GIS for rapid epidemiological mapping and health-care management with special reference to filariasis in India

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Received July 21, 2014. Accepted July 29, 2014

Abstract

This study was carried out to apply geographic information systems (GIS) technology for rapid epidemiological mapping and health-care management of filariasis in India. GIS has essentially become important role in epidemiological mapping, disease monitoring and health information management in India. It has been customized inbuilt facilities to store, retrieve, analysis, and mapping of horizontal and vertical structure of the disease epidemiological information. This study aimed on the application of GIS for rapid epidemiological mapping of disease occurrences, infection rate, age group, sex, disease transmission, site specification of the patients, host availability of the parasite or virus loads, and so on. It was used to state the horizontal and vertical structure of the diseases, history of the disease, etc. with reference to space and times. GIS is not only used to mapping the geographical distributions of disease prevalence (communicable and noncommunicable diseases), but also been used to analyze the spatial trend of the disease transmission and the spatial modeling of environmental aspects of disease occurrences, above and beyond. GIS has been used to updating and mapping the disease epidemiological information and perhaps, it was used for disease surveillance, mapping disease transmission risk and for spatial modeling. And hence, it has also become essential tool in mapping the epidemiological information, disease surveillance, health monitoring, surveying, sampling design, disease control programs, predicting the disease transmission, and most importantly, it has become the important decision-making tool in public health disease surveillance and monitoring disease control programs, site selection of health services, health information systems toward and tool for providing a datum of guidelines for decision making and planning toward the achievements of health-care management in India successfully.

KEY WORDS: Filariasis, epidemiological mapping, morbidity management, health information and monitoring, spatial analysis, disease surveillance, health-care management

Introduction

Vector-borne disease epidemics have major challenging problems and have become essentially a public health importance in the countries where tropical region of Asia, especially in India for the recent years. The geographic information systems (GIS) is the computer software for data capturing, thematic mapping, updating, retrieving, structured querying and analyzing the distribution and the differentiation of various phenomenon including communicable and non-communicable diseases across the world with reference to various time periods. It has facilitated mapping the information relevant to the name of the diseases, disease infection rate, age group, sex, disease transmission, site specification of the patients, host availability of the parasite or virus loads, and so on, besides, it was used to state the horizontal and vertical structure of the diseases, history of the disease, and so on, with reference to space and times. GIS has been used to mapping the geographical distributions of disease

Access this article online	
Website: http://www.ijmsph.com	Quick Response Code:
DOI: 10.5455/ijmsph.2015.21072014213	

prevalence, the trend of the disease transmission and the spatial modeling of environmental aspects of disease occurrences (Liu and Chen, 2006, Palaniyandi 2013, and 2012, Srividya *et al.* 2002 and Sabesan *et al.* 2000). The GIS were also used for spatial analysis, spatial modeling, cause and effect analysis, temporal analysis etc. It has been used for studding and mapping the surrogate information relevant to the environments of the disease transmission, disease surveillance, and monitoring disease control programs (Palaniyandi, 2013, 2012, and 2008).

GIS is used to mapping the geographical distributions of disease prevalence, and to analyze the disease transmission spatial trend and the spatial modeling of environmental aspects of disease occurrences (Liu and Chen, 2006, Lindsay et al., 1998, Palaniyandi, 2013, and 2012). GIS has been used to updating and mapping the disease epidemiological information and perhaps, it was used for disease surveillance, for mapping disease transmission risk, and for spatial modeling. And hence, it has also become essential tool for rapid epidemiological mapping, disease surveillance, health monitoring, systematic surveying, sampling design, disease control programs, and intervention measures disease transmission control and management at the local as well as national level. Socioeconomic and the environment with different cultural regions in the country has vector-borne disease endemic problem where the districts are prone to epidemic nature. It is important to analyze the environmental determinants of vector breeding habitats in the urban and rural environments in the epidemic districts. GIS is used for rapid epidemiological mapping and to environmental management toward achievement of epidemic control and health-care management in the country (Palaniyandi, 2013, 2013, and 2012).

