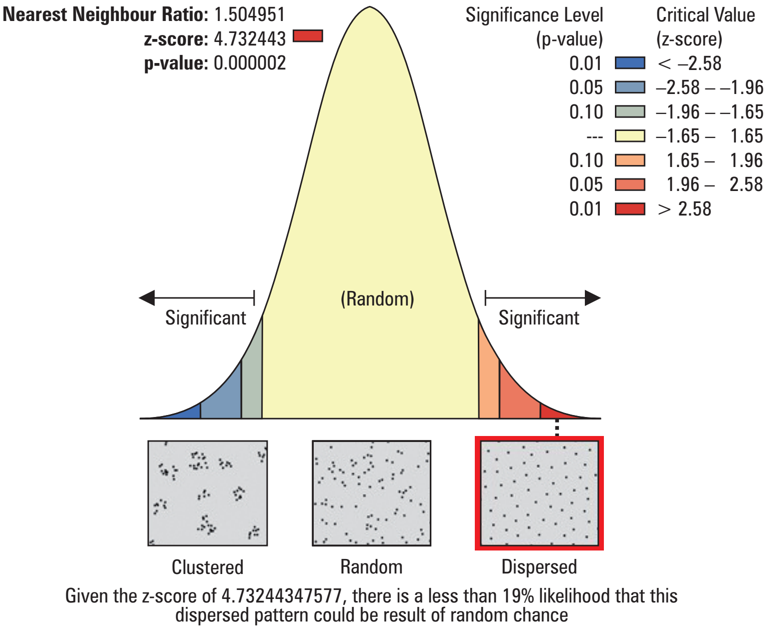
4.1. Directional distribution

The directional distribution allows us to see whether the distribution of features is elongated and, hence, has a particular orientation. In our study, primary schools are oriented from the northeast to the southwest with a rotation of 74.66 degrees, because the northeastern part of the city is not expandable, and the southern side is an unplanned neighbourhood. The results of the analyses are shown in Figure 3.



Source: Authors' own study

Fig. 3. Ain Touta, geostatistics results in the geographical database



Source: Authors' own study

Fig. 4. Average nearest neighbour values for the primary schools in Ain Touta

4.2. The nearest neighbour

The nearest neighbour method statistically determines the spatial distribution pattern of the geographical location of the schools, which gives us the degree of clustering and dispersal of features. By running the average nearest neighbour tool (Fig. 4) with the city's area (541ha) as input, the distribution pattern of the schools in Ain Touta is dispersed. This is confirmed by the ANN score, ANN = 1.504951, z-score = 4.732443, and p-value = 0.000002. Thus, the given results (z-score), 'there is a less than 1% likelihood that this dispersed pattern could be a result of random chance'. With an average distance of 357.2607 m from each school and its nearest neighbour.

The primary school facilities are dispersed, allowing to expand the service area to cover the entire city, which has a positive effect on accessibility, except in the suburban areas in the southeast, since their residential neighbourhoods are chaotic and have a deficit of school facilities.

4.3. The service area

The service area tool offered by the network analysis allowed us to model, calculate, simulate, optimize and visualize the area of influence of the educational facilities, from pupils' homes to the nearest primary school, taking into account the various existing barriers in order to identify the accessibility to the educational facilities or and to detect a spatial deficit.

We compared two service area threshold distances. The first distance (service area radius) of 357m is based on the previous ANN analysis results, which covered 53.62% of the urban island, rather than the practical distance service area of 600m covered 86.23% of the urban island in the city (Fig. 5).

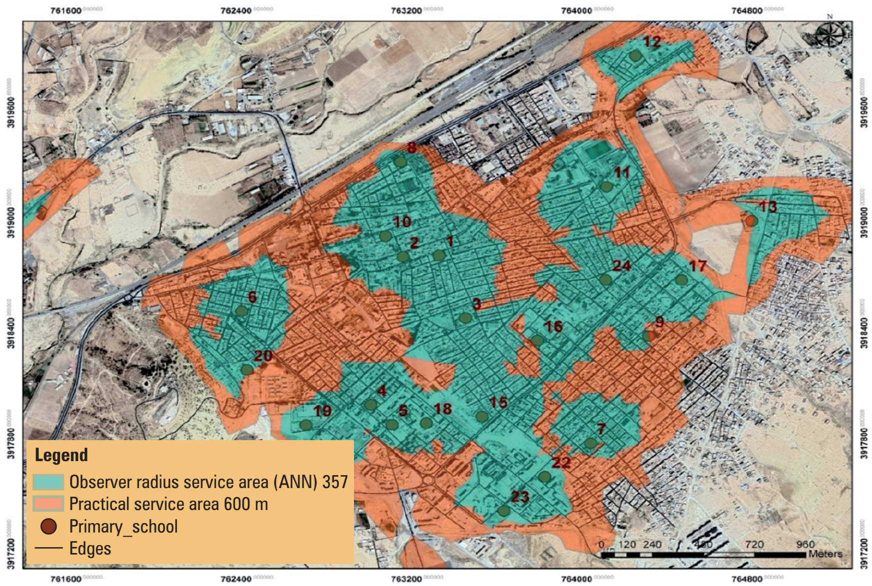


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Fig. 5. Ain Touta, observed and practical service area of the primary schools

The southeastern part of the city needs to be covered by either the practical or the observed service area distance. This result confirms the previous analysis results, where our main hypothesis is that the city's spatial inequality is reproduced in relation to the school facilities.

