Methodological Review

Health GIS and HIV/AIDS studies: Perspective and retrospective

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Abstract

GIS (Geographic Information System) is a useful tool that aids and assists in health research, health education, planning, monitoring and evaluation of health programmes that are meant to control and eradicate certain life threatening diseases and epidemics. HIV/AIDS is one such epidemic that poses a serious challenge and threatens the overall human welfare. This communication is an attempt to link and understand the health scenario in a GIS context with emphasis on HIV/AIDS. Various GIS based functionalities for health studies and their scope in analyzing and controlling epidemiological diseases are explored. Overall scenario of the spread of HIV/AIDS around the world is presented along with the Indian perspective. Finally, we conclude with the general management problems, issues and challenges related to HIV/AIDS prevailing in India.

1. Introduction

Health is vital for all of us and understanding the determinants of a disease, its spread from person to person and community to community has become increasingly global [1]. As expressed by Scholten and De Lepper [40], “health and ill-health are affected by a variety of life-style and environmental factors, including where people live”. There are various factors such as climate, environment, water quality and management, education, air pollution, natural disasters, social and many others which are the reasons for the emergence of diseases as shown in Fig. 1 (also known as the Dahlgren-Whitehead model). The characteristics of these locations (including socio-demographic and environmental exposure) offer a valuable source for epidemiological research studies on health and the environment.

Epidemiological research ranges from outbreak investigation, data collection, design and analysis including the development of statistical models. Since health is a geographical phenomenon and various factors attributing to the health diagnostics and planning are geography dependent, as such, GIS (Geographic Information System) for health studies serves as an important tool. GIS can be useful for health researchers and planners because it plays a vital role in strengthening the whole process of epidemiological surveillance, information management and analysis. It serves as a common platform for convergence of multi-disease surveillance activities. The standardized 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 study. Public health resources, specific diseases and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructures. GIS is being used by public health administrators and professionals, including policy makers, statisticians, regional and district medical officers [44]. Some of its applications in public health are: (1) geographical distribution and variation of diseases (2) analysis of spatial and temporal trends (3) identifying gaps in immunizations (4) mapping populations at risk and stratifying risk factors (5) documenting health care needs of a community and assessing resource allocations (6) forecasting epidemics (7) planning and targeting interventions (8) monitoring diseases and interventions over time (9) managing patient care environments, materials, supplies and human resources (10) monitoring the utilization of health centers (11) route health workers, equipments and supplies to service locations (12) publishing health information using maps, etc.

Health and ill-health therefore, always have a spatial dimension. More than a century ago, epidemiologist and other medical scientists began to explore the potential of maps for understanding the spatial dynamics of diseases. A study carried out by Dr. Snow [17] is often cited to show that the importance of spatial dynamics in understanding of diseases, and the use of maps to describe and analyze it, is not so recent [8]. Dr. Snow made the hypothesis that cholera might be spread by the infected water supplies more than a
century ago using maps to demonstrate the spatial correlation between cholera deaths and contaminated water supplies in the area of Soho in 1854. Scholten and Lepper [40] use the example of AIDS, stressing the importance of spatial distribution of the disease, which they say has been too often overlooked. Another study highlighted that modeling and spatial distribution of AIDS can contribute to both educational interventions and the planning of health care delivery systems [19]. Mapping can play an important role in both areas as it is an excellent means of communication. In order to be of use to resource planners, prediction of AIDS should include a spatial component. Looking into the spatial aspects of health augments the understanding of particular diseases of interest also serves as means to plan interventions and help planners to take important decisions [2,47]. It is interesting to study and analyze the domain knowledge of GIS and statistics and integrate it with medical science to understand the advances and gaps. It is being widely used in public health, environmental health and epidemiological research in general. World Health Organization (WHO), United Nations Children’s Fund (UNCF), US Center for Diseases, United Nations Member States, Public Health Agencies of different countries have been widely using GIS at large in epidemiology.

