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CONTRIBUTION OF GIS IN HEALTH PLANNING, CASES OF ONCOLOGY IN ALGERIA

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Abstract: Geographic Information Systems (GIS) have become an essential tool in health planning, allowing for the analysis and visualization of spatial data to improve healthcare. In Algeria, the use of GIS in oncological care is still in its early stages, but has the potential to greatly enhance the planning and delivery of cancer services. This study aims to assess the contribution of GIS to health planning in the provision of oncological care in Algeria. Specifically, we will examine how Network analysis can be used to identify areas with high accessibility, map out healthcare facilities and resources, and optimize the allocation of resources to improve access to cancer treatment.A review of existing literature on the use of GIS in health planning and oncological care will be conducted, along with an analysis of cancer incidence data in Algeria. GIS software will be used to map out accessibility rates, healthcare facilities, and population distribution to identify areas in need of improved oncological services. The results of this study will provide valuable insights into how GIS can be utilized to enhance health planning in the provision of oncological care in Algeria. By identifying areas with high accessibility rates and mapping out healthcare resources, policymakers and healthcare providers can better allocate resources to improve access to cancer treatment and ultimately improve patient outcomes.

Keywords: GIS, accessibility, road network, Oncology, Algeria

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INTRODUCTION

The use of geographic information and geomatics tools is a reality no longer demonstrated. Experience around the world has so far raised many questions about the role that these tools should now play in the management of territories. This work explains to us the methods of analysis of medical geography and how this discipline, taking into account the contributions of other social sciences, can be used to improve the practice of health planning.

The East makes it possible to highlight atypical territories in terms of links between social inequalities and health inequalities which require a more in-depth analysis. "Finally, the cartographic comparison between epidemiological and social indicators is very delicate" (Telle-Lamberton et al., 2016). In 2017, Bonastre et al analyzed the effects of the recomposition of the supply in oncology based on the evolution of access distances and departmental referral rates. However, the supply of care marks centralizations and concentrations in certain territories, which reflect a spatial inequality in the distribution of the supply of care, in this subject Bonastre et al note that "First of all, as in other therapeutic areas, a policy of concentrating the supply of cancer care has been implemented to improve the quality of care" (Bonastre et al., 2017).

Equity in the quality and quantity of care offered are the fundamental values of the health planning process. Given the great importance of the oncological service in urban and rural spaces, many humanities, applied sciences, planning and geography have paid great attention to the capabilities and diversity of the service. Cancer is classified as a non-communicable disease. According to Ferlay cancer is "the second cause of death in the world, cancer causes around 10 million deaths per year. Nearly one in six deaths is due to cancer worldwide (Ferlay et al., 2021). In 2014 Hamdi-Cherif declared that: "cancer is currently one of the main public health problems in Algeria" (Hamdi-Cherif et al., 2014). As the cases of cancers are continuously increasing in Algeria and the internal elements of contemporary urban planning evolve, the criteria for health planning differ in terms of geographical distribution and correlation.6

It was becoming difficult to maintain the centrality of oncological services due to the large size of the wilayas and the need to be located near residential areas. This makes oncology services one of the most important services to plan for distribution in the wilayas to ensure their access as soon as possible. The planning of their distribution is an important and essential determinant of the effectiveness of this service. In terms of geographic information, the use of references has become practical, that is to say, that we use the cartography of certain reference data, which have known geometric characteristics (data, projection system, " coordinates" of location, degree of precision of the data, etc.), and which are useful for geo-referencing and geo-research of information.

The importance of cartography is crucial in the geography of health to facilitate the analysis and interpretation of several indicators in this subject. In 2021, Laurent and other researchers examined how to apply a spatial approach

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(relational and geographical) to the journeys of breast cancer care for their better integration within their territories where they affirmed that: “Maps can help define how to develop integrated and patient-centered care services” (Laurent, 2021).

In the context of the geography of health and non-communicable diseases, in 2020, Léa Prost, proposes, via “the mobilization of geographical approaches, a (different) reading of the risks of carcinogenic exposure in adults. It shows that the geography of the disease is not only the reflection of the geography of the risk factors and that the circumstances in which these exposures take place are complex, in particular because they are part of the articulation of individual trajectories and territorial trajectories" (Léa, 2020). By leveraging master data management, city departments can pull together all of their data efforts in a unified strategy accessible to all members concerned. This approach will better support everyone. The data on the road network of the wilayas are part of the strategic data for the management of these wilayas. These markers are used in many commercial applications, whether for administrative reasons, to inform the place of residence of families, but also for technical reasons, to locate interventions on the public road, and finally, to adapt the infrastructures to the needs of the population. The two researchers used GIS technology as the latest applied fields that help support contemporary geographic studies by providing a mechanism to analyze spatial data and relate it to descriptive information (attribute data) to yield positive or negative results.

On the other hand, Tina and Abdelmadjid, 2024 confirms that The Network Analyst extension which resides in the GIS produced the best routes between the port locations and the activity areas on the road network based on the time and length of the journey. Other research confirms that geographic information systems are the best ecosystem for acquiring, managing, analyzing, mapping and representing spatial information (Gianluca et al., 2024) GIS (Geographic Information Systems) plays a crucial role in health planning, especially in the field of oncology in Algeria. Here are some of the contributions of GIS in health planning for oncology in Algeria. To effectively plan for the distribution of oncological services in the wilayas, it is important to consider factors such as population density, accessibility, and existing healthcare infrastructure. Geographic information systems (GIS) can be utilized to analyze these factors and determine the most strategic locations for oncology services.GIS technology allows for the visualization and analysis of spatial data, making it easier to identify areas with high demand for oncological services and areas that are currently underserved.