Rationale

Lymphatic filariasis represents a major vector-borne, public health problem in India. The disease has been known in the country for millennia, the earliest known description of symptoms dating to 600 BC. Current estimates indicate that about 38% (48 million) cases of lymphatic filariasis occurring globally are found in India. The existence of a national program for filariasis control designated the National Filariasis Control Programme (NFCP) since 1955, attests to the recognition by health planners of the public health importance of the disease in India. India is also a signatory to the resolution 50.29 of the 1998 World Health Assembly, calling for the elimination of lymphatic filariasis as a public health problem globally. Currently, the national mass drug administration (MDA) program in different states is implemented toward the elimination of filariasis disease in India. It is mandatory to monitor the current situation of the prevalence of filariasis disease in the country, and to resurvey the areas for health monitoring, or need not be surveyed. The map showing the districts are resurveyed for filarial antigenemia detection, and hence, priorities to be given for continuing the national annual mass single-dose administration toward the elimination of lymphatic filariasis at the national level.

Study Area

The whole India has been selected as the case study, it has located wholly in the northern hemisphere and the geographical extent of the main land is from 8^0 4′ 28″ N to 37^0 17′ 53″ N latitudes and from 68^0 7′ 53″ E to 97^0 24′ 47″ E longitudes. The total geographical area is 3287,240 km^2, and the political administrative area consists of 28 states and 7 union territories. The annual mean temperature is 25–27.5 °C and it receives rainfall by both southwest (June–September) and northeast (October–February) monsoons. The country has been receiving the annual mean rainfall of 800–3000 mm.

Materials and Methods

The data pertinent to the filariasis were used for this study. MapInfo Professional 4.5 and ArcView 3.2 softwares were used for mapping the disease prevalence and the disease monitoring programs in different part of the country. ArcView Spatial analyst and AV Image analyst were used to customize the embed mapping of the real-time epidemiological disease information for browsing the information from the public domain of health GIS websites to make use of the data to the individual and planners as the hypothetical model.

GIS for Rapid Epidemiological Mapping

GIS software has been used for rapid epidemiological mapping, and spatial interpolation of point data is carried out for prediction of spatial trend and for data not available/unsurveyed places (Bailey 1995, Cressie 1993, Srividya et al. 2002). The GPS instrument was used to collect the filariasis epidemiological information of the selected villages using the GIS-based 25 km × 25 km grid sample procedures, the data pertaining to the micro filariasis (mF) and disease rate were mapped with graduated point symbol, and the interpolation of contour surface was created for predicting the filariasis mF rate in the areas where data were not collected. The mF infection rate of selected sample villages was overlaid on the interpolation of contour surface of the predicted filariasis map of part of Tamil Nadu, India [Figures 1 and 2]. The procedures applied in the study have been used for mapping the disease infection in the area where data were not available (Rossi et al. 1992, Srividya et al. 2002) and these were used for action plan for implementing the disease surveillance, management of disease control programs, and management of the disease in the country that has vast areas such as India (Palaniyandi 2014, Rossi et al. 1992, Srividya et al. 2002).

GPS under the GIS Umbrella for Disease Surveillance

The global positioning systems (GPS) have been used to directly on top of a map or site-specific location to collect field data in real-time, convert and log real-time GPS coordinates, it has been assisting to conduct a field survey to collecting the information continuously and to automatically update the geographic coordinates with minimum of 500 points. The