2. GIS for health

The representation and analysis of maps of disease incidence data are basic tools in the analysis of regional variation in public health. The development of methods for mapping disease incident has progressed considerably in recent years. This growth in interest has led to a greater use of geographical or spatial statistical tools in the analysis of data both routinely collected for public health purposes and in the analysis of data found within ecological studies of disease relating to explanatory variables. The study of geographical distribution of diseases can have a variety of uses and can fit into any of the three classes [10]:

- Disease mapping – usually the object of the analysis is to provide (estimate) the true relative risk of a disease of interest across a geographical area. Application of such methods lies in health service resource allocation.
- Disease clustering – this aids in public health surveillance, to decide where it may be important to be able to assess whether a disease map is clustered and where the clusters are located. The analysis of disease incidence around a putative source of hazard is a special case of cluster detection.
- Ecological analysis – this focuses on the analysis of the geographical distribution of disease in relation to explanatory covariates, usually at an aggregated spatial level.

2.1. GIS operation

Generally, the objectives of GIS are the management (acquisition, storage and maintenance), analysis (statistical and spatial modeling) and display (graphics and mapping) of geographical data and hence producing meaningful results. The methods which generally apply to health-related analyses using GIS include overlay analysis of thematic data and spatial intersection, buffer generation, neighborhood analysis, vector-based grid generation, network analysis and raster surface modeling. These GIS methods need to be coupled with proper spatio-temporal statistical methods to ensure valid analyses and robust conclusions [3]. It is a valuable tool to assist in health research, health education, planning, monitoring and evaluation of health programmes and health systems [2]. At the basic level, GIS can provide map-based ‘point and click’ access to view information about a particular feature, such as a district or facility, while more advanced users can employ spatial analysis techniques to answer questions related to their health-sector concerns accessing relevant data from a Data Base Management System (DBMS) or Relational DBMS. DBMS is central to GIS and contains two main types (more or less closely integrated depending on the system); a spatial database containing location data and describing the location of earth’s surface features (shape, position), and an attribute database containing certain characteristics of spatial features.

Within the domain of spatial analysis techniques, the geographic boundaries of study areas can be accessed and modified, data class intervals and symbologies restructured, map layers (variables) vertically overlaid and integrated, new independent map variables added for multivariate spatial statistical analysis, spatial weights computed, spatial autocorrelation on predictor

![Fig. 1. The Dahlgren-Whitehead model. Factors responsible for the world-wide emergence of diseases (adopted from The Future of the Public’s Health in the 21st Century [52]).](image-url)
variables assessed, and probability scenarios of mapped variables explored based on modeled changes in regression coefficients over time, with unparalleled computational speed and ease. By creation of buffer zones, it is possible to plan or investigate the occurrences of diseases around important locations for which planning of new/ additional health facilities are required. The user can specify the size of the buffer and then intersect or merge the information with the disease incidence data to determine the counts of the illness that fall within the zone. GIS also enable multi-dimensional surface images to be drawn to scale, a feature important in studies involving elevation or subsurface shape. The mathematical treatment of topographic or surface statistical values can be used as a filter against other variables or other surfaces. A range of statistical techniques have evolved that are well suited to GIS analysis, including density kernel estimation, grid and probability estimation, and kriging. Spatial statistics can be divided into (i) methods for point pattern analysis, (ii) methods for lattice data and (iii) geostatistics. Lattice data are discrete spatial units that are not a sample from an underlying continuous surface (geostatistical data) or locations of events (point patterns). Of these, the geostatistical approach is most relevant to epidemiological analysis conducted at the landscape scale which are usually regional phenomenon and are based on remote sensing and GIS. Spatial statistical methods like spatial autocorrelation, spatial pattern analysis and clustering account for the spatial variation inherent in spatial data and can be used for statistical inference. This spatial prediction can be based entirely on a stochastic model or in combination with a deterministic trend [3,14,16,29,39,50,53].

Further, the analytical tools available within GIS make it possible to integrate a variety of factors that influence the spread and development of the disease. In particular, these factors relate to census data, economic and socio-cultural characteristics of countries or regions that affect the pattern and development of such diseases [3,24,31]. Economic factors include life expectancy, income, gender inequality, and labor mobility. Socio-cultural variables include education, religion, the ethnic composition of a population and the type of living environment. Other factors are the age of the epidemic, the types and availability of treatments and sexual practices [31].