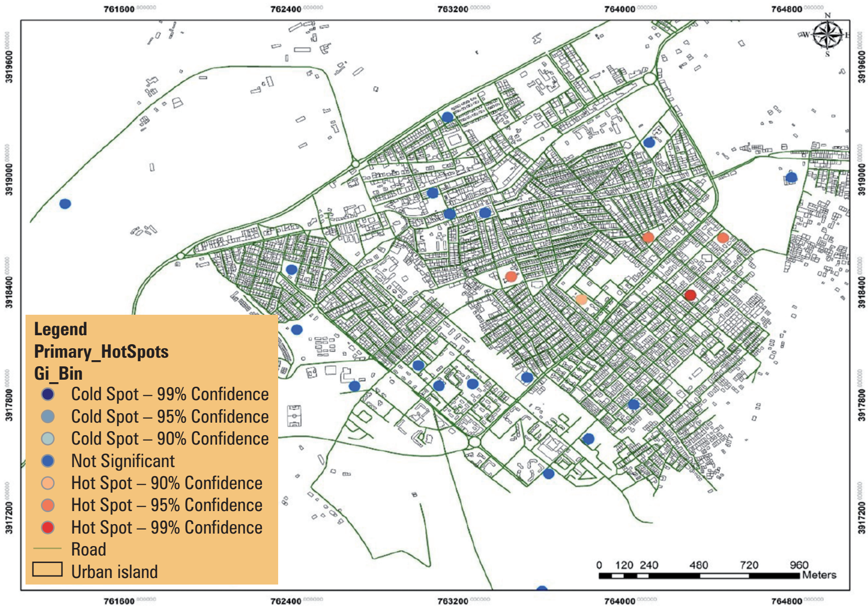
It must be pointed out that private land ownership is one of the most important reasons for spatial inequality, since the transfer of private property for public use requires legal procedures and financial compensation for the owner.

4.4. Hotspot analysis

To determine the geographic locations of school under- or oversupply in the city, we used hotspot analysis that highlights high-density areas in red and low-density areas in blue. This analysis helps decision-makers interpret the spatial factors affecting the distribution of educational services in the city.

Schools, ID 3, 9, are considered hotspots at a confidence level of 99%. In comparison, schools with ID 13 (the confidence level of 90%) to large (a confidence level of 95%) hotspots.

The schools with z-scores close to zero have *p*-values > 0.05 and therefore insignificant. The results of the hotspot analysis (Fig. 6) indicate the concentration of high values in the south of the city because they attract pupils from non-planned neighbourhoods.



Source: Authors' own study

Fig. 6. Educational facilities in Ain Touta, Hotspot Analysis

4.5. Pupil-Teacher Ratio (PTR)

The pupil-teacher ratio (PTR) and the number of students per group are among the indicators measuring the quality of education.

PTR ratio varies depending on the location of the school. For example, school ID 9 records the highest value (52 pupils/class), where it is the nearest school for non-planed neighbourhoods in the southeast of the city. On the other hand, we find the lowest value (14 pupils in a class) in another suburban school, which is the furthest from the non-planed neighbourhood and serves local pupils.

We created an effective communication and coordination tool based on the results obtained by the education department and the technical department of Urban Planning. This tool must be applied rigorously to update the database and ensure the associated retention.

5. Conclusion

All previous analyses, the average nearest neighbour, the service area, the hotspot analysis, and the pupils/teacher ratio, confirmed the spatial inequality in the distribution of educational facilities in Ain Touta. This spatial undersupply has a negative impact on the quality of education, as the pupils living in suburban areas have to travel to the nearest schools in the planned neighbourhoods.

Based on the previous analyses, it is recommended to improve the school map by integrating the GIS, which allows us to improve the education quality function through:

- Creating two new schools in the planned neighbourhoods (southern part of the city) and another two schools in the northern suburban area.
- expanding areas of high-density of education facilities, adopting double-shift teaching time, and improving pupils' orientation in other schools.

As a final outcome, this paper contributes to the application of GIS as a coherent tool for the control, management and organization of educational facilities for the implementation of the development plan, by ensuring the following:

- Identifying spatial inequality.
- Identifying functional deficits.
- Suggesting the location of future educational facilities based on the spatial and functional indicators.
- Promoting education management based on modern techniques (GIS and SDSS).

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