FIELD REPORT

Non-communicable disease surveillance in India using Geographical Information System-An experience from Punjab

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Abstract	Introduction	Methodology	Results	Conclusion	References	Citation	Tables / Figures

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Abstract

"Geographic information system (GIS) collects various kinds of data based on the geographic relationship across space." Data in GIS is stored to visualize, analyze, and interpret geographic data to learn about an area, an ongoing project, site planning, business, health economics and health-related surveys and information. GIS has evolved from ancient disease maps to 3D digital maps and continues to grow even today. The visual-spatial mapping of the data has given us an insight into different diseases ranging from diarrhea, pneumonia to non-communicable diseases like diabetes mellitus, hypertension, cardiovascular diseases, or risk factors like obesity, being overweight, etc. All in a while, this information has highlighted health-related issues and knowledge about these in a contemporary manner worldwide. Researchers, scientists, and administrators use GIS for research project planning, execution, and disease management. Cases of diseases in a specific area or region, the number of hospitals, roads, waterways, and health catchment areas are examples of spatially referenced data that can be captured and easily presented using GIS. Currently, we are facing an epidemic of non-communicable diseases, and a powerful tool like GIS can be used efficiently in such a situation. GIS can provide a powerful and robust framework for effectively monitoring and identifying the leading cause behind such diseases. GIS, which provides a spatial viewpoint regarding the disease spectrum, pattern, and distribution, is of particular importance in this area and helps better understand disease transmission dynamics and spatial determinants. The use of GIS in public health will be a practical approach for surveillance, monitoring, planning, optimization, and service delivery of health resources to the people at large. The GIS platform can link environmental and spatial information with the disease itself, which makes it an asset in disease control progression all over the globe.

Keywords

Geographical Information System; Disease surveillance; Non-Communicable Disease

Introduction

Population data is an essential source of information for any public health professional, medical statistician, or researcher etc. When presented as virtual images based on geographic relationships, quantity or type of disease, population data can be very thrilling. On similar lines, a computer-based science and technology tool, "Geographic information system (GIS) collects various kinds of data based on the geographic relationship across space."

There are five main principles by which the GIS structure usually run. These are: (a) A spatially reference data for collection and stockpile into a relational geodatabase, (b) For physically storage and collection of the data hardware is required, (c) Software is necessary by which the user assembles the interface algorithms, and can access the database, ask questions and can perform the analysis of the captured data (d) The algorithms (mathematical/statistical) and measures for data management, and (e

) The public, who are both creators and consumers of spatial data. (1) In short, GIS is a database those diverse users can use to meet various information needs. A series of information captured by GIS is known as "layers". Individually these layers contain raw data (e.g., topographic data/satellite data/ thematic data like health services. The most exciting feature of GIS is that it can change spatial data into the geographic data or coordinate system, which enriches the users' information. (1)

Basically, the software applications that are used in public health can be classified into three distinct programs: ArcView (ArcView software is a desktop version of GIS from the Environmental Systems Research Institute, Inc), Health Mapper (To address medical and health-based problems, designed and developed by the WHO and UNICEF for mapping health services) and EpiMap (This software was produced by the Center for Disease Control, USA.) uses shapefile format which is the commonly available format of data availability.

As previously discussed, GIS stores the data to visualize data, analyze and interpret geographic data to learn about an area, an ongoing project, site planning, business, health economics and health-related surveys and information, and many things, among others. (2) Details are given in (Table-1)

Most are unaware that the field of medical geography is as old as the medical sciences. The history of this field tells us the tale, which is supported by contemporary examples of GIS, public health influences, spatial mapping and the future trend of this discipline which is backed by massive data. GIS has evolved from ancient disease maps to 3D digital maps and continues to grow even today. The visual-spatial mapping of the data has given us an insight into different diseases ranging from diarrhea, pneumonia to diseases like diabetes mellitus, cardiovascular diseases, hypertension, or risk factors like obesity, being overweight, etc. All in a while, this information has highlighted health-related issues and knowledge about these in a contemporary manner worldwide. (3)