2.2. Temporal dimension

Time plays a major role in any type of medical analysis. So spatial analysis alone is not sufficient unless we incorporate the temporal dimension of variation into the study. Advanced spatial and temporal epidemiological studies have been done by many researchers using the concept of spatio-temporal cluster and statistical analysis [13,21,26,35,42]. The basic problems in geographical surveillance for a spatially distributed disease are the identification of areas of exceptionally high prevalence, to test their statistical significance, and to identify the reasons behind the elevated prevalence of the disease [42]. Temporal, spatial and space time scan statistics are commonly used for disease cluster detection and evaluation [20,43,45,48]. One theme which is of particular interest both to the medical community and to the GIS specialists is temporal animation. It is highly suitable for implementation in a temporal GIS (TGIS) environment [28,36]. To date, the development and implementation of geographical visualization (GVIs) and TGIS has yet to be realized. The implementation enables users to visualize the data and focus on what is relevant, thereby transcending the presentational realms of visualization. Implementing exploratory temporal animation is synonymous with current work that seeks to integrate GVIs, GIS and knowledge discovery in databases (KDD) into comprehensive systems that have interactive visual displays, temporal geospatial operations and data mining capabilities [24,25]. Immubing animation with domain intelligence is an area of study that has great significance for geo-applications dealing with disaster prevention, early warnings and emergency fields [4,5,24,36].

2.3. Data mining

Another challenge in the field of medicine is knowledge discovery from the growing volume of data. Health-care is a knowledge-intensive domain in which neither data gathering nor data analysis can be successful without using knowledge about both the problem domain and the data analysis process. Most of these applications are particular and involve individual machine learning technique, such as data mining. Data mining, also known as “knowledge discovery in databases”, is the process of discovering interesting patterns in databases that are meaningful in decision-making and is also an application area that can provide significant competitive advantage to an organization [23–25,32]. It is concerned with finding models and pattern from the available data. Data mining includes predictive data mining algorithms, which result in models that can be used for prediction and classification, and descriptive data mining algorithms for finding interesting patterns in the data, like associations, clusters and subgroups [25].

2.4. Location/allocation facilities and health services management

It is evident that many questions concerning the provision of health care are related to space. People are distributed in space and not evenly. Health problems vary in space and so do the needs of the people. Location of health care centres and services offered by these to cater the needs of populations varying in number, dimension and densities can be addressed and resolved with spatial analysis tools. GIS is a relatively new and complex technology, which explains why they have not been used to their full potential, especially in the health domain where they are extremely promising. We are not at a point where their possibilities are more clearly seen with developments in hardware and softwares. However, GIS has been widely used for developing prototypes for health management, disease surveillance, disease control, facility management and other related aspects [5,6,11,13,18,47]. These health information systems have different uses catering to the needs of a wide audience ranging from medical practitioners, government agencies, general public and the research fraternity. They help the planners and decision makers to effectively plan the control measures.

2.5. Software applications

Epi Info® (www.cdc.gov/epiinfo), Health Mapper® (www.healthmap.org/en), ChildInfo® (www.childinfo.org), SIGEpi® (www.paho.org), Research Analyst®, SaTScan® (www.satscan.org) are some of the specially designed application packages for health studies. Most of them are either open source under the GNU’s General Public License (GPL) or freeware and are freely downloadable via internet. They help in easy form and database construction, data entry, and analysis with epidemiologic statistics, maps, and graphs, revealing trends, dependencies and inter-relations. Estimation and Projection Package® (EPP) is a relatively new software package used to estimate and project adult HIV prevalence from surveillance data. While EPP can be used in all countries with sufficient surveillance data, it is specifically recommended for countries with generalized epidemics (www.unaids.org/en/KnowledgeCentre/HIVData/Epidemiology/epi_software2007.asp). Some software like SIGEpi and Research Analyst disseminates the use of GIS as a tool for analysis and problem-solving. The package offers simplified tools and interfaces to efficiently carry out biostatistical and geographical analysis to support decision-making in
public health. Such information when mapped together creates a powerful tool for monitoring and management of disease and other public health programmes. Other than these individual packages the bigger players in the software industry, like ESRI ArcView®, ArcGIS® (including ArcMap, ARC/INFO) for advanced users and ArcIMS®, the Internet Map Server, basically used for web GIS (www.esri.com), GRASS®: a public domain software under the GNU’s General Public License (GPL) (http://grass.itc.it), AutoDesk Map2000® (www.usa.autodesk.com) and Intergraph GeoMedia® (www.intergraph.com) provide individual health modules.