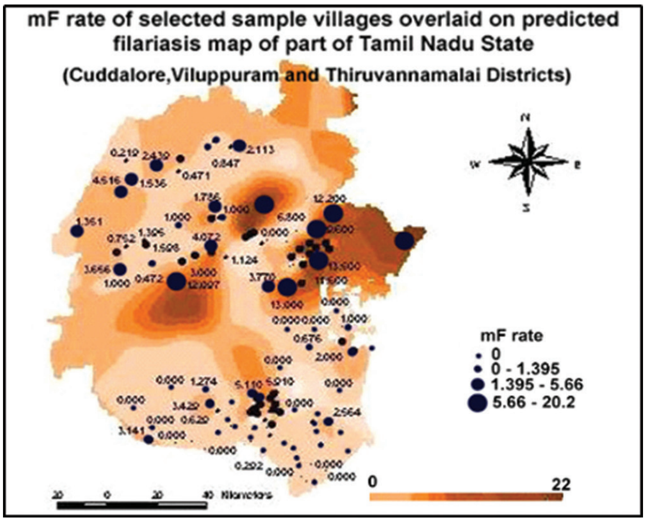

Figure 1: The filariasis mF rate was mapped using graduated point symbol and it was superimposed on the predicted interpolation map of filariasis in part of Tamil Nadu, India.

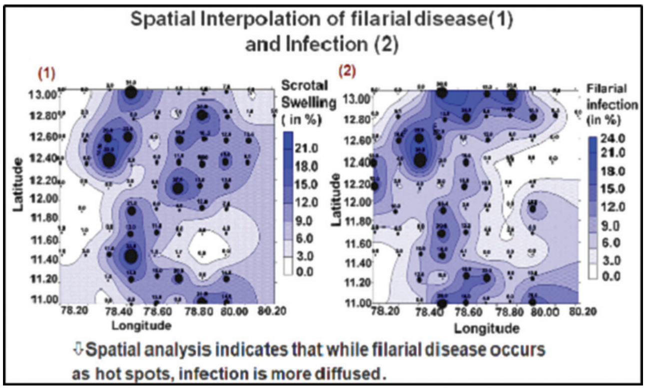

Figure 2: The filarial disease (1) and the mF infection rate (2) of selected samples points, and the predicted map of spatial diffusion of filariasis transmission.

latest version of Geographic Tracker includes a MapBasic application, which allows the "GPS Tracking" by showing a real-time GPS-derived position directly on top of a map background. It has facilities to collect and attribute field data directly into your geospatial database engine (GIS software) in real time, an exciting concept may be coined "GPS Geo-coding." The Geographic Tracker can process live or simulated GPS message data ("Live GPS Data" or "Simulated GPS Data") on online data base connectivity. The GPS was used for disease surveillance in the crucial situation such as dengue epidemic in India (Palaniyandi, 2014). The reconnaissance survey could be conducted in the nearest house of closeness to the intersection points of 100 m grid samples. The available GPS instruments has the inbuilt error of (+) or (–) 100 m. Therefore, the GPS instruments could be used to mapping the dengue vector breeding habitats with site specifications of house locations with interval of 100 m. GPS could be used for mapping the epidemiological information and the ongoing disease monitoring and control programs including the house locations, streets, house type, and locality of the areas (Palaniyandi, 2014). The same approach could be adopted for filariasis vector mosquito control and management.

GIS for Disease Surveillance

The sporadic nature of disease epidemic was serious threat to the public and it becomes major public health problems to the nation, and hence, the periodical close observation of disease epidemiological surveillance was needed for disease outbreaks control. GIS-based surveillance was assisting to updating and mapping the public health disease epidemiological information and used for monitoring the national ongoing disease control programs at the grassroots level using the geostatistical reconnaissance survey methods or the random survey methods, such as, stratified random, systematic random, and pilot survey. The national mass drug single-dose administration programs were implemented in different states toward the elimination of filariasis disease and control in India. To know the current scenario of the mF active infection rate in the districts where the annual mass drug administration was implemented, the GIS-based systematic grid sampling method was applied. It shows that grid sampling techniques with less than 10 km distance were reliable and accurate for updating and mapping the prevalence of filarial antigenemia, using immunochromatographic test a reliable and more sensitive technique, which will indicate the prevalence of filarial antigenemia (active infection), besides the vector prevalence (Palaniyandi 2014, 2013, Srividya et al. 2002).