By overlaying demographic data, transportation networks, and existing healthcare facilities on a map, planners can identify optimal locations for new oncology centers. Additionally, GIS can be used to model different scenarios and assess the potential impact of different distribution strategies. By simulating the effects of different location decisions, planners can make informed decisions that maximize the accessibility and effectiveness of oncological services in the wilayas. Overall, the use of GIS technology in the planning of oncological services distribution is crucial for ensuring that these essential services are accessible to all residents in a timely and efficient manner. By leveraging the power of geographic information, planners can optimize the distribution of oncology services and improve the overall quality of cancer care in the wilayas.

The are in specialized centers can lead to spatial inequality in access to care for patients living in remote or rural areas. This can result in longer travel distances and increased costs for patients seeking treatment. Geographic information systems (GIS) and geomatics tools can be used to analyze these spatial inequalities and help health planners make informed decisions about the distribution of healthcare services. By mapping out access distances and referral rates, planners can identify areas that are underserved and in need of additional resources.

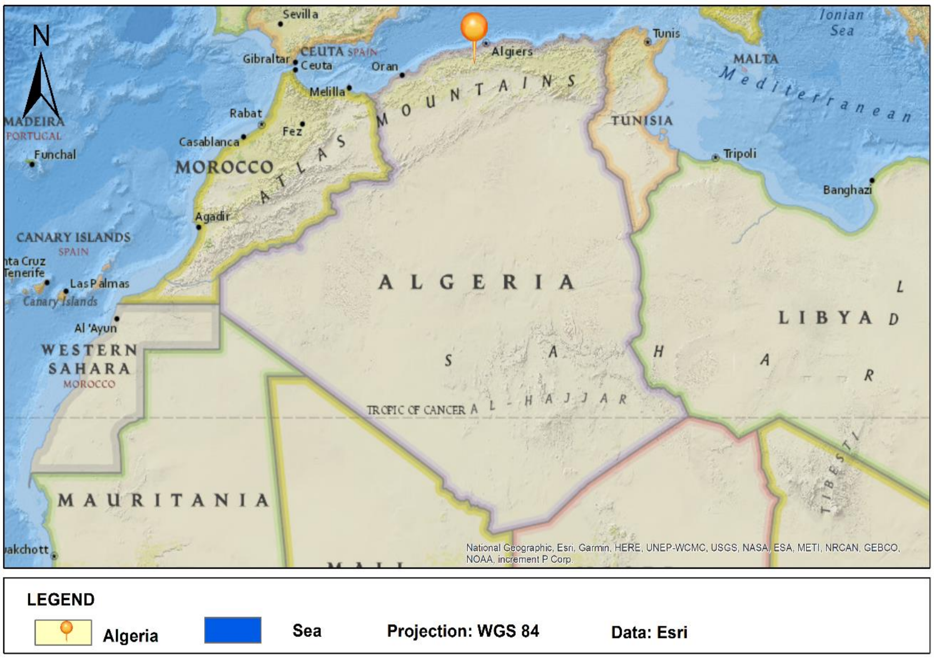

Figure 1. Study area (Source: Realized by authors)

In addition, medical geography can also be used to study the social determinants of health and how they impact health outcomes. By analyzing the relationship between social inequalities and health inequalities, planners can develop targeted interventions to address the root causes of these disparities. Overall, the use of geographic information and geomatics tools in medical geography can help improve the practice of health planning by providing valuable insights into the spatial distribution of healthcare services and the social factors that influence health outcomes. By taking a holistic approach that incorporates the contributions of other social sciences, planners can develop more effective and equitable healthcare policies that benefit all members of society.

MATERIALS AND METHODS

1. Study Area

Algeria, situated as the gateway to Africa, holds significant prominence due to its expansive geographical area, covering 238,741 square kilometers and housing a population of approximately 43 million inhabitants (Lagha and Bachi, 2018). The country itself is marked by a diverse range of physical features, economic circumstances, social customs, and governmental initiatives. Originally divided into 48 wilayas, the administrative organization of Algeria has been updated to encompass 58 wilayas, as per the latest division established by law n° 19-12 in 2019 (Figure 1). This adjustment aims to enhance the management of this vast territory (Naili and Telaidjia, 2022).

2. Data source

In any location-allocation model, the location of facilities the set of demand points and the supply networks by which facilities fulfill the needs of demand points are essential. In this study, we relied on several data sources for various purposes (Table 1). Firstly, we utilized data on the location of oncology services (oncology service locations (the facilities) in Algeria, and their respective capacities were obtained from the MSPRH for the year 2021) to identify the available facilities in the study area. This information was crucial for understanding the existing infrastructure and its spatial distribution. Secondly, we obtained data on population distribution (collected from MSPRH for the year), which helped us identify the demand points for the service users. This demographic information allowed us to assess the potential accessibility and coverage of the oncology services. Lastly, we incorporated data on the road network (GIS database was built using OSM map to build a network dataset. This dataset served as a foundation for analyzing travel times, distances, and routes between the population locations and the oncology service facilities. By combining these data sources, we aimed to study the spatial dynamics of oncology services and their accessibility to the population.

Table1. Data sources and their utilization in the study

Data	Source	Use
Location of oncology service	MSPRH	To determine the location of available facilities
Population location	RGPH	To know the demand points of the service users
Road network	OSM	TO build the network dataset

