Application of Geographic Information Systems and Global Positioning Systems for Public Health Rapid Needs Assessments in Disaster Settings

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ABSTRACT

Rapid needs assessments are an important post-disaster epidemiologic method used to determine the magnitude and severity of a situation, the amount of resources required, as well as the need for and feasibility of interventions. GIS is a tool for linking epidemiologic information with other data sources that can improve rapid needs assessment methods by enhancing area identification, sampling, data collection, analysis and dissemination of information. This paper illustrates uses of GIS technology in conducting rapid needs assessments.

KEYWORDS: geographic information systems; global positioning systems; natural disasters; rapid needs assessment

1.0 INTRODUCTION

Information about changing health parameters and physical needs becomes critical after a disaster event as large numbers of people may become injured or ill or are killed, populations displaced, living conditions overcrowded, usual sanitation and hygiene compromised and normal public health programs interrupted or ceased (Gunn, 1990; PAHO, 1982). Community-based rapid needs assessments are one of the most important post-disaster methods used to determine the magnitude and severity of the situation, the amount of resources needed, as well as the need and feasibility of an intervention (Kaiser, 2003).

Rapid needs assessment refers to a set of tools—epidemiologic, statistical, and anthropologic—designed to provide, quickly and at low cost, accurate and reliable population-based information about an affected community's needs after a disaster in a simple format to decision makers (WHO, 1999). The primary objective is to obtain information about the needs of an affected community as these needs change in the aftermath of a disaster event. Rapid needs assessments have addressed: (1) general needs that may be common among affected populations (e.g., access to transportation and prescription medications); and (2) specific needs that may be relevant to local conditions (e.g., access to particular communications media such as a radio station), or to the nature of a particular disaster event (e.g., use of gasoline-powered generators in an ice storm.) (Malilay, 2000). The technique has been applied to numerous hurricane and earthquake events to describe the impact of the event on the health status of affected communities; characterize the demographics of affected communities; determine the critical needs (i.e., food, water, shelter, electricity) of affected communities; prevent or reduce adverse effects on health; and evaluate the effectiveness of relief programs.

Geographic Information Systems (GIS) and Global Positioning Systems (GPS) are powerful computerized tools that examine the spatial location component of epidemiology and link it with person and time information to examine key relationships between the health characteristics of populations and both human and physical environmental characteristics. In a disaster setting, GIS and GPS can refine the way in which information about infrastructure, population distribution, and climatic conditions are collected, analyzed, and disseminated.

GIS, GPS and remote sensing are technologies that can be used in tandem during disaster and non-disaster events. The U.S. Geological Survey (USGS) describes GIS as "a computer system capable of storing, manipulating, and displaying geographically referenced information (i.e., data identified according to their locations) from the real world for a particular set of purposes" (USGS, 2005). GPS is a constellation of earth-orbiting satellites that transmit information to hand-held or built-in receivers that can calculate a location with a potential precision of one square meters (i.e., longitude, latitude and elevation) (CDC, 1993). Remote sensing or satellite imagery refers to the data obtained by sensors on earth-orbiting satellites. Remote sensing data can be used in GIS to show surface areas of water, deserts and forests; and human activity (e.g., settlements, roads, land usage) (CDC, 1993).

GIS mapping has been used to assess and model catastrophic events such as earthquakes and hurricanes (Croner, 1996) and is being used to enhance epidemiologic methods such as rapid needs assessment used in post-disaster situations. GIS can link epidemiologic information with other data sources to enhance area identification, sampling, data collection, analysis and dissemination. This paper illustrates uses of GIS technology in conducting rapid needs assessments.

2.0 IMPLEMENTATION OF GIS SYSTEMS IN DISASTER FIELD SETTINGS

2.1 Area Identification

When a sudden-impact disaster strikes, one of the most important tasks is to ascertain the geography of the affected area, ascertaining the spatial extent of the catastrophe by defining its perimeter and identifying cardinal points (Alexander, 2000). Information initially collected during rapid needs assessments should focus on the geographic areas most severely affected (WHO, 1999). These areas are likely to be the places where the majority of affected persons are located and where public health interventions can have the greatest impact. In order to ensure a timely and appropriate emergency response, it is essential to locate these areas and complete initial assessments as quickly as possible. In order to accomplish this, different types of information from a variety of sources (e.g., storm surge and storm path information from the National Hurricane Center, power outages from electric companies, aerial damage assessments from the Federal Emergency Management Agency [FEMA], phoned-in reports from county emergency managers, injury and illness information from hospitals, color images of damage from IKNONOS satellites) must be collected and synthesized to develop a coherent picture of the affected area. Initial assessments may be delayed while information is processed or risk misidentifying the affected areas (WHO, 1999).

