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Use and potential of geographic information systems for health mapping in the Eastern Mediterranean Region

It is estimated that nearly 80% of the information needs of local health system decision and policy makers involve geographical positioning, which means using maps in one way or the other. Health mapping utilizes the technology of geographic information systems to add value to information for public health planning and decision making. Published studies indicate that many countries in the Region are already using mapping techniques to identify and address priority public health concerns. However, in most countries a coordinated effort and strategy are missing. The Regional Committee is invited to discuss the value of health mapping and to consider ways to strengthen the development and utilization of health maps for planning and decision-making.

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Executive summary

The importance of health mapping, in association with health indicators, monitoring and evaluation, as an e-health application is growing at a very rapid rate to support health systems development. WHO has been using mapping techniques coupled with surveillance to monitor the global health situation and present it through user-friendly and modern tools such as geographic information systems. Public health mapping utilizes the technology of geographic information systems to add value to information for public health planning and decision making. The role of health mapping has many aspects and influences the performance of health systems in many ways. It improves the ability of decision-makers, planners, academicians, researchers and health care professionals to organize and link thematic and spatial datasets. It provides the ability to create relations between datasets that may seem unrelated without using the geographical dimension. These links help in discovering and creating new health knowledge which can be translated into action or policies. Mapping enables professionals to understand complex spatial relationships visually, and as planning has an element of informed prediction, mapping can be a powerful tool for forecasting and trend analysis. Communities can share the same knowledge about their own health and development issues.

Health mapping is most valuable in analysis of demographic data and its distribution over geography; disease distribution; distribution of high risk groups; site selection and location of health services; hydrographical and water supply and sanitation systems; hydrologic modelling and water resources management and delivery; emergency preparedness and disaster management; identification of hazardous sites and disaster-prone locations (natural or man-made); health services centres and distribution and categorization of human resources. The regional situation with regard to health mapping is diversified. The Regional Office has made extensive investment in development of infrastructure, capacity building, development of systems and tools, data collection and production of health maps. Many Member States have taken steps to support health mapping activities, with more emphasis on certain communicable diseases and areas under emergency situations. A regional survey shows that most countries have health mapping units and some infrastructure, but lack trained human resources. Recommendations to Member States with regard to furthering the development of public health mapping include awareness raising, resource allocation, strengthening data collection, infrastructure building and human resources development to develop, maintain and sustain national health maps.

1. Introduction

Maps have been used for thousands of years as a tool for sharing knowledge. Knowledge on a map is presented in a graphical format on paper or more recently as a three-dimensional display on computer screens and electronic means. Maps carry spatial data which is information about the location and shape of, and relationships among, geographic features, usually stored as coordinates and topology [1].

The function of the map as a medium for communication is well-recognized. Maps can provide concise, clear, logical, flexible and expandable messages using minimum natural language representation building on the power of graphic presentation. Maps gain their value in three ways [2]:

- As a way of recording and storing information. Governments, business and society at large must store large quantities of information about the environment and the location of natural resources, capital assets, and people;
- As a means of analysing locational distributions and spatial patterns. Maps allow the user to recognize spatial distributions and relationships and make it possible to visualize and hence conceptualize patterns and processes that operate through space;
- As a method of presenting information and communicating findings. Maps can convey information and findings that are difficult to express verbally. Maps can also be used to convince and persuade, or even propagandize.

Health mapping refers to the activities, techniques and tools that are used to link geography or location as the common factor that pulls health and community data together. The health map generally aims to create a cartographic representation of the environmental setting, the distribution of diseases and the health services. Health mapping aims to support public health's core functions of surveillance, targeting and intervention. These functions are supported by public health practices including assessment, policy development and assurance. The real value of health mapping emerges when maps are linked to disease control and prevention efforts.

The aim of this paper is to increase awareness of the value and potential role of health mapping, present a situation analysis on the use of health mapping in countries of the Region, identify constraints to the further development of health mapping in the Region and provide recommendations to countries to strengthen the development, maintenance and utilization of health maps for planning and decision-making.

