GIS: A Tool for Monitoring and Management of Epidemics

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Abstract: GIS provides excellent means for visualising and analysing epidemiological data, revealing trends, dependencies and inter-relationships. It can acquire, store, manage, and geographically integrate large amounts of information from different sources, programmes and sectors. GIS serves as a common platform for convergence of multi-disease surveillance activities. Standardised geo-referencing of epidemiological data facilitates structured approaches to data management. Once the basic structure is ready, it is easy to convert it to surveillance system for any other disease. Public health resources, specific diseases and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructures. Such information when mapped together creates a powerful tool for monitoring and management of epidemics. GIS helps generate thematic maps that depict the intensity of a disease or vector. It can create buffer zones around selected features and then combine this information with disease incidence data to determine how many cases fall within the buffer. It can also map the impact zone of vector breeding site, where control activity needs to be strengthened. GIS can identify catchment areas of health centres and also locate suitable site for a new health facility. It can overlay different pieces of information and carry out specific calculations. GIS allows interactive queries of information contained within the map, table or graph. It permits a dynamic link between databases and maps so that data updates are automatically reflected on the maps. Dynamic maps published on the Internet assist patients in locating the most convenient health services easily. GIS can process aerial/satellite images to allow information like temperature, soil types and landuse to be easily integrated, and spatial correlations between potential risk factors and the occurrence of diseases to be determined.

1. Introduction

Recent advances in geographical information and mapping technologies have created new opportunities for public health administrators to enhance planning, analysis, monitoring and management of health systems. Health mapping has evolved from Dr. John Snow's cholera

death mapping in mid-nineteenth century to the latest Internet-based mapping where data have been shared across the Internet. Since much of the data used and generated by health and social service agencies has a spatial dimension, geographic information system (GIS) is particularly useful to health professionals and administrators in planning and day-to-day management (Colledge et al., 1996).

A typical GIS comprises an organised collection of computer hardware, software, geographic data and personnel, designed to efficiently capture, store, update, analyse and display all forms of geographically referenced information. Each piece of information is related in the system through specific geographical coordinates (e.g. latitude and longitude) to a geographical entity (e.g. health centre, school, dam, drainage, village or state). The information can be displayed in the form of maps, graphs, charts and tables.

Despite tremendous potential of GIS, the health sector in India has not fully explored it. Majority of the health departments and research organisations in India do not have the hardware, software or trained staff that would enable them to apply GIS technology. However, the interest in GIS has increased during the late 1990s. Many health organisations, such as Malaria Research Centre, DANLEP and Vector Control Research Centre, are exploring its potential utility in medical research and disease control. In this paper, we highlight the role of GIS in monitoring and management of epidemics.

2. GIS and Epidemiology

Understanding the determinants of a disease, and its spread from person to person and community to community, has become increasingly global (ESRI White Paper, 1999). GIS plays a vital tool in strengthening the whole process of epidemiological surveillance information management and analysis. GIS provides excellent means for visualising and analysing epidemiological data, revealing trends, dependencies and inter-relationships that would be more difficult to discover in tabular formats. Public health resources, specific diseases and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructures. Such information when mapped together creates a powerful tool for monitoring and management of diseases and public health programmes.

The underlying factors likely to lead to increased incidence of diseases, including adverse environmental, behavioural and socio-economic conditions, need to be monitored regularly. By tracking the sources of diseases and the movement of contagions, health agencies can respond more effectively to the outbreaks of epidemics by identifying populations at risk.

Software packages such as BodyViewer by GeoHealth, help medical personnel visualise clinical data. Integration of clinical information is accomplished by linking unique codes directly to a graphical representation of the human body and to the geographical location where the patient

has originated (ESRI White Paper, 1999). Such geoclinical information system is a useful tool when evaluating environmental risks and exposures.

3. Advantages of GIS

GIS has several advantages over conventional methods used in health planning, management and research. **Data management:** GIS can be used to capture, store, handle and geographically integrate large amounts of information from different sources, programmes and sectors; including epidemiological surveillance, census, environment and others. Surveillance of diseases requires continuous and systematic collection and analysis of data. A GIS can eliminate the duplication of effort involved in data collection across an organisation, and hence substantially reduce the cost involved in it. GIS serves as a common platform for convergence of multi-disease surveillance activities. Each data record has to be georefenced to a desired level of accuracy. Standardised geo-referencing of epidemiological data facilitates structured approaches to data management (Weekly Epidemiological Record, 1999). Once the basic structure is ready, it is easy to convert it to surveillance system for any other disease, by replacing data of one disease with data of another disease (Srivastava & Nagpal, 2000).