In GIS, a wide variety of geo-referenced data can be analyzed among various topics associated with a location on a map or anything that can be mapped. (4) In GIS, the data is in the form of attributes or description. We have a data set of district hospitals in a particular state that can be mapped. Using the descriptive analysis and associated attributes, we can determine and display the number of bed available for the patients, specialized services offered to the community, the number of doctors available, etc. And using the analytical data, the disease pattern within the community, rates of a particular disease, and disease distribution around the health facility can be determined. Researchers, scientists, and administrators use GIS for research project planning, execution, and disease management. (2) Cases of diseases in a specific area or region, the number of hospitals, roads, waterways, and health catchment areas are examples of spatially referenced data that can be captured and easily presented using GIS. (4) Currently, we are facing an epidemic of non-communicable diseases, and a powerful tool like GIS can be used efficiently in such a situation. GIS can provide a powerful and robust framework for effectively monitoring and identifying the leading cause behind such diseases. (3) As GIS has over and above provided an improved response to the public health problems, its popularity and adoption have been increased among health-related domains and nationwide settings over the past decade. (5)

Public health issues are often complex and solving them requires complex interdisciplinary measures. GIS, which provides a spatial viewpoint regarding the disease spectrum, pattern, and distribution, is of particular importance in this area and helps better understand the dynamics and spatial determinants of disease transmission. (5) About 17.7% of the world's population resides in India in 2021. (6) The enormous size of the population has commensurate public health challenges to deal with. India bears the world's most considerable burden of chronic conditions such as diabetes, hypertension, obesity and cancers. (7) These chronic conditions are related to the risk factors which have environmental influence and have spatial parameters too. Geographic mapping methods like GIS can help understand the ecological and spatial determinants of such disease conditions. This manuscript focuses on detailing the evolutionary history of the GIS, its uses in different sectors, including the health sector, the current status use of GIS in the public health system, and the way forward.

Brief history of Medical Geography: Medical geography uses geographic techniques such as mapping and GIS to study the impact of environmental conditions on one health. Using medical geography can be found in several ancient literature pieces from China, Greece, and India. Hippocrates has first observed human health's relationship with the surrounding environment in the 5th Century BCE. (1,8) Some earlier studies have used medical geography to estimate malaria prevalence among those living in higher versus lower plains and found the malarial prevalence more significant among those living near water bodies located at lower tables. (8) During the 18th century, French physicians coined the term medical geography, and it was Leonhard Ludwig Finke, a German physician who created the first disease map in 1792. The map became a vital assessment tool for effective learning, understanding disease incidence, disease spread, and determining spatial associations with the environment. (8) There are many such examples of medical geography, including the mapping of cholera cases by Dr Robert Baker in Leeds, dot density map of cholera outbreak in Exeter by Dr Thomas Shapter, and series of cholera maps of the

British Isles by Augustus Petermann. (9) But perhaps the most famous and known to almost everyone is the favorite dot map created by John Snow, the father of modern epidemiology. John Snow identified the cholera outbreak's reason and demonstrated the water-borne origin of the disease by plotting cholera related mortality in London on a hand-drawn map. Additionally, he plotted the location of the water pumps. He identified the area with the highest clustering of cases, the Broad Street Pump, by drawing concentric circles around the served area of pumps. (8) He then removed the handle of the pump, and consequently, there was an end to the recent cholera disease cases. John snow's research on cholera outbreak eventually became a part of disease diffusion mapping which states that disease starts at a central point and spreads as per the conditions and patterns of the surrounding environment. (2) These early mapping geographic techniques proved much helpful in explaining a disease's relationship with the surrounding environmental conditions. During the last century, with modern techniques, maps and devices, medical geography has undergone a significant transition with many new publications, literature, and societies fervent to it. (10)

Milestones of GIS evolution (11): Over the past six decades, we have seen GIS evolving from a simple hand drawn concept to a complete scientific package. Several milestones mark the evolution of GIS from a elementary tool to a completely advanced, modern day scientific technocrat platform which is enlisted in (Table 2).