2. Geographic information systems technology

A geographic information system is an organized collection of computer hardware and software, geographic and tabular data, and personnel and knowledge designed to capture, store, manipulate, update, analyse and display spatial data [3]. The use of geographic information systems (GIS) as a major technology for map storage, production and dissemination has been fully recognized. GIS technology gives data a spatial dimension. It is a tool to represent knowledge in a visual format by linking statistical and thematic data to geographic locations on maps. GIS and mapping are closely linked. Maps are digitized to become an integral part of a geographic information system, and GIS technology produces maps with layers of spatial and thematic data.

Statistical and surveillance data can be presented or visualized in a number of ways, including in tables, graphs and maps. Maps incorporate two major types of data: thematic and spatial. They allow the full incorporation, online manipulation, classification and visualization of data. Maps connect facts and figures with places.

There is a strong link between health and geography. Disease distribution and health outcomes are very much affected by the places where people live. The characteristics of a place, for example whether it is urban, rural, arid or tropical, influence disease patterns, life expectancy, mortality, morbidity, education, income and lifestyle, among other things. In short, "places form people as much as places are formed from peoples" [4].

It is estimated that nearly 80% of the information needs of local health system decision and policy makers involve geographical positioning, which means using maps in one way or the other [5]. Maps can help in identification of critical and priority areas which require intervention by the health system. Maps can be used to construct health indicators, including specific unmet health needs, absence of health facilities and services, presence of health hazards, poverty and other factors, and any association between them.

The World Bank's Online Atlas of the Millennium Development Goals (MDGs) exemplifies the value of the map [6]. It allows the user to explore maps of key indicators for each of the eight MDGs, resize countries to reflect comparative values, zoom in on countries and pull up quick tables of supporting indicators.

3. Areas of public health mapping

3.1 Disease surveillance

A functional disease surveillance system depends on timely dissemination of surveillance data to health officials and the public. Temporal and spatial trends in disease outbreaks can be visualized by preparing maps showing for each location the date of peak disease incidence, i.e. the week or month when the largest number of cases occurred. An integrated approach and enabling technology for disease surveillance can be supported by an effective public health mapping programme [7]. Health mapping can be used as a unifying factor for different disease surveillance activities, since location is the common element among them all.

3.2 Epidemiology

Epidemiologists are able to trace the spread of a disease as they study outbreaks of the disease through time, location and population. By mapping the location of a population or subgroup and looking at the presence of ill health among the population over time, it is possible to identify the source of a disease and how it spreads. Identifying these elements can help the national authorities as part of the health system to create a plan to combat the spread of the disease.

3.3 Water supply and delivery

The quantity and quality of water supply have a direct impact on the health of people. The first known application of health mapping was related to water sources, when Johan Snow mapped cholera cases during an outbreak in London in 1854 and linked them to a specific water source [8].

Mapping the location of water sources and the flood seasons connected to these locations facilitates control and prevention of diseases such as malaria, onchocerciasis, cholera and other water-borne diseases. Maps can also be generated to identify the relationship between water supply sources and areas of high dental caries prevalence [9].

3.4 Poverty

Reaching the Millennium Development Goals will require identification of target populations and their geographic locations in a detailed manner. Poverty mapping involves a household survey and a population census as data sources. Poverty maps allow easy comparison of indicators of poverty or well-being with data from other assessments. As well, by showing the spatial distribution of poverty, maps provide evidence for the targeting of intervention or development projects. Mapped information on the levels and distribution of poverty facilitates the communication of findings, which greatly assists in the implementation of development projects and in advocacy [10]. These poverty maps also offer the promise of generating useful data about poverty and inequality at the local level, information which has potential applications in both the policy and research spheres [11].

3.5 Emergency and disasters

The challenge facing emergency preparedness and response planning is mainly concerned with the interaction between humans and their environment under conditions thought to be hazardous either to life or to habitat [12].