The Internet GIS for Health Monitoring

The case history of the occurrences of the disease epidemics and the detailed epidemiological information relevant to patient's age, sex, site specification, name of the disease, viciousness of the disease, nature of the disease (migrant or indigenous), occupation, geographical location, reiterate of the disease/number of times, season and duration of the disease occurrences are carefully mapped with API in Web-mapping GIS for updating the disease information. In collaboration with public health departments of state governments, data containing the epidemiological information and disease transmission have to be entered in the geo-database engine for Web-mapping GIS application programming interface (API) for developing a simulation model for prediction of disease transmission. The layers of information derived from the Web-mapping GIS API, provides the datum of knowledge for analyzing the nature, infectious state, and situation of the diseases at a particular time points, this information could be useful for taking right decision and appropriate action plan for taking disease control measures [Figure 3].

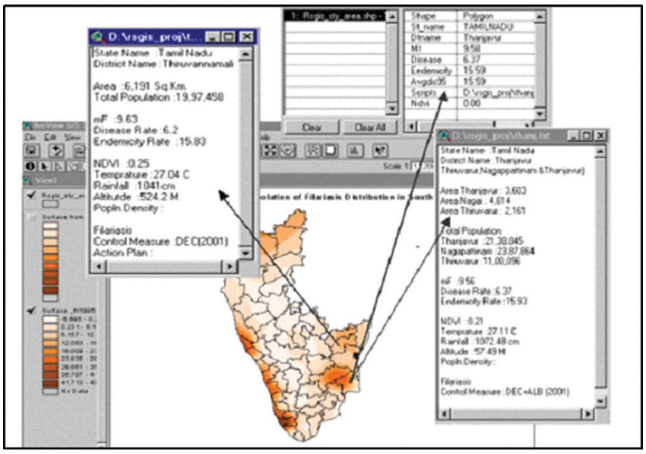

Figure 3: The customized mapping of user friendly structured query of spatial data base of filariasis epidemiological information available in the server. Source: Palaniyandi (2014).

The Web-mapping API are becoming important, mainly the embed customized Web-mapping GIS technology (ASP, .Net, html, java, python, CSS, PHP, Arc IMS, Geo ext, C, C++, Visual Basic, Arc objects) has user interface facilities for browsing, spatial structured querying, thematic mapping and table sorting and drawing the information, and the significant risk variables associated with disease epidemics. This Web-mapping information could be essentially useful for the ongoing disease control operations at the national level. GIS tool has also allowed the online database connectivity (ODBC) for updating and mapping the real-time epidemiological information for quick and clear visualization of the disease with site specifications from anywhere in India. GIS has facilitated structured querying and decision-making process at certain level. The spatial queries related to demographic features, disease prevalence, environmental aspects, and the socio-economic risk factors could be provided the diffusion of disease transmission, and hence, the action plan for the disease control operations could be taken to prevent the disease epidemics. The Web-mapping GIS using API has been readily available to customize the embed mapping of the real-time epidemiological disease information to the individuals and planners for browsing the information from the public domain of health GIS websites, and thus, a conceptual framework of this study of Web-mapping GIS API technology could be used for mapping and updating the real-time epidemiological information for monitoring the spatial distribution of disease cases and action plan for control measures at the national level [Figure 3].

The GIS is not only assisting to updating and mapping the disease prevalence, but also essential tool for disease surveillance and public health information management, perhaps, decision-making tool for monitoring filariasis endemic situation in the country (Palaniyandi, 2014, 2013). The endemic nature of filariasis in the country has become major problems, social stigmata, and discrimination within the community and has been essentially the public health important at the national level and hence, the full-fledged GIS-based national surveillance must be needed for monitoring, control, management, and elimination of filariasis in the country successfully. GPS, one of the components of GIS has been assisting to conduct a survey, and it has the inbuilt facilities to collect the information continuously with 500 points of geographical coordinates. The flight range of filariasis vector mosquito is between 100 and 250 m, and the filariasis vector mosquitoes have both indoor and outdoor resting habitats and they are the night biting mosquitoes particularly after 9.00 pm. A combined mass drug administration, chemotherapy for filariasis morbidity management, and comprehensive integrated vector control through the community mobilization and cooperation conducted in the housing settlement clusters areas, monitoring mosquito and human density based on the GIS-based intersection points with less than 200 m interval of grids survey, consequently data have to be updated for situation analysis (Palaniyandi 2014, 2013).