3. Method

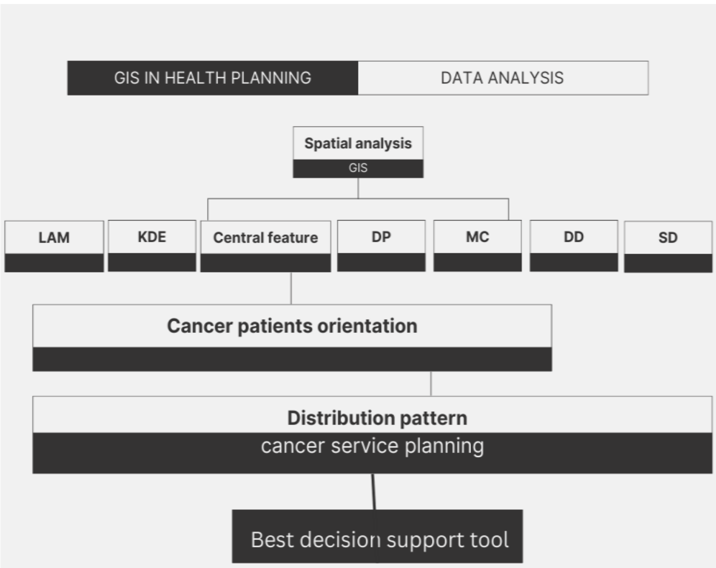

Figure 2. Method of using GIS in health planning

3.1. Location allocation modeling (LAM)

Minimizing weighted impedance or p-median modelling available by Arc GIS software was used in our study to identify a certain number of oncology services between a range of candidate facility locations in Algeria reducing the overall distance of travel from the districts to their closest oncology services (Figure 2). In p-median allocation problem solutions, Facilities are situated in such a manner that the amount of all weighted costs between the demand points and the solution facilities are reduced. The objective function is to make Z as small as possible (Church and Murray, 2008) Mathematically, the P-median problem can be summarized as follows:

Components: Z: objective function to be minimized; ∑i∈I: sum over all demand areas; ∑j∈J: sum over all possible facilities; ai: weight or cost associated with demand area I; dij: distance between demand area i and facility j; xij: binary variable indicating whether demand area i is assigned to facility j; p: number of facilities to be located; (i, j): pair of demand area and facility; Xi j: binary variable indicating whether demand from demand area i is assigned to facility j

Units: Geographic coordinates (X, Y) for demand areas and facilities; Distance units for dij (e.g. miles, kilometers); Binary values (0,1) for Xi j and xij.

Minimize Z= ∑i∈I ∑j∈Jaidijxij (1) (Daskin, 2009).

Subjective to possible constraints, an individual demand site must be assigned to a facility described as:

∑j∈Jxij = 1 for all i (2) (Daskin, 2009).

Demand must be assigned to an open facility as follows:

xij ≤ ∑xjj for all (i, j) (3) (Daskin, 2009).

The number of facilities (p) must be located (the number of communities assigned to themselves equals the number of facilities to be located):

∑j∈Jxij = p (4) (Daskin, 2009).

All demand from an individual demand site is assigned to only one facility:

Xi j= (0,1) for all (i, j) (5) (Daskin, 2009).

where Z is the objective function; I the set of demand areas (usually nodes of a network); the subscript i an index denoting a particular demand area;

J is the set of candidate facility sites (usually nodes of a network); the subscript j an index denoting a particular facility site; ai the number of people from demand site i; dij the distance separating place i from candidate facility site j.

dij = 1 if demand at place i is assigned to a facility opened at site j or = 0 if demand at place i is not assigned to that site. p is the number of facilities to be located. Road network coverage was used for the P-median model, and it was applied using oncology services as p and the location of population as i (demand location).

ArcGIS network analysis was used to produce the P-median location-allocation model for Algeria oncology services (Figure 8). This output helped us to the optimum location of each oncology service. For example, Annaba center was allocated to four Provinces. The Allocation function of ArcGIS produces a table output that defines the optimum health care centre allocations, including the name of the health centre and its assigned Provinces.

3.2 Kernel density estimation (KDE)

Kernel Density Estimation (KDE) is one of the useful tools for determining the spatial intensity of a point process, and understanding and predicting potential event patterns (Gavin et al., 1993). It describes the global trend of a parameter, and the KDE method uses kernel density interpolation to reveal the distribution of event points in the study area (Silverman, 2018).

3.3. Distribution pattern (DP)

One of the most important analyses in urban planning is statistical analysis especially the spatial distribution of facilities based on the principles of proximity (Batty, 2013). To analyze the pattern of the spatial distribution of oncological service. We will use a set of analyses found in the distribution pattern extension.

3.4. Central feature (CF)

The Central Feature tool identifies the most centrally located feature in a point, line, or polygon feature class. Distances from each feature centroid to every other feature centroid in the datasets are calculated and summed, then the feature associated with the shortest accumulative distance to all other features (weighted if weight is specified) is selected and copied to a newly created output feature class (Anselin et al., 2004).

3.5. Mean center (MC)

The mean center is the mean x, y and (if available) z coordinate of all entities within the study area. It allows you to track changes in the distribution or compare distributions of different types of entities (Getis, 2010).

3.6. Directional distribution (DD)

A common way of measuring the trend for a set of points or areas is to calculate the standard distance separately in the x-, y- and z-directions. These measures define the axes of an ellipse (or ellipsoid) encompassing the distribution of features. The ellipse is referred to as the standard deviational ellipse since the method calculates the standard deviation of the x-coordinates and y-coordinates from the mean center to define the axes of the ellipse (Anselin et al., 1992).

3.7 Standard distance (SD)

Measuring the compactness of a distribution provides a single value representing the dispersion of features around the center. The value is a distance, so the compactness of a set of features can be represented on a map by drawing a circle or a sphere with the radius equal to the standard distance value. The Standard Distance tool creates a circle polygon or a multipatch sphere if your data is z enabled.

RESULTS

1. Access to oncology services:

Access to oncology services is a multidimensional concept that describes people’s ability to use health services when and where they are needed. It describes the relationship between attributes of service and the characteristics of service delivery systems. Using maps for health service locations is an important GIS application. There are four main ways of measuring accessibility to health locations which include: (a) Spherical distance, which measures the distance along a great circle connecting two points (used for small-scale investigations); (b) Euclidean (straight-line) distance, which works with projected geographical coordinates; however, it fails to consider transportation routes and barriers to movement; (c) Manhattan metric, which is used to calculate distance with areas that follow a grid pattern road network; and (d) network distance, which computes the length of the shortest path along the transport network. Looking at these four accessibility techniques, network distance is selected because it is the more accurate and real index that produces accessibility zones that take into account the road network of the study area.