Use of GIS in other sectors: GIS has been instrumental in many sectors, and its application and technical approach to analysis has significantly enhanced its use and domain. GIS has proved over and again as a powerful decision-making tool for any industry because of its variability in analyzing different sets of data viz a viz demographic, topographic and environmental. Below mentioned are some of the sectors where GIS helps industries make informed decisions. (12)

a) **Mapping**: As GIS provides a visual interpretation of data, its use for navigation purposes has been instrumental. Applications like Google maps is the best example of the use of GIS for mapping purpose.
b) **Tele information and Network Providers**: The use of spatial and geo-referenced data is used by organizations to develop designs, planning, maintenance and optimization activities. This data helps in the identification of locations where the customers are located.
c) **Analysis of accidents and Hot Spot analysis**: Data from GIs can be analyzed to identify the location of accidents happening on roads, plan better traffic plans, and identify accident Hot Spot for better optimization of service delivery.
d) **Urban Planning**: The growth of urban localities can be visualized and expansions identified. GIS data can help us better plan the development of urban localities keeping in view the surrounding environment.
e) **Traffic management**: Data from GIS can be effectively used in the planning of new roads, and rail routes etc., due to the incorporation of topographic and environmental data in the GIS platform.
f) **Environmental analysis**: GIS data has been able to integrate human civilization's impact on the environment, so data interpretation from GIS can help plan conservative measures to protect natural resources.
g) **Mitigation and management of disasters**: Efficient GIS platform can help assess environmental risk factors deemed to cause disasters and plan more efficiently in risk analysis and mitigation activities. Areas affected by floods, cyclones, earthquakes etc., can be identified, and better planning for relief efforts can be done.
h) **Banking system**: Banks' services are usually customer-driven, and GIS plays an essential role in organizing, planning, and decision-making activities for the bank industry.
i) **Taxation:** GIS platform provides an excellent opportunity for the taxation industry to build permits, engineering assignments and offers a system to identify locations for property tax extraction.
j) **Geological science**: Analysis of soil, rocks and water, seismic assessments and creation of 3D virtual maps are some of the usefulness of GIS for geologists.

There is a profound impact of GIS on the business and industries as well as on the public. Sooner or later, we shall realize the importance of GIS data in our lives and work if only the technologies were eliminated someday.

Current use of GIS in public health sector: Over the past decade, we have seen an enormous literature review pertaining to the research methods and analytical techniques using geography, spatial mapping and epidemiology. May epidemiological studies have employed GIS in their workplan, especially in health disparities and related behaviour and availability of resources. Furthermore, the GIS platform application has been more fundamentally used in cancer research and field epidemiology with special mention to environmental factors. (13) GIS platform provides access to determine the proximity of cases, aggregation, and clustering of patients to find out the hot spots of any disease. (12) Currently, the determination of disease cluster or Hot Spot is the main application of GIS in epidemiology. However, GIS in disease surveillance and monitoring has also been explored and has proved much useful. (14)

Use of GIS in understanding dynamics of Non-Communicable Diseases (NCDs): The global contribution of NCD deaths is estimated at around 68% of all deaths because of all causes, and these figures are somewhat the same for India, where 60% or 5.87 million deaths occur each year because of NCDs. The rising NCDs, especially in LMIC like India, are attributed to an epidemiological health transition among the people due to rapid urbanization, sedentary lifestyle, endocrine disruptions, and transforming nutritional preferences. Diets rich in fat, salt and sugars, and the lack of physical activity are regarded as the major contributing factor for NCDs. The global population has been exposed to unhealthy diets over the last few decades, increasing the incidence and overall prevalence of being overweight. It is critical to address this issue of rising NCDs in all forms before it's too late.