GIS provides a means of integrating information from numerous sources to accurately identify affected areas. For example, GIS could be used to overlay data about storm path, power outages, storm surge, flood zones and daily rainfall after a hurricane. After an earthquake, GIS can be used to overlay information about the modified Mercalli index intensity, proportion of damaged buildings, density of buildings and population, location of the epicenter, and patterns of building failures. The information collected can be continually updated as new reports become available. GIS can also be used to identify vulnerable populations (e.g., mobile home residents, elderly residents) within the affected area. This information could be used to target assessments of particular groups known to be at high risk during the post-disaster period.

HAZUS-MH, FEMA’s software program for estimating potential losses from disasters, may aid in predicting areas likely to be affected before a disaster even occurs (FEMA, 2005). Data systems like HAZUS-MH and others like those supported by the Louisiana State University, Center for the Study of Public Health Impacts of Hurricanes are able to create high resolution models of disaster damage such as storm surge and flooding. These in turn provide emergency managers with precise information about populations that are likely to be affected by disasters (CSPHIH, 2005).

2.2 Sample Selection

In the aftermath of a disaster there is frequently an absence of adequate baseline data against which to measure the impact of the disaster (Noji, 2005). GIS methods may increase accuracy (through improving random sample selection) and precision (time-saving methods may allow increasing sample size) (Roper and Mays, 1999). For example, a sampling method commonly used in conducting community based rapid needs assessments is based on a modification of the World Health Organization (WHO) Expanded Programme on Immunisations (EPI) methodology which requires that the approximate population size and location of sub-areas (e.g., census blocks, villages, clinic referral areas) or clusters are known (Malilay, 1996). In the first stage, clusters are selected proportional to population size. In the second stage, boundaries of clusters are mapped, and all or a portion of households in the selected clusters are surveyed. In the United States, GIS maps with block level information from the US Census 2000 (e.g., number of occupied households, race, gender, age) are readily available. GIS mapping techniques can facilitate these processes and remote sensing information such as imagery from Space Imagining's Ikonos satellite can be incorporated to show detail including individual shelters, narrow streets and paths, and small rivers (USIP, 2004).

Following an ice storm in Maine in 1998, we used GIS and GPS for mapping and selecting clusters based on US 1990 Census data (CDC, 1998). Road segments were mapped to the selected clusters to aid survey teams in locating the clusters. After Hurricane Charley (August, 2004), the North Carolina Division of Public Health demonstrated new sampling capabilities with the use of GIS technology and handheld computers. The state team used mapping software to generate and map seven random points in each of the selected clusters, and interview teams navigated to the random points in their assigned census blocks by using handheld computers equipped with global positioning system plotters. Interview data were collected on the handheld computers from the household closest to the random point in the census block. These modifications simplified the mapping process and introduced a new method for randomization in the selection of households within the census block group (CDC, 2004).

2.3 Field Navigation and Data Collection

Information capture and exchange is crucial in conducting epidemiologic field investigations. Software applications and hardware that make technology available in the field can improve the efficiency of current epidemiologic methods. GIS and GPS can provide maps for navigating survey areas and collecting spatial information while teams are in the field conducting the survey. For example, the positions of key landmarks, such as latrines, water points and health clinics can be recorded, mapped and used in conjunction with data recorded from households to aid in interpretation and assessment of spatial patterns (Kaiser, 2003). Handheld devices (e.g., PDA) interfaced with GPS were used after Hurricanes Charley, Frances, and Ivan in conducting rapid needs assessments in Florida. Survey teams used paper maps generated by GIS and handheld GPS to maneuver to selected clusters and move through disaster affected areas where damage to street signs and landmarks complicated navigation.

Household health assessments were conducted by the Florida Department of Health's Disaster Community Health Action Teams (DCHAT) after Hurricanes Charley, Frances and Ivan (DCHAT, 2005). DCHAT teams used portable devices equipped with GPS units to rapidly collect electronic information which was uploaded and analyzed daily. Technology developed by GeoAge was then used to seamlessly integrate the location intelligent data with interactive maps and reports (GeoAge, 2005). As data were updated, results and interactive maps were immediately available to authorized users with an Internet connection and standard browser. DCHAT teams also used GPS to identify the location of households that had urgent needs in order to direct emergency services to their location.