GIS for Optimum Health Service Coverage

The spatial clustering, nearest neighborhood analysis was performed for easy understanding of the filariasis spatial pattern and disease clustering and the spatial ring buffering was created for the optimum service coverage of the patients. The different distance rules of 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9 km were created over the disease distribution map, using spatial ring buffering technique at GIS platform. The minimum, maximum, and the mean distances of each disease cluster are calculated against to each distance rule/ring buffering. The list of existing PHC/GH is depicted on the Puducherry urban boundary map. The lymphodema cases are proportionally high in the age group of 56–75 years and the high percentage of lymphodema grades II and III cases are reported. The study results that 0.7-km ring buffering distance is having the optimum service coverage. The hypothesis of this study that the aged patients could travel less than 1 km distance from their residence to the health centers for morbidity management is carefully examined (Palaniyandi 2008). The study area required 15 centers with 0.7-km ring buffer or coverage area, out of 15, 10 centers already existed, and 5 more new centers are required to cover all the patients for lymphatic filariasis morbidity management [Figure 4].

GIS for Mapping, Health Monitoring, and Decision Making

GIS has been facilitating to mapping, visualizing, monitoring, retrieving, analyzing, and modeling the georeferenced data with high accuracy (Palaniyandi 2014, 2013, 2012, 2008). It was used for mapping and for monitoring the ongoing disease control program in India [Figures 5 and 6]. The current situation of the disease prevalence in the country, based on the historical data may cause error in the disease control program. Therefore, it is mandatory to resurveying the areas for health monitoring, or need not be surveyed (Sabesan et al. 2000). The map showing the districts where resurveying

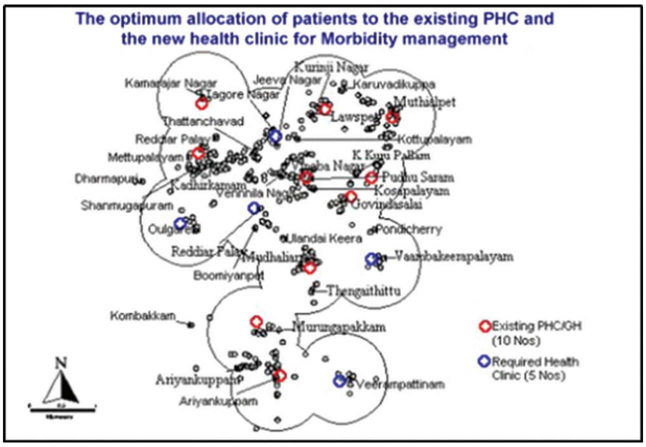

Figure 4: The GIS-based optimum allocation of the patients to the existing PHC and the proposed new health clinic for lymphatic filariasis morbidity treatment.

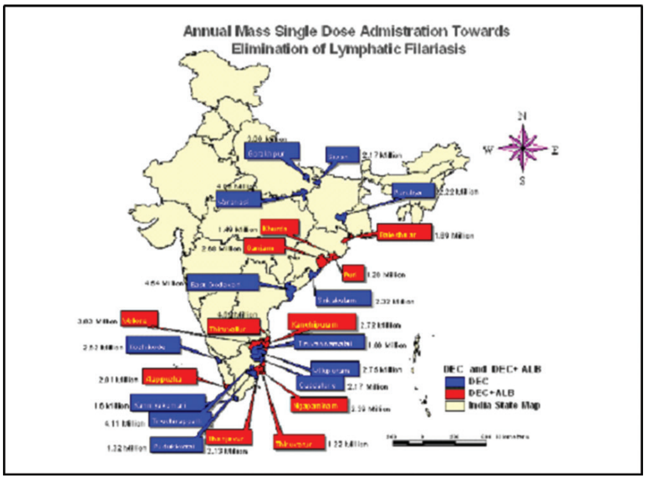

Figure 5: The national mass drug single-doss administration programs in different states towards the elimination of filariasis disease and control in India.