Mapping locations of potential natural and man-made disasters to strengthen early warning and vulnerability analysis is one of the earliest applications of GIS. Mapping activities to support planning, response to emergencies and decision-making depend on systematically making available information about both the potential sources of hazards and disasters and their likely locations. Identifying methods of access to these locations and defining the populations and health services around them can facilitate the management of disasters and help to mitigate their impact.

Mapping plays a major role in documenting locations, extent of damage and affected populations and helps in predicting possible recurrence of disasters. Locations for temporary camps for displaced persons, emergency and relief centres, access routes, field hospitals and logistics support can only be properly planned using maps.

Environmental risk assessment can be translated into maps showing the geographical distribution, susceptible populations, potential exposures and health outcomes. When known hazards and potential sources of disasters are mapped, better decisions and plans can be made.

3.6 Access to health care services

Access to health care services and delivery centres is concerned with the ability of a population to obtain a specified set of health care services [13]. Developing and making available maps to identify locations of health services, or what is called health services mapping, is one of the major applications of public health mapping. Health services mapping includes identification of patterns of settlement, type of services in relation to human settlements, and the proximity of primary health care centres, secondary and tertiary services. Mappable factors such as distances between settlements and health services (hospital, primary health care centre, emergency station), road infrastructure and types of transportation available greatly influence accessibility of health services.

4. Global and regional situation with regard to health mapping

4.1 Global mapping initiatives

The United Nations Geographic Information Working Group (UNGIWG) was established in March 2000 with the overarching objective of promoting the use of geographic information within the United Nations system and Member States for better decision-making. The UNGIWG aims to:

- identify and implement protocols for sharing, maintaining and assuring the quality of geographic information within the UN system for efficient and cost effective use of such information to the benefit of Member States in cooperation with other institutions;
- identify, develop and maintain common geographic databases as a crucial capacity-building effort to enhance normative, programme and operational capabilities and efficiencies within the UN system [14].

Each agency contributes to the working group in its area of specialization, such as health, environment, water, food and agriculture, through its membership in UNGIWG. WHO is an active member in the UNGIWG and makes a substantial contribution in the area of health mapping.

UNGIWG works through six task groups that have been established to coordinate the work at the global level. The work of the groups covers a variety of services and products including standardization and policy setting, compilation and production of databases, production of maps, training, technology transfer and capacity building in Member States.

The Second Administrative Level Boundaries data set project is an interagency project aimed at creating a homogeneous data set for improving the collection, management analysis and signing of subnational data. The project builds on work done in the context of the UNGIWG and on different efforts that took place in the 1990s where the delimitation of the administrative boundaries was needed for the creation of population distribution grids [15].

Service Availability Mapping is a global effort organized by WHO to collect and present basic information on health services: health infrastructure, human resources and services offered. Its main application is at the subnational or district level, where district health management teams can use the results in conjunction with WHO's HealthMapper application.

WHO's Communicable Disease Global Atlas brings together for analysis and comparison standardized data and statistics for infectious diseases at country, regional and global levels. The analysis and interpretation of data are further supported through information on demography, socioeconomic conditions and environmental factors, in recognition of the broad range of determinants that influence patterns of infectious disease transmission.

The Atlas aims to provide a single point of access to data and information on the major diseases of poverty including malaria, HIV/AIDS and tuberculosis, diseases targeted for eradication or elimination (such as guinea-worm disease, leprosy, lymphatic filariasis), epidemic-prone diseases such as meningitis, cholera and yellow fever and emerging diseases or areas of concern such as antimicrobial resistance. In addition to epidemiological information, the Atlas provides information on essential support services such as the network of communicable diseases collaborating centres and the Global Outbreak Alert and Response Network among others. The database is updated on an ongoing basis.

WHO has developed a computer-based system called The HealthMapper to address critical surveillance information needs across infectious disease programmes at national and global levels. The HealthMapper is a data management and mapping system customized specifically for public health users. The system facilitates data standardization, collection and updating of data on epidemiology and on interventions and allows immediate visualization of data in the form of maps, tables and charts. The HealthMapper also includes a database of core baseline geographic, demographic and health information, including the location of communities, health care and education facilities, roads and safe water sources.

