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An analysis of the spatial pattern of distribution and dispersion of extraneous service units in the city using spatial analysis and spatial statistics capabilities in the ArcGIS environment (Case study: pharmacy units in the city of Ardabil)[1]

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Abstract

Background and Objective: The spatial distribution of urban services and facilities, particularly in the field of health and healthcare, is a key issue in urban planning. Pharmacies, as critical units for providing medications and health services, must be spatially distributed in a way that ensures spatial justice and equitable access for all citizens. Therefore, both qualitative and quantitative assessments of land use within the city's spatial structure and their locational suitability across defined zones are of great importance. In recent years, Ardabil has experienced rapid population growth and physical expansion, intensifying the need for the development and equitable distribution of pharmaceutical services. The aim of this study is to examine the pattern of distribution, spatial dispersion, and location allocation of pharmacies across the districts of Ardabil city using the capabilities and tools of ArcGIS.

Methodology: This research is descriptive-analytical in nature and the required data were collected through documentary and field methods. The statistical population includes all active pharmacies in the city of Ardabil. Considering the trans-neighborhood operation of pharmacies, the analyses were conducted at the scale of urban areas. To examine the spatial pattern of distribution and dispersion of pharmacies, several analytical capabilities were used in the ArcGIS environment; including hot spot analysis (Getis-Ord Gi) to identify statistically significant clusters*, Moran's spatial autocorrelation index (Moran's I) to measure the degree of spatial dependence, and nearest neighbor mean analysis to identify the type of cluster or dispersed pattern in the spatial distribution of pharmacies. Spatial data were collected using GPS and transferred to the ArcGIS environment via Google Earth. The simultaneous combination of these analytical tools along with the high accuracy of spatial data is the main innovation of this research compared to previous studies.

Results and Findings: In terms of quantity, District 2-1, with 57 pharmacies, represents the main concentration center of pharmacies in Ardabil, whereas Districts 2-3, 2-4, and 1-5 each have only one pharmacy. The results of Hot Spot analysis indicated high Z-values and a significant hot spot in District 2-1 with a 99% confidence level, while other districts did not exhibit similar patterns. The Moran's I index (0.0808) suggests a random distribution pattern of pharmacies across the city districts. However, the average nearest neighbor ratio (0.49) indicates a clustered pattern in the spatial distribution of pharmacies within Ardabil. The study reveals a spatial concentration of pharmacies in certain districts of Ardabil, particularly in District 2-1, leading to unequal access across the city. Central districts benefit from better service coverage due to their proximity to healthcare centers, while peripheral areas face shortages. Although this clustering improves efficiency in some areas, it undermines spatial equity. The research highlights the need to revise location policies for pharmacies and calls for a more balanced distribution to enhance access, improve service efficiency, and promote equity in the urban health system.

Keywords: Spatial analysis, Geographic information system, Pharmacy, Ardabil city.

[1] This article is extracted from the first author's MSc Dissertation" entitled" Analysis of the spatial dispersion and distribution of pharmacy and eyeglass stores in the city of Ardabil using spatial analysis and spatial statistics tools in the ArcGIS environment."

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Extended Abstract

Introduction:
Balanced distribution of health services in urban space is one of the key components of achieving spatial justice and improving public health. Pharmacies, as the first point of contact for many citizens with health services, should be located in a way that all city residents, especially vulnerable groups, have appropriate access. The city of Ardabil has experienced rapid population and physical growth in recent decades, but the development of health infrastructure such as pharmacies has not been uniform. The aim of this study is to analyze the spatial distribution pattern of pharmacies in urban areas of Ardabil and to assess their concentration or dispersion using spatial analysis tools.