The use of GIS and the global positioning system (GPS) can be an effective intervention to ascertain the habitation of those with the NCDs. Using the GIS platform's spatial technology, the exact location of an individual suffering from NCDs can be determined. Simultaneously, the geographic coordinates would give an idea about the environmental risk factors and risk factors affecting the healthy behaviour of that individual. Among NCDs' risk factors are the behavioural characteristics, which are critical to effective prevention and treatment. Most behavioural factors that cause NCDs include intake of an unhealthy diet, diet rich in fat, salt and sugars, physical inactivity, alcohol consumption, and cigarette smoking.

Using geospatial technology and spatiotemporal epidemiological tools, we can understand the disease dynamics behind the NCD distribution within a particular community or geographical area. (4) Furthermore, individuals with the unhealthiest behaviour can be located easily. Clustering such harmful behaviour at a specific geographic area could hint towards any particular risk factor present within the surrounding community. GIS platform can further help in associating a typical unhealthy behaviour with likely geographically associated risk factor. Using GIS mapping, the NCD cases can be easily mapped along with a particular geographic space. Health officials can quickly identify them to optimize interventions, planning's, surveillance and monitoring activities. (11) Such planning interventions could prove highly beneficial and cost-effective to the Governments in the prevention and control of NCDs.

Case Study: Here, we present a case study from the state of Punjab, India. The study is based on the teleconsultation data calls received during the COVID-19 lockdown from various Punjab districts. A total of 37265 calls were received during March 2020 up to March 2021 for teleconsultations regarding various health issues. All the calls were recorded with the patients' consent, and socio-demographic and clinical diagnosis data were collected. For this manuscript, only data related to NCDs (diabetes and hypertension) were analyzed using appropriate statistical software and presented in the form of frequency and percentage. A total of 37265 teleconsultations were done, which were associated with NCDs, especially diabetes type-2 and hypertension (Table-3). Most calls received from patients suffering from hypertension 5254(62.2%), followed by those with diabetes mellitus 3201(37.8%). Among the districts, most calls related to NCDs were received from the districts of Mansa (1692), Rupnagar (1210), Moga (1060), and Ludhiana (634). District wise NCD case consultation done during the study period are shown in (Table 3).

Inference from the Data: As is quite evident that there is a high prevalence of NCDs within the study population. Among the total NCDs, 5254(62.2%) had hypertension and 3201(37.8%) had diabetes mellitus. (Figure-1) In order to plan intervention for such individuals who are suffering from chronic diseases, including NCDs, GIS platforms can be much helpful. GIS helps determine patients' location, clustering of cases, environmental factors responsible for such disease dynamics and overall, helps in making efficient decisions and plan treatment modalities with fewer costs involved.

It also helps in finding unhealthy behaviour among the cases, relation and distance of various health institutions and other sectors to implement preventive measures involving a multi-sectoral approach. Figure 1 shows the district map of the State of Punjab with teleconsultations' frequency based on NCDs from each district. GIS platform, helps in locating the geographic area with many cases or clustering of cases and helps in appropriate planning and preventive health measures.

Conclusion

There are demand and a lot of scope for GIS in the field of health sciences. GIS is an evolving field and parallels the advancement in the control of diseases. The use of GIS will be a practical approach for surveillance, monitoring, planning, optimization, and service delivery of health resources to the people at large. The GIS platform can link environmental and spatial information with the disease itself, which makes it an asset in the progression of disease control all over the globe.

Ethical Issues: The study has used secondary data for the case study for which no ethical clearance was required. Although, permission to use the data was obtained from the competent authority.