4.2 Regional mapping activities

GIS infrastructure

In 2007, a survey was conducted in countries of the Region to assess the situation of health mapping and the use of GIS in ministries of health. The survey collected data on information and communication technology infrastructure (human resources, hardware, software and telecommunication), data (health database and digital maps) and procedures.

Out of 16 countries that completed the survey questionnaire, 15 indicated that they have GIS activities as part of the national health information centre or computer department. Five countries have independent GIS units within the ministry of health, while four have special budgets for GIS activities. The earliest activities using GIS technology were initiated in Yemen in 1994, while the majority of countries started activities between 2001 and 2003. The presence of a GIS unit was an indicator of strong coordination with planning, emergency, health statistics, surveillance and epidemiology departments. Countries reported a total of 12 GIS network servers. Thirteen countries use specialized GIS software, mainly ArcGIS/ArcView, a commercial software package, or HealthMapper, which is provided by WHO free-of-charge. Other commercial packages are also used.

Spatial databases are maintained in 12 countries. The vast majority of countries maintain data on health services and facilities, while others also keep disease surveillance, health statistics and demographic data. Eleven countries maintain a digital map of the country with varying scales according to need. These same countries have digital maps at the district/province level. It is not clear how other countries manage the spatial database without these maps. Few countries have maps at subdistrict or regional levels. The majority of countries have specialized staff operating GIS services, including cartographers, computer engineers, statisticians and epidemiologists. Five countries indicated the availability of regulations or routine procedures for informing GIS teams of any changes in the country administrative structure, while six countries have regulations or routine procedures within the Ministry of Health to inform GIS teams of newly built or relocated health facilities with the

geographic location. Maps (spatial data in general) are collected from the specialized agency in the country or from international agencies including WHO.

Use of health mapping

A review of published literature showed that a number of countries in the Region have used GIS for health mapping. The common element in all these studies is the strong link between geography (location) and the health problem being addressed. Presenting health data in a map, using GIS, was employed in these studies to help show the influence of geography on health.

A GIS-based analysis was conducted in the Islamic Republic of Iran to map the incidence of childhood cancer in districts of the Tehran metropolitan area and to explore possible clustering of cancer cases in the diverse environments of this area [16]. In a study of the Rift Valley fever outbreak in Yemen in 2000–2001, GIS technology enabled researchers to study the spatial distribution of outbreaks at the national and local levels [17].

In Egypt, health mapping techniques have been used for a number of different purposes. Several studies were conducted in which GIS functions were used to identify environmental indicators for villages at high risk of filaria transmission [18,19]. Another GIS-based application was shown in a study of access to family planning services. The study used geographic information to link data from a population-based survey with an independently sampled health facility survey [20]. Another study, which used remote sensing and GIS technology to identify mosquito breeding habitats and delineate associated health risks, demonstrated the practical and successful application of remote sensing and GIS in assisting decision-making for health and development [21]. Another study analysing under-five mortality in Alexandria used GIS to determine regional variations in the under-5 mortality rate [22]. Environmental variables in a malaria GIS database were analysed in another study in Egypt to identify governorates at high and low risk of malaria [23].

In Afghanistan, a study was conducted using GIS technology and population-weighted raster maps to assess mine education performance, coverage and costs [24]. In Saudi Arabia, GIS technology was used to produce catchment area and patient profile, distribution and flow models to support local health planners in their health care decision-making [25].

A study in Lebanon integrated different data sources using GIS techniques to support decision-making in the humanitarian sector. In the humanitarian community, data integration for health mapping has served as a powerful coordination mechanism and led to the creation of UN-led Humanitarian Information Centers [26]. In Kuwait, a GIS application was used to model exposures to smoke from oil fires by integrating spatial and temporal records of smoke concentrations and population movements. The exposures were then linked with reports of upper respiratory ailments [27].

5. Future directions

In early 2001, a geographic information systems strategy and plan was prepared that aimed at two main products: integrated GIS capacity at the Regional Office, and functional national health GIS capacity, initially in at least 12 countries of the Region. The plan is updated on a continuous basis to respond to emerging needs. The Regional Office has built a GIS infrastructure and established staffing and a repository of digital maps of the countries of the Region. In countries, GIS capacity has been developed through needs assessment, training, publishing of health maps and building a repository of digital maps.