To further analyze the location and distribution of oncology services, the drive-distance analysis technique was applied for our study. To, calculate the travel distance between oncology service locations in Algeria, the ArcGIS software was used to define the route connecting health center locations and to sum the estimated travel distance along each road segment in the route. Therefore, our work has applied the same travel time values (30 min) to oncology services in Algeria

To more accurately analyze the accessibility of oncology services in our study, we calculated 100 km 300 km 600 km travel distances for oncology services, then selected nearby oncology services for each province (demand point) using the extension ArcGIS Network Analyst and generated network service areas and nearest facility, for each health center location in Algeria. The resulting service area is a region that covers all accessible routes (i.e., streets that are within 100,300 or 600 km travel Distance to oncology services) come about, closest facility path is the shortest route to the nearby oncology services of each province (demand point).

Figure 3 shows, which parts of the study area, have low accessibility based on the criteria of 100,300 and 600 km travel Distance. These parts are located mainly in the north, and southwest of our study area. Based on this output, several areas of Algeria have low accessibility to oncology services because they fall outside the 100,300 or the 600 km drive-Distance service area. These are located in the western, eastern, and southern Algeria.

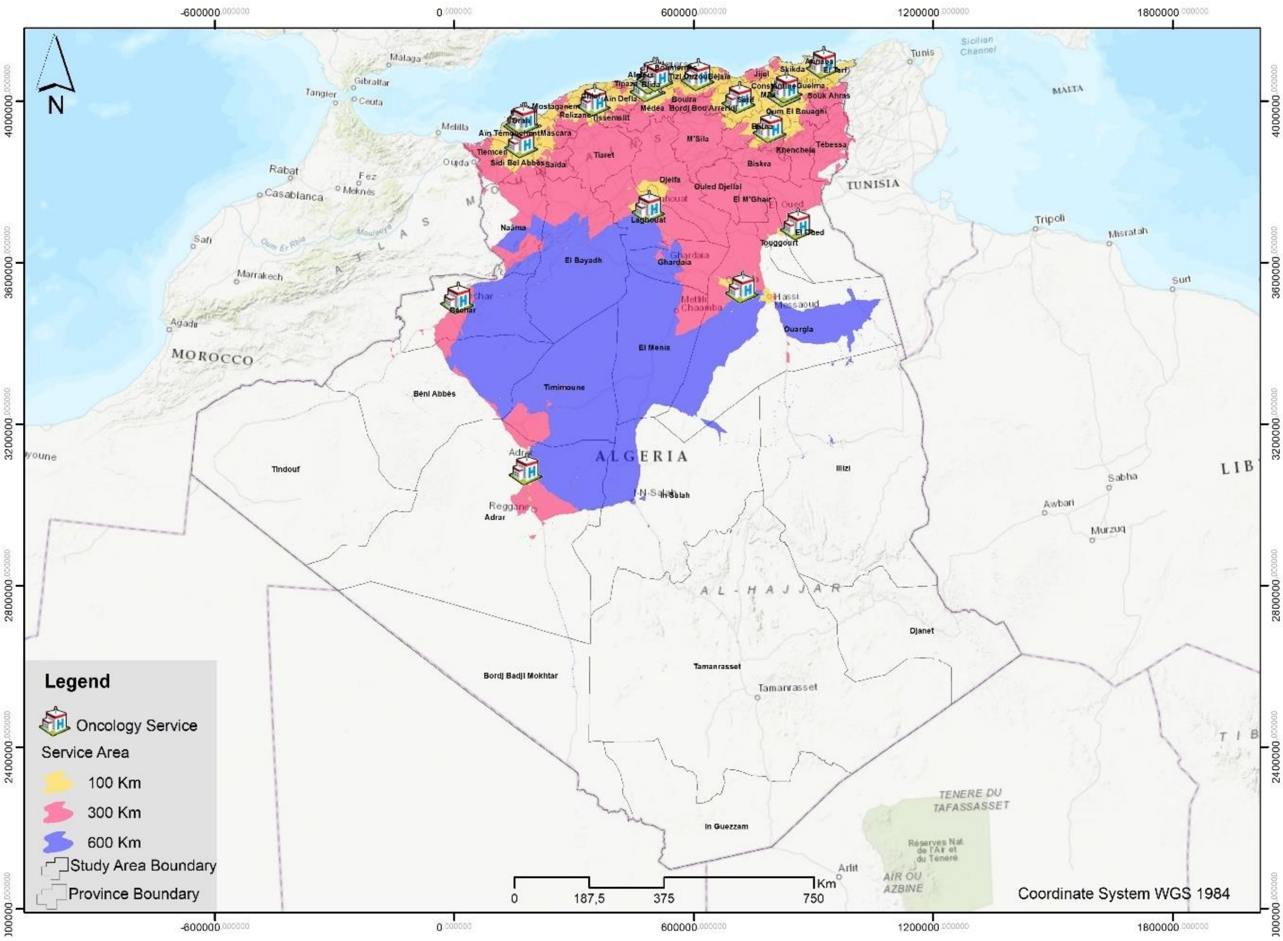

Figure 3. Drive-Distance service areas for oncology services in Algeria (Source: Realized by authors)

2. Closest facility path

The closest facility path available through Arc GIS software was used in our study to find out how well oncology services are served, depending on one or more nearby services of each province based on travel distance. Figure 4 shows; which parts of the study area, have low accessibility based on one or more nearby services for each province, and these parts are mainly located north of our study area. Based on this output, in general, the analysis of the closest facility gave us negative results due to the lack of any oncology service close to some provinces and others close to more than one service.