While the developed countries have taken initiatives to establish well organized GIS based health surveillance systems, the developing countries are still facing increasingly diverse and complex problems mainly due to resource constraints and non-availability of reliable information about diseases and those affected. In addition, the formulation of a proper GIS system faces some constraints which include problems in having updated information from the field, including delays, non-reporting, non-response and generally, unsatisfactory quality of generated data from primary sources. With a proper availability of database, the analysis in GIS extends the capabilities to analyze the information based on their common geographic occurrences that makes GIS a very valuable tool in understanding the health/disease related research. This analysis not only helps in understanding the reasons for poor utilizations of health services, but also to plan the future needs for improving the scenario [4,13,18,26,47].

3. HIV/AIDS: an overall scenario

Acquired immune deficiency syndrome or acquired immunodeficiency syndrome (AIDS) is a collection of symptoms and infections resulting from the specific damage to the immune system caused by the human immunodeficiency virus (HIV) in humans. The late stage of the condition leaves individuals susceptible to opportunistic infections and tumors. Most researchers believe that HIV originated in sub-Saharan Africa during the twentieth century, it is now a pandemic, with an estimated 38.6 million people now living with the disease worldwide. As of January 2006, the Joint United Nations Programme on HIV/AIDS (UNAIDS) and the WHO estimate that AIDS has killed more than 25 million people since it was first recognized on June 5, 1981, making it one of the most destructive epidemics in recorded history. An estimated 33 million people were living with HIV in 2007 (Fig. 2).

There were 2.7 million new HIV infections and 2 million AIDS-related deaths in the year 2007. The rate of new HIV infections has fallen in several countries, but globally these favorable trends are at least partially offset by increases in new infections in other countries. Globally, women account for half of all HIV infections – this percentage has remained stable for the past several years. The global percentage of adults living with HIV has leveled off since 2000. In virtually all regions outside sub-Saharan Africa, HIV disproportionately affects people who inject drugs, men who have sex with men and sex workers [38].

In Asia, an estimated 5 million people were living with HIV in 2007. The number of new infections and people who died from AIDS-related illnesses was 380,000 in 2007. Injecting drug use is a major risk factor in several Asian countries. In some countries, HIV prevalence has remained very low (less than 0.1 percent in the 15–49 year old population). HIV surveillance has found only a few cases of HIV infection among female sex workers, male STD (sexually transmitted diseases) clinic patients. In the Philippines, AIDS case reporting has slowly increased to a total of 8200 as of end of 2007. It is estimated that in China in 2006, slightly fewer than half the people living with HIV are believed to have been infected through use of contaminated injecting equipment. Similar scenarios are estimated to be occurring in parts of India, Pakistan and Vietnam. Similarly, a small number of AIDS cases and low levels of HIV infection have been reported from Indonesia. Injection-drug-use is an important factor in Myanmar, near Afghanistan and Pakistan, and in major cities. HIV is also transmitted perinatally and through breast-feeding. When examined through the lens of current national HIV prevalence and incidence rates, most other countries in Asia and the Pacific would conform to a pattern of low prevalence and slow HIV spread. It is estimated that 5.7 million HIV-infected people are present in India as compared with 5.5 million in South Africa according to UNAIDS estimates of 2006 [41]. With more HIV infections than any other country in the world, India gives the impression that HIV infection is common and that there is a severe epidemic in the country. However, a preliminary analysis of the National Family Health Survey – which was conducted under international supervision and with U.S. funding – suggests that India has between two million and three million people living with HIV/AIDS, according to several sources, including U.S. epidemiologists and the Indian Ministry of Health and Family Welfare. The survey concluded last year [51]. However, the estimated 2.5 million HIV infections should be considered in the context of more than 1 billion population of India. The prevalence of HIV is about 0.3 percent, a rate much lower than many other countries in the Asia-Pacific region.

3.1. Indian scenario

According to a report by WHO, 2006 [46], the scenario of HIV/AIDS in India is alarming and rapidly changing. It is the second largest population in the world; the total population surpassed 1 billion in the year 2001 of which a total of 67% population lives in rural areas and 33% in urban areas [12]. India has 35 states and union territories, and over 600 districts. HIV infection is not evenly distributed throughout the country and the infection is actually highly localized [38] as shown in Fig. 3.