2.4 Analysis

Spatial statistics for public health application is now a rapidly evolving field. Methods include calculation of crude adjusted and smoothed rates; tests for spatial randomness; and regression analysis to examine associations between geographic distribution of exposure and disease (Kulldorff, 1999). While these types of advanced methods have not yet been applied to rapid needs assessments, GIS has contributed to the advancement of analysis of rapid needs data. In the immediate post-disaster phase, population size estimates are necessary to determine the scope of the emergency, estimate resources needed, and provide reasonably accurate population denominators for health indicators. This often requires dividing an area into clusters, randomly selecting clusters, and counting the population in all households or a random sub-sample of households in each randomly selected cluster. The number of people estimated per square block can then be extrapolated to the total population as can needs assessed among households in those selected blocks. GIS and GPS can be used for mapping the area, creating the clusters, locating the selected clusters, and determining the number of households in each cluster (Kaiser, 2003). For example, teams equipped with electronic maps of a selected cluster on a PDA could edit maps as they drive or walk through the area noting the exact number and location of houses. In places where previous population data are not available, area probability sampling, using geographical area and population density, can be used to estimate population size (Noji, 2005). When information such as the location of health clinics, food distribution sites, or drinking-water sources is collected, the distance between surveyed households and these locations can be used to assess access of the population to essential services (Kaiser, 2003).

2.5 Presentation and Dissemination

GIS methods provide improved ways of presenting traditional epidemiologic data as well as new spatio-temporal information that has a variety of implications for programmatic decision-making, monitoring and evaluation in post-disaster situations (Kaiser, 2003). In order to make optimal decisions to reduce the loss of life and property, stakeholders uniformly must be able to obtain the needed information in a format that is appropriate for their capabilities and share information in a seamless fashion (Roper, 2004). GIS allows public health officials and emergency managers to visualize and integrate multiple data layers and facilitates frequent, rapid updates and distribution of information. After an assessment has been conducted, GIS can be used to evaluate recovery efforts or aid programs—monitoring locations of surveys relative to aid activities and food distribution sites to show whether resources are adequately allocated or whether programs need adjustment according to changing needs of emergency-affected populations.

3.0 DISCUSSION

Epidemiology has long been concerned with understanding the role of place, space, and distance relative to the health of a population. The main contribution of GIS in conducting rapid needs assessments has been to provide maps for decision-making and advocacy through overlaying types of information that may not normally be linked (Kaiser, 2003). Though its primary role has been as a mapping tool rather than an analytic system, the role of GIS in rapid needs assessments and other post-disaster assessments is evolving. Rapid needs assessments represent one GIS field application in post-disaster public health. Hazard vulnerability and risk assessments; disease distribution and outbreak investigations; program monitoring and evaluation; and survey methods can also employ GIS. We used GIS to spatially link deaths related to Hurricane Andrew with the location of designated evacuation zones and with structural damage assessment data to help identify potential risk factors for death and injury (CDC, 1992; Malilay, 1993). GIS software was used to map injury locations after the 1994 Northridge earthquake in California to show that factors such as age and activity of people during the earthquake may be as important as seismic features in predicting injury from earthquakes (Peek-Asa, 2000).

Expanding the role of GIS and GPS in post-disaster assessments is dependent upon equipment and methodologies being practical and appropriate for field use. Timeliness, consistency, understandability, accuracy, and flexibility are key attributes to their application after disaster events (Roper, 2004). Inconsistent data standards can make integration of data difficult and information delivery systems often become overloaded during crises. Even more alarmingly, users are sometimes unaware of the limitations and uncertainties in data or are presented with conflicting interpretations of data without the means to assess the reliability of the sources (Roper, 2004). Putting data into its spatial context can actually introduce a significant amount of other information and allows many biases and patterns of learning to potentially reduce the ability to usefully interpret the information (Ricketts, 2003). All can reduce the efficacy of the decision-making process. Users must be able to effectively and efficiently share information, precisely integrate and georeference variant data layers, compile them into a single view, and correctly interpret maps. Further discussions of the technology will be necessary to determine their utility relative to their limitations (e.g., data standards, interpretability, field readiness and durability). Additionally, studies are needed to compare the sampling methods that incorporate GIS and GPS with the standard EPI method in terms of quality of the outcome estimate, cost and degree of difficulty (Kaiser, 2003).

4.0 CONCLUSION

Effective public health action within the context of disaster epidemiology relies upon collection of accurate and timely data, precise analysis and interpretation of these data, and effective dissemination to decision makers. GIS and GPS can enhance each step in this process through improving sampling, data collection and techniques as well as heightening the effectiveness with which results are conveyed to decision-makers.

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