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Tables

TABLE 1 GIS DATA FEATURES USED IN PUBLIC HEALTH PROGRAMS BY WORLD HEALTH ORGANIZATION

Data boundary	Data feature
Map files digital boundary maps	Global border map Regional border maps Subnational Administrative Purposes
Geographic features	Road network maps Rivers, lakes Parks Land use/Forests Elevations
Geographic features	Location of cities, Towns, Location of settlements by type Urban areas, Rural areas
Health services data	Location of health services by type Health district boundaries Health-care catchment areas Location of laboratories NGO intervention areas
Social services	Location of schools by type Location of water supply points by type Location of trading areas/markets
Data files demographic data	National population estimates District population estimates Village/town/city population estimates Population density distribution model

TABLE 2 HISTORICAL MILESTONES

The Early History of GIS (1960)	With the emerging of computer technology, the concept of descriptive computational geography also emerged. In 1960s, academic community started research work using GIS. Later, the "National Center for Geographic Information and Analysis" started working on key topics related to GIS, including visualization and spatial analysis.
The First GIS (1963)	In 1963, the revolutionary work by Roger Tomlinson's to initiate, plan, and develop the Canada Geographic Information System resulted in the first computerized GIS. Roger Tomlinson also gave GIS its name.
The Harvard Laboratory (1965)	In 1964, SYMAP the first computer mapping software was developed by Howard Fisher. Later in 1965, a Harvard Laboratory for Computer Graphics was established, which became the center for visualization and spatial analysis.
Esri is Founded (1969)	In 1969, members from the Harvard lab-Jack Dangermond and Laura founded Environmental Systems Research Institute, Inc. (Esri). Later, GIS was pragmatic to support land planning by Esri to make informed decisions and problem-solving methods.
GIS Goes Commercial (1981)	With the development of super computers, Eris also improved its GIS software with robust technology and started working in projects dealing with real-world problems which gained a lot of attention and recognition for the company. As the need for examining an increasing quantity of projects become a necessity, Esri developed and launched ARC/INFO—the first commercially available GIS product. The technology was launched in 1981 and began the evolution and journey of Esri into a software company.
GIS Current Status	GIS enable user's ability to create their own digital map layers to help solve real-world problems just with a click of few buttons. GIS has also evolved into a means for sharing data and collaboration on a larger scale, inspiring a bigger vision that is now rapidly becoming a big reality—a continuous, overlapping, and interoperable GIS database of the world, about virtually all developing subjects. Today, hundreds of thousands of leading organizations are sharing their work and creating billions of maps every day to tell their stories and reveal patterns, trends, and relationships about everything to the world through GIS system.

TABLE 3 DISTRIBUTION OF NON-COMMUNICABLE DISEASES (DM AND HTN) AMONG VARIOUS DISTRICT OF STATE OF PUNJAB. (BASED ON TELE-CONSULTATIONS DONE BETWEEN MARCH 2020 TO MARCH 2021)

S. No	Diagnosis			
	District	Diabetes Mellitus	Hypertension	Total
1	Amritsar	137	214	351
2	Barnala	102	118	220
3	Bathinda	67	217	284
4	Faridkot	39	112	151
5	Fatehgarh Sahib	56	117	173
6	Fazilka	79	132	211
7	Ferozepur	64	92	156
8	Gurdaspur	78	145	223
9	Hoshiarpur	112	281	393
10	Jalandhar	76	147	223
11	Kapurthala	20	31	51
12	Ludhiana	248	386	634
13	Malerkotla	2	0	2
14	Mansa	582	1110	1692
15	Moga	485	575	1060
16	Mohali	178	212	390
17	Muktsar Sahib	134	156	290
18	Pathankot	36	54	90
19	Patiala	87	143	230
20	Rupnagar	489	721	1210
21	Sangrur	84	213	297
22	Tarn Taran	46	78	124
		3201(37.8%)	5254(62.2%)	8455(100%)

Figures

FIGURE 1 DISTRIBUTION OF NCD (DM AND HTN) AMONG VARIOUS DISTRICT OF STATE OF PUNJAB.