The Regional Office is collaborating with countries to build health mapping capability. All countries have digital maps covering the first administrative level, i.e. border areas, with the majority including the elevation and population density, transportation networks (roads, rail and airports) and lakes and rivers. Ten countries have maps showing the second and third administrative levels. Publishing of health maps on the internet at the national level has given better visibility and allowed for development and collaboration among national authorities.

A number of mapping initiatives are also under way or being planned in the Region.

- Poverty mapping has been initiated in support of the community-based initiatives (CBI) in the Region. A comprehensive database of CBI projects is being developed, showing the country profiles, poverty lines, activities and health indicators. An initiative is under way to create a map of the Region with CBI data.
- Services availability mapping has started in a number of countries in collaboration with the Regional Office and aims at developing maps at the district level showing all health facilities and their profiles.
- The Regional Office has been among the major contributors to the WHO Communicable Disease Global Atlas by providing health and disease data on a regular basis through the regional reporting systems. In particular, extensive effort was made by the Roll Back Malaria programme to finalize this project.
- The first volume of the Atlas of Disaster Risk has been published in order to encourage and stimulate ministries of health and other stakeholders within the health community to improve their disaster management capacity. More specifically, it is expected that the Atlas will be used as a tool to advocate for resources to improve disaster preparedness in the health sector, aid emergency response measures through better baseline information, assist in identifying, planning and prioritizing areas for mitigation activities to minimize the effects of natural hazards and provide a springboard for transitional and early recovery activities after an emergency [28].
- Mapping efforts were undertaken in support of disaster management in the Islamic Republic of Iran during the Bam earthquake, in Pakistan during the Kashmir earthquake, in Lebanon during the crisis in 2006 and in conflict areas in Somalia and Sudan.
- Disease-specific maps are being developed at the country and regional levels through close collaboration with technical control programmes for malaria, tuberculosis, poliomyelitis, human influenza and others.

There is clear evidence that the application of geographic information systems for health mapping can play a major role in public health management. Mapping tools can be used to support decision-making and planning in epidemiological studies, disease surveillance, disaster management, health services, environmental health assessment and social determinants of health. A number of countries have taken steps to build infrastructure and initiate activities to support health mapping. Published studies indicate that many countries in the Region are already using mapping techniques to identify priority public health concerns and address them. However, in most countries a coordinated effort and strategy are missing.

Efforts to further develop health mapping must also focus on overcoming a number of key constraints. In some countries maps are treated as a confidential source of information associated with national security and are handled by the military, limiting use of these maps at the national level. Base maps that are available for health mapping are often outdated or of poor quality. In many countries, maps are compiled and supplied by variety of agencies for different purposes with different coding and standards of accuracy and scale, which makes them difficult to integrate and use at national level. Cooperation is often weak between the Ministry of Health and other ministries, especially the Ministry of Information and Communication, Ministry of Interior and mapping authorities. Coordination is lacking in existing mapping activities within ministries of health, for example for malaria, disaster activities or health facilities and services. Also lacking are trained human resources to produce, ensure quality control and manage health maps in collaboration with health statisticians and epidemiologists. Overall, there is a great need to increase awareness of the value of mapping as a tool for health managers, planners and practitioners.

6. Recommendations to Member States

1. Develop an institutional framework, policies and procedures necessary to support regular health data collection, health mapping and reporting to encourage evidence-based policy-making and planning at all levels.

2. Establish health mapping units with the necessary infrastructure and resources, including human resources, to support health mapping activities at country level and collaborative efforts at regional and global levels.
3. Develop integrated national systems for the management of health data and link the systems to digital maps, allowing technical programmes to input, verify, update and view health data on maps online.
4. Build, develop and maintain a comprehensive collection of national and local digital maps including detailed administrative and health levels, water resources, transportation, hazardous areas, disaster-prone areas and health care facilities.

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