The first case of HIV infection in India was reported in 1986. In 1987, HIV sentinel surveillance and AIDS case identification was launched. Initially, HIV got spread among female sex workers and their male clients, STI clinic patients, and professional blood donors. It subsequently began to spread among populations including women attending antenatal clinics. Steinbrook [41], 2007 presented a picture of the HIV/AIDS scenario quoting that perhaps 85% of HIV transmission in India is through sexual contact. India still has many paid blood donors; contaminated blood and blood products account for about 2% of HIV infections. Accessing complete, comparable data for all regions, states, union territories and districts is a major challenge. HIV prevalence among sex workers in India varies widely from state to state, with high HIV prevalence in western and southern India to low levels of HIV in eastern and northern India. In a few of India’s states, data show high HIV prevalence among sex workers, and possibly rising HIV prevalence among people who inject drugs and men engaged in multi-sex practices. Although HIV has spread into the wider population and, in some states, is affecting increasing numbers of women considered to be at low risk of infection, the country’s epidemic is largely a result of HIV transmission within, between and immediately beyond those most-at-risk populations. Furthermore, sex between men is a significant, yet under-researched aspect of India’s HIV epidemic [38]. Fig. 4 shows a time series plot of number of people with HIV in India based on data from report on the Global AIDS epidemic, 2008. According to earlier estimates (www.web.worldbank.org) about 2.45 million Indians were living with HIV with an adult prevalence rate of 0.41% in 2006 and among almost 100,000 adults (aged 15–49 years) tested for HIV in the most recent national population-based survey [34], reported prevalence was 0.28%.
The epidemic is largely concentrated in six Indian states – in the industrialized south and west, and in the north-eastern tip. On average, HIV prevalence in southern states overall was about five times higher than in northern states in 2000–2004 [22]. Reported adult HIV prevalence in six states included in the recent national population-based survey [34] varied from 0.07% in Uttar Pradesh, 0.34% in Tamil Nadu, 0.62% in Maharashtra, 0.69% in Karnataka, 0.97% in Andhra Pradesh, to 1.13% in Manipur.

According to India’s National AIDS Control Organization (NACO) (www.nacoonline.org/NACO), the bulk of HIV infections in India occur during unprotected heterosexual intercourse. Consequently, as the epidemic has matured, women account for a growing proportion of people living with HIV (38 percent in 2005), especially in rural areas. The low rate of multiple partners concurrent sexual relationships among the wider community seem to have, so far, protected the larger body of people with 99 percent of the adult Indian population being HIV negative. However, although overall prevalence remains low, even relatively minor increases in HIV infection rates in a country of more than one billion people could translate into large numbers of people becoming infected [49].

3.2. HIV/AIDS issues and challenges in India

While the government’s response has been scaled up markedly over the last decade, major challenges remain in raising the overall effectiveness of various level programs, expanding the participation of other sectors, and increasing safe behavior and reducing stigma associated with HIV-positive people among the population. Several factors are responsible for the rapid spread of HIV if effective prevention and control measures are not scaled up. Below are the major issues and challenges associated with HIV/AIDS research which have been predominantly summarized from the World Bank Report 2008 [49].

- **Inadequate competence at the institutional level.** These include the institutional constraints, including structural and managerial, temporal data collection and analysis to scale up at the national and state levels. These factors should be addressed as the program expands its response to the epidemic in the direction for a stronger multi-sector response for the next phase of HIV/AIDS program. The states and Union Territories need to provide implementation capacity to put a robust program into place. There is a need for better coordination among the benefactors.

- **Benefactor synchronization.** There is a need for better coordinating mechanisms among the benefactors to reduce the transaction costs since they have own mandate and requirements, as well as areas of focus. The transaction cost to the government as a result of attending to the various demands of the benefactors is huge [49].

- **Effective decision making using available data/reports.** There remains a need for greater use of data for decision making, including program data and epidemiological data. A lot of data that are being generated is not adequately used for managing the program or informing policies and priorities. Results-based management and linking incentives to the use of data should be explored [49].

- **Stigma and discrimination.** Stigma and discrimination against people living with HIV/AIDS and those considered to be at high risk remain entrenched. Stigma and denial undermine efforts to increase the coverage of effective interventions among high risk groups [9,37,49].
Low awareness. In a context of a severe gap of knowledge about prevailing risk-taking sexual behaviors, creates great uncertainty about the future course and impact of the epidemics. An appreciation of this fact is important in planning suitable interventions. New approaches need to be tried to reach communities with information about HIV/AIDS and how to prevent and treat HIV/AIDS [9,49].