3. Kernel density estimation

We applied KDE to map the distribution of population location and oncology services in Algeria. The implementation of this function is based on Quadratic Kernel developed by Silverman. The bandwidth calculated was 9512.5 m and it was used for the kernel density estimation. The density surface allows for visualizing the distribution of oncology service occurrences in terms of concentration (Figure 5).

Figure 4 illustrates this trend, showing a gradual expansion of oncology services from high concentrations in the northwest to lower concentrations in the east, south, and northeast regions of the study area. The density is indicated by varying color intensities, with darker colors representing higher densities and lighter colors indicating lower densities. The population density surface can serve as a visual representation of the concentration of demand for oncology services.

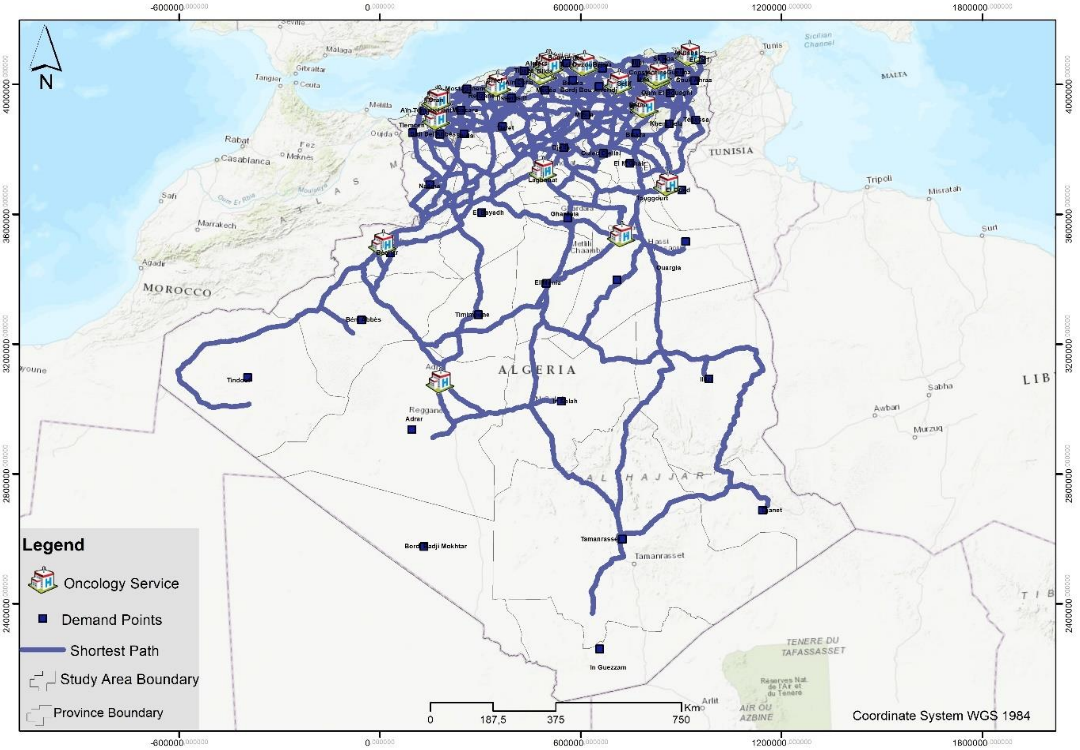

Figure 4. Closest facility path for oncology services in Algeria (Source: Realized by authors)

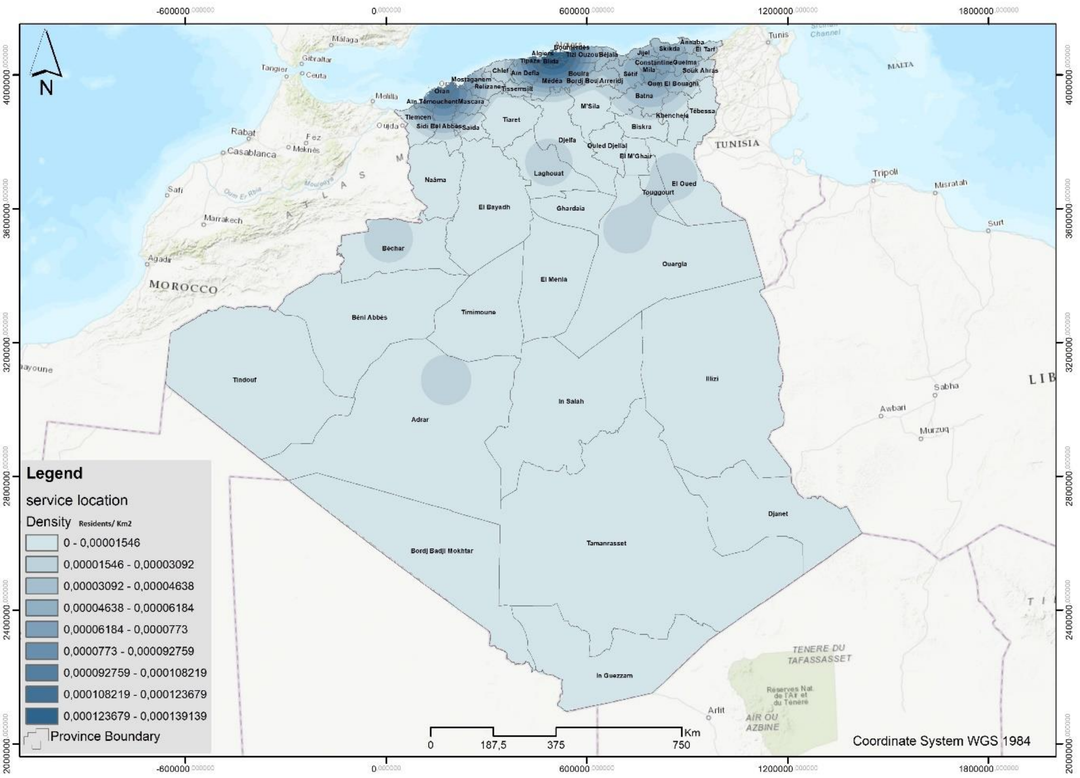

Figure 5. Kernel density estimation for oncology services in Algeria (Source: Realized by authors)