Methodology
This research is descriptive-analytical and aims to investigate the spatial pattern of pharmacy distribution in urban areas of Ardabil. The main focus of the research is on identifying the type of spatial distribution, the degree of concentration or dispersion, and the pattern of access to pharmacies using spatial analysis tools in the ArcGIS software environment. Data collection The information required for this research was collected in two ways. Descriptive data related to pharmacies, including their names, administrative locations, and activity status, were received from the Food and Drug Administration of Ardabil University of Medical Sciences. Spatial data was also recorded in the field through precise positioning of geographic coordinates (GPS) using Google Maps, and then converted to KML format in Google Earth, loaded into the ArcGIS environment, and converted into Shapefile in ArcGIS. This combination of official data and field observations has increased the accuracy and analytical validity of the research. Population and Unit of Analysis The population of the study includes all licensed pharmacies in the city of Ardabil, the number of which is 156 pharmacies based on the final data. The unit of analysis is the urban areas covered by the Ardabil Municipality, which have been selected as the spatial framework of the analysis. Tools and Analysis Method For data analysis and extraction of spatial patterns, ArcGIS software version 10.8.2 was used. In this regard, three main analytical tools were used, each of which plays a complementary role in identifying the spatial distribution of pharmacies:
Hot Spot Analysis (Getis-Ord Gi): This analysis was used to identify points in the city that have a significant high or low concentration in terms of the number of pharmacies. This tool identifies clusters with high or low density (Hot Spots) by calculating the Z score and p value and helps to understand the dispersion of pharmaceutical services more accurately.
Moran's Spatial Autocorrelation Index (Moran's I): This index is used to measure the general pattern of spatial distribution of pharmacies at the urban area level. This analysis shows whether the spatial distribution of pharmacies is random, scattered or clustered, and its significance level is also examined.
Average Nearest Neighbor Analysis: This method helps determine the type of spatial pattern by calculating the distance between each point (pharmacy) and its nearest neighbor. Values less than one indicate spatial concentration (clustering) and values greater than one indicate regular dispersion.
The combined use of these three analytical methods has led to the examination of the spatial location of pharmacies from different angles and the reliance on a single indicator, which may lead to inaccurate interpretation, has been eliminated. This multi-indicator approach has enabled a more comprehensive assessment of spatial justice in the distribution of health services in the city of Ardabil.

Conclusion

In terms of the number of pharmacy units, District 2-1, with 57 pharmacies, represents the main concentration hub of pharmacies in Ardabil city. In contrast, Districts 2-3, 2-4, and 1-5 each contain only one pharmacy unit. The results of the Hot Spot Analysis regarding the spatial distribution of pharmacies across the city's districts indicate high Z-values in District 2-1 and low Z-values in Districts 2-3, 2-4, and 1-5. Moreover, based on the Gi_Bin index, District 2-1, at a 99% confidence level, is classified as a significant hot spot compared to other districts in Ardabil. The remaining districts, according to their Gi_Bin values, do not fall within the classified confidence levels presented in the map legend. The result of the Spatial Autocorrelation (Moran's I) analysis for the distribution of pharmacies across city districts shows a Moran's I value of 0.080825. Since this value is neither close to +1 nor near -1, it suggests a random spatial pattern in the overall distribution of pharmacies. On the other hand, according to the outcome of the Average Nearest Neighbor analysis, applied over the area corresponding to the legal boundaries of Ardabil, the nearest neighbor ratio was found to be 0.490038, which clearly indicates a clustered spatial distribution pattern of pharmacy units across the city.

The pattern of concentration of pharmacies in the central areas of Ardabil, especially near health centers, has facilitated access for residents of these areas, but at the same time has led to the deprivation of marginal and underserved areas. This imbalance has increased the cost and time of access to pharmaceutical services for a group of citizens and has undermined spatial justice. The findings of this study highlight the need to review the licensing and establishment policies of pharmacies with an emphasis on demographic, economic, and spatial indicators. It is recommended that future pharmacy location planning be conducted with a data-driven, equity-oriented, and multi-indicator approach to provide more equitable access to urban health services.

Declarations

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•**Conflict of Interest:** The authors declare no conflict of interest.

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