4. Research perspective: GIS and HIV/AIDS

HIV/AIDS epidemic has started to challenge recent developmental achievements and to raise fundamental issues of human rights concerning people living with HIV/AIDS. The study conducted by Mahal and Rao [30] is an intense review to elaborate on the major elements of the national and international economic research to data on HIV/AIDS. The study highlights the fact that very little work on the influence of HIV on technological progress exists at present, except mainly through its impact on biomedical research. Economics can contribute usefully to thinking about and measuring the potential impacts of the HIV/AIDS epidemic and in the development of optimal strategies to address it.

As mapping is an excellent means of communication, GIS produces materials which are both useful and conducive to public participation in community health projects. From this, effects in health domains are obvious. Sources of information about, and examples of, mapping AIDS and representation of disease events is provided by Smallman et al. [56] in their atlas. Visualization which is the simplest application of GIS has been attempted to understand the spatial spread of HIV/AIDS [57,58]. Similar approach was exemplified on a temporal scale by Jones et al. [55]. GIS was used to map the number of HIV services in a given area in order to understand access to prevention and health care [59,60]. They also calculated the distance of the prevention center from the highly infected regions, thus aiding in the decision making policy.

Spatial Data Infrastructure (SDI) can play a key role by designing spatial database for epidemics. This information may again...
be useful for analysis in a geographical context. Busgeeth and Rivett [6] designed and developed an HIV/AIDS database, which is embedded in a Spatial Information Management System (SIMS). SIMS can play a critical role in determining where and when to intervene, improving the quality of care for HIV+ patients, increasing accessibility of service and delivering a cost-effective mode of information. The study was carried out in a district in South Africa which is experiencing an HIV/AIDS pandemic of shattering dimensions. The systems function as an information system containing accurate HIV/AIDS and infrastructure data and support decision-making and management. The advantage of these methods in GIS is that they can provide spatial information required by the government agencies to plan better intervention. On similar lines, an open source management system has been proposed by Vanneulebroek et al. [61]. Given the resource constraints of the local government context, particularly in small municipalities, they proposed that open source software should be used for the prototype system.

Modeling approaches have proven to be highly relevant in HIV/AIDS studies that include either inductive/empirical models or deductive/theoretical models. Similar spatial and temporal models for AIDS cases in US have been developed by Casetti and Fan [7] and Gould et al. [15] and are used for prediction. Loytonen [27] did inductive modeling to study HIV diffusion in Finland. Dynamic compartmental simulation model for Bostswana and India, was developed by Nagelkerke et al. [54], to identify the best strategies for preventing spread of HIV/AIDS. Nakaya et al. [33], attempted spatial temporal modeling of the HIV epidemic in Japan by employing an estimation method that allows the inclusion of geographically varying parameters. This research discusses the earlier use of trend model, epidemiological model and the micro-simulation models for projection of the epidemic cases.

5. Conclusion

GIS supported by spatial data infrastructure and vibrant routine health data can give planners valuable information to address the issues related to HIV/AIDS and support monitoring, evaluation and planning. GIS can also be used as an effective tool to manage and monitor HIV/AIDS and related routine activities. As health is largely determined by spatial factors (including the socio-cultural and physical environment, which vary greatly in space), it always has an important spatial dimension. Like all powerful technologies, GIS can be applied by practitioners versed in public health methodologies. It can certainly be a tool of prime importance to health research and education. The spatial modeling capacities offered by GIS can help to understand the spatial variation in the incidence of disease, and its covariation with environmental factors with health care.

The facts and figures presented here for the Indian scenario brings out that it is often misleading to consider a country as a homogenous entity as far as HIV/AIDS is concerned. There is a sharp increase in the estimated number of HIV infections that could translate into large numbers of people becoming infected. An understanding of epidemiological principles and methods is required to structure studies and interpret results for proper socio-economic development at various levels of the society. GIS based mapping is therefore necessary to generalize, symbolize, and classify data so that maps communicate effectively rather than distorting the data behind the map and can aid in combating with the spread of the disease once the geographical incidence, trend of spread and related social-economic-geographical features are ascertained. An appreciation of this fact is important in planning suitable interventions and effective measures for controlling the epidemic.

Acknowledgments

We thank National AIDS Control Organisation (NACO), Ministry of Health and Family welfare, Government of India, New Delhi for providing the HIV data and Indian Institute of Technology, Roorkee for financial assistance and infrastructure support.

References