As depicted in the Figure 6, the demand for oncology services was predominantly concentrated in the northeastern parts of the study area, while it was relatively lower in the western, southern, and northwestern regions. By examining the population density surface, we can gain insights into the spatial distribution of the demand for oncology services and identify areas with higher levels of demand. Upon conducting a comparison between the expansion of oncology services and the density of population locations, we arrived at the conclusion that the distribution of oncology services is influenced by the density of population location

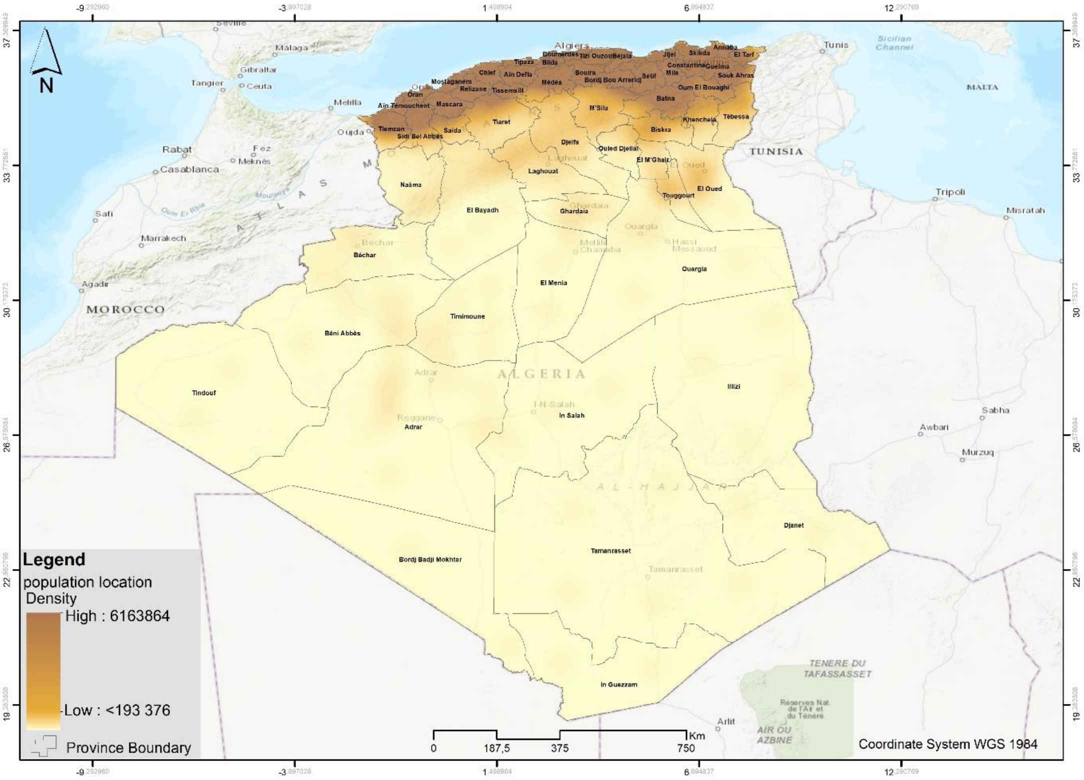

Figure 6. Density of population locations (Source: Realized by authors)

3.4. Special Autocorrelation Analysis

The results of the Special Autocorrelation Analysis (Figure 7), using Moran's I, indicate that the observed pattern of clustering is unlikely to be the result of random chance, given the z-score of 2.17, which corresponds to a significance level of less than 5%. The Moran's index value is calculated as 1.05, with a corresponding p-value of 0.029864 (Anselin, 1995)

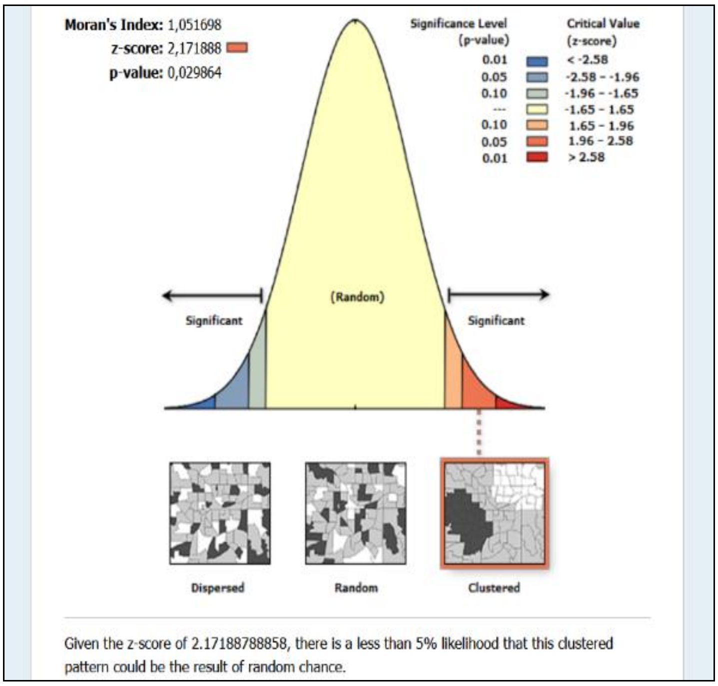

Figure 7. Spatial autocorrelation report (Source: Realized by authors with ArcGIS Software)

The analysis reveals an uneven distribution of oncology services, with a significant concentration in the northern part of Algeria. The result of the spatial statistical analysis returned five values within the software interface: Observed Mean Distance, Expected Mean Distance, Nearest Neighbour Ratio, zscore and P-value respectively the average nearest neighbor ratio automatically by dividing the observed average distances by the expected average distances with expected average distances being based on a hypothetical random distribution with the same number of facilities covering.