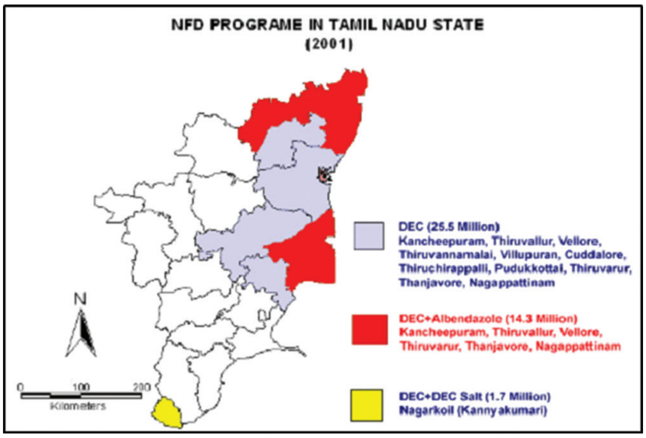

Figure 6: The national mass drug single-doss administration programs in Tamil Nadu state towards the elimination of filariasis disease.

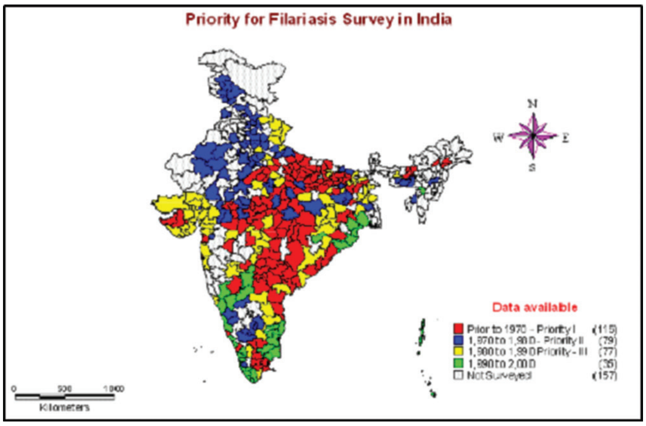

Figure 7: The map showing the districts where resurveying for filarial antigenaemia detection to be carried out and for implementing the national filariasis disease control program.

to be carried out for filarial antigenemia detection and has to be given priorities for implementing the national annual mass single-dose administration toward the elimination of lymphatic filariasis at the national level [Figure 7].

Conclusion

GIS has become essential tool in epidemiological investigation, disease monitoring, and health information systems, and health-care management. It has become important decision-making apparatus to public health management in the world especially in India for the recent decades for mapping disease prevalence, parasites, virus or bacterial load, host and disease infection. Besides, it has been used to study the disease transmission epicenter, spatial diffusion and direction and magnitude of the disease transmission, and most importantly, incorporated the geospatial epidemiological analysis of proximity, similarity, geometry, and cognitive of the disease incidence and the socioeconomic and the ecological variables. It was not only used for mapping the geographical distribution of disease prevalence and but also been used for disease surveillance, epidemiological investigation, health monitoring, ongoing disease control programs, intervention measures, health information systems, site selection of health services, and for providing a datum of guidelines for decision making toward the achievement of filariasis health-care management in India. Similarly, it is also used to geospatial epidemiological research, and hence, derived guidelines for decision making for vector-borne disease control and management at the local and national level (filariasis, malaria, JE, dengue and chikungunya, and visceral Leishmaniasis). Perhaps, it is used for national disease control programs, disease surveillance, spatial modeling, and disease transmission, beyond mapping and it has no limit with field of restriction. And further accomplished, GIS is used for rapid epidemiological mapping and to environmental management toward achievement of epidemic control, management of monitoring endemic situation as well health-care management in the country.

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How to cite this article: Masimalai P. GIS for rapid epidemiological mapping and health care-management with special reference to filariasis in India. Int J Med Sci Public Health 2015;4: 1141-1146

Source of Support: Nil, **Conflict of Interest:** None declared.