GIS provides access to additional information from a wide variety of sources. Global positioning systems (GPS) can be used to obtain locations of point features on a map, such as wells or septic tanks, precisely. GIS can process aerial or satellite imageries to allow information such as temperature, soil types and landuse to be easily integrated, and spatial correlations between potential risk factors and the occurrence of diseases to be determined (Weekly Epidemiological Record, 1999). High resolution satellite imageries and aerial photographs can be used to obtain accurate and up-to-date maps of any region. Latest, accurate, low-cast maps are essential for epidemiological surveillance. Temporal satellite imageries can be used to monitor landuse and landcover changes over time.

Visualisation: GIS offers powerful tools to present spatial information to the level of individual occurrence, and conduct predictive modelling. It determines geographical distribution and variation of diseases, and their prevalence and incidence. For example, in studying the surveillance of poliomyelitis in India, it is important to find out which type of polio is occurring in which parts of the country, as this has important implications for the disease eradication strategy employed (Balaji, 2000). GIS can help in generating thematic maps - ranged colour maps or proportional symbol maps to denote the intensity of a disease or a vector. In comparison with tables and charts, maps developed using GIS can be extremely effective means for communicating messages clearly even to those who are not familiar with technology. GIS keeps track of the geographical locations of service providers, customers, resources, and health plans and programmes. It allows policy makers to easily understand and visualise the problems in

relation to the resources, and effectively target resources to those communities in need. GIS permits dynamic link between databases and maps so that data updates are automatically reflected on the maps.

Overlay analysis: GIS can overlay different pieces of information. This helps in decision making and medical research through multicriteria modelling (for example, in understanding the association between prevalence of certain diseases and specific geographic features).

Buffer analysis: GIS can create buffer zones around selected features. For example, a radius of 10 km around a hospital to depict its catchment area or 1 km around a pollution site or 5 m on both sides of sewerage to indicate the spread of hazardous material. The user can specify the size of the buffer and then combine this information with disease incidence data to determine how many cases fall within the buffer. Buffer or proximity analysis can be used to map the impact zones of vector breeding sites, where control activity needs to be strengthened (Srivastava & Nagpal, 2000).

Network analysis: GIS provides the ability to quickly access the geodemographic dynamics of an organisation's existing service area in contrast to the likely demand for services at a new location (ESRI White Paper, 1999). It can identify catchment areas of health centres and also locate suitable site for a new health facility. Health services delivered at home (e.g. polio vaccination) can be scheduled in a more efficient manner by analysing transportation factors and street patterns, and by recommending the most efficient route. GIS Provides accurate and timely information about where health services are located and instructions and maps on how to get there.

Statistical analysis: GIS can carry out specific calculations, for example, proportion of population falling within a certain radius of a health centre or dam. It can also calculate distances and areas, for example, distance of a community to a health centre, and area covered by a particular health programme.

Query: GIS allows interactive queries for extracting information contained within the map, table or graph. It can answer queries of location, condition, trends, spatial patterns and modelling.

Extrapolation: GIS provides a range of extrapolation techniques. For example, vector distribution in inaccessible and unsampled areas can be mapped using GIS.

Web GIS: One of the recent advancements in GIS technology is web-based GIS. Health data is stored in a central server which can be accessed from various terminals connected to the server through internet or intranet. Statistical and epidemiological methods need to be developed to protect individual confidentiality while accessing data (Richards et al., 1999). Internet based GIS technology eliminates the traditional method of flow of information, and the information is instantly available across the globe. Dynamic maps published on the web allow patients to locate the most convenient services to their home or work easily.

4. Applications of GIS in Health

GIS is being used by public health administrators and professionals, including policy makers, statisticians, epidemiologists, regional and district medical officers (Weekly Epidemiological Record, 1999). Some of its applications in public health are mentioned below:

- Find out geographical distribution and variation of diseases
- Analyse spatial and temporal trends
- Identify gaps in immunisations
- Map populations at risk and stratify risk factors
- Document health care needs of a community and assess resource allocations
- Forecast epidemics
- Plan and target interventions
- Monitor diseases and interventions over time
- Manage patient care environments, materials, supplies and human resources
- Monitor the utilisation of health centres
- Route health workers, equipments and supplies to service locations
- Publish health information using maps on the Internet
- Locate the nearest health facility.

5. Conclusions

GIS aids in faster and better health mapping and analysis than the conventional methods. It gives health professionals quick and easy access to large volumes of data. It provides a variety of dynamic analysis tools and display techniques for monitoring and management of epidemics. GIS has a vital role to play in the future. The possibilities that can be explored are limitless, depending on the skill and imaginative use of the researchers and the willingness of health sector management to resource its implementation. Health administrators, professionals and researchers need training and user support in GIS technology, data and epidemiological methods in order to use GIS properly and effectively.

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