Figure 7 shows that there is less than 5% (0.05 level of significance) likelihood that the spatial pattern of the distribution of oncology services in Algeria is clustered and this could be a result of random chance and it may not be unconnected with the clustering number of oncology services in our study area.

3.5. Location-Allocation analysis for cancer patients Orientation

The Location-Allocation analysis gave us negative results because there are one or more locations in oncology services could not be reached by one or more locations in Provinces. The network may have areas that are disconnected, unbuilt, or disconnected due to turn restrictions, restriction attributes, or barriers. Incomplete network connectivity may result in a non-optimal solution, so only 19 oncology services are present in the solution set see Figure 7 Locating 23 services will not result in a better solution because some services have redundant locations. The location-allocation performed using the minimize weighted impedance (P-Median) problem type chose oncology services so that the total sum of weighted impedances (Province allocated to an oncology service multiplied by the impedance to the service) is minimized (Figure 8).

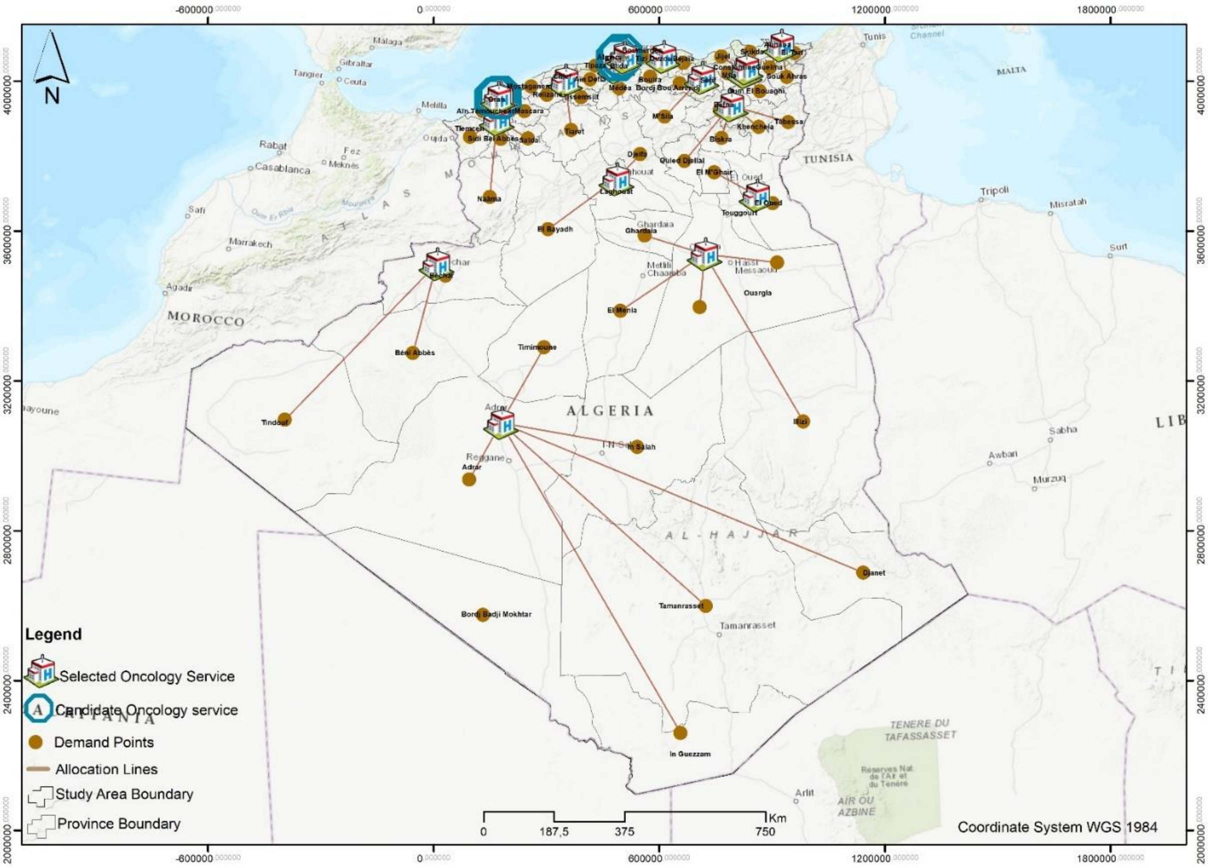

Figure 8. Location-Allocation map for cancer patients Orientation (Source: Realized by authors)

3.6. Interpretation of the distribution pattern:

Our methodology for analyzing the distribution pattern of analogical services in our study area (ALGERIA) has yielded significant findings Figure 9. Firstly, we determined that the central analogical service is located in the province of Blida, situated in the northern region of Algeria. Furthermore, the Mean Center of analogical services is identified in the province of Djelfa, which is positioned in the central part of Algeria.

Additionally, our directional distribution analysis reveals a distinct contraction pattern observed among the analogical services in our study area. This pattern demonstrates an extension from the southwest (SW) to the northeast (NE) region of Algeria.Moreover, the results of the Standard Distance analysis indicate that the analogical services are dispersed around their mean center, suggesting a spatial distribution that deviates from a concentrated or clustered arrangement.

Table 2. Interpretation of the distribution pattern of analogical services

Central Feature	Blida
Mean Center	Djelfa
Directionel Distribution	SW-NE
Standard Distance	Intersect With 46 Wilaya

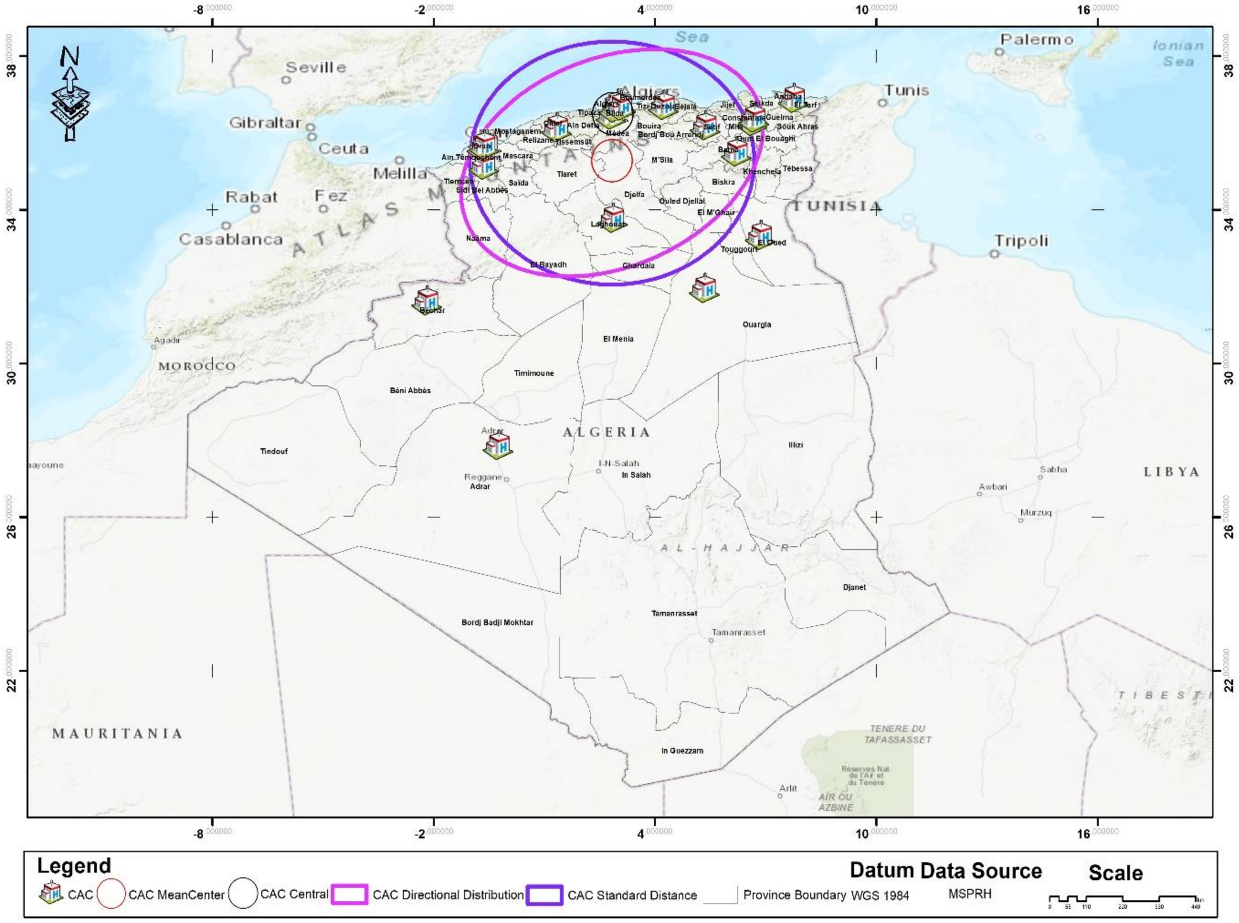

Figure 9. The distribution pattern of oncological services in Algeria (Source: Realized by authors)

CONCLUSION

In summary, Geographical Information Systems (GIS) play a vital role in advancing oncology access and shaping the future of healthcare in Algeria. This technology provides critical spatial data to enhance cancer care delivery, optimize oncological service accessibility, and bridge healthcare gaps. By configuring and effectively utilizing GIS and the various data sources, oncological accessibility in Algeria can be improved for the benefit of patients and the healthcare system as a whole. GIS enables policy-makers and healthcare providers to make data-driven decisions, identifying service coverage disparities and incorporating these findings into strategic planning for oncological services. This insight leads to more patient-centered approaches in cancer care, improves patient journeys, and ultimately results in better treatment outcomes and quality of life for cancer patients in Algeria. ArcGIS is a collaboration for using, creating, and sharing maps, applications, and data, including authoritative base maps. Finally, a survey of oncology services in Algeria was carried out based on the GIS network analysis technique and using the GIS spatial statistical analysis function, it could define the distribution of inequalities services. This methodology could help planners and public health decision-makers to manage the distribution of future oncology services in Algeria.

The most important results of this study were:

- The analyses used in this study are very valuable, and they have helped us to manage and organize the health sector in Algeria.

- Spatial statistics and location-allocation can represent the first step in building a strategic plan to develop the supply of oncology care in our study area as part of a broader plan to improve the health system as a whole and therefore to improve the economic conditions in Algeria.

- Location-Allocation and the new course are very valuable tools to assess the orientation of cancer patients.

- Further research should use dynamic modeling to further illustrate this mutual relationship. Additionally, the inclusion of the concept of Spatial Decision Support Systems (SDSS) based on GIS technology should be considered in future analyses.

As we look forward to future directions for GIS in oncological service accessibility, it is crucial to stay abreast of technological advancements and further develop policies to support the integration of GIS technology in cancer service planning. In doing so, Algeria can continue to progress in providing equitable healthcare access, leading to healthier communities and improved patient outcomes in the 58 wilayas of Algeria.

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and S.B.; data curation, M.N. and T.D and S.B.; writing - original draft preparation, M.N. and S.B.; writing - review and editing, M.N. and S.B.; visualization, M.N. and S.B.; supervision, M.N. and S.B. and D.T.; project administration, M.N. All authors have read and agreed to the published version of the manuscript.

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