The Added Value of Geographical Information Systems in Public and Environmental Health

edited by

MARION J.C. DE LEPPER

National Institute for Public Health and Environmental Protection, Bilthoven, The Netherlands

HENK J. SCHOLTEN

Department of Regional Economics, Free University & GEODAN bv, Amsterdam, The Netherlands

and

RICHARD M. STERN

World Health Organization, European Centre for Environment and Health, Bilthoven, The Netherlands

KLUWER ACADEMIC PUBLISHERS

DORDRECHT / BOSTON / LONDON

EUROPE

Published on behalf of the
World Health Organization Regional Office for Europe

13 GEOGRAPHICAL SOFTWARE APPLICATIONS FOR HEALTH SECTOR PLANNING: EXPERIENCES FROM A STUDY FOR FAMINE MANAGEMENT

Debarati Guha-Sapir

Abstract
The use of geographical techniques in the health sector has been an issue of increasing interest. Along with facilities in graphic presentations rendered easy by new software techniques in computers, mapping and related interpretations of numerical data has captured the attention of health care specialists as an useful tool. The stumbling block, however, has been the potential for analysis and the concrete uses that such a marriage would bring. The resolution and the accuracy of the data used in the health sector is generally far below the standards required for the proper application of geographical tools. Terminologies and underlying concepts also differ sufficiently to make interdisciplinary initiatives difficult. Despite these hurdles, in 1987, within a study financed by the World Health Organization (WHO) on information systems for famine management in Africa, the WHO Collaborating Centre for Research on Disaster Epidemiology (Brussels, Belgium) experimented with a specific application of geographical techniques for health sector planning. Although applications of geographical techniques were not the principle objective of the study, the potential for geographical information systems for health priority-setting and optimal planning, especially in situations where a rapid response is required, was considered worth a certain investment in research and development for appropriate applications.

13.1 Background and objectives of the study

Information systems, in the context of famines are, principally, of two kinds: early-warning systems and management systems. The former have had great success in the last two years. The latter have been, on the contrary, visibly neglected. The purpose of this case study, called consolidated information system for famine management in Africa (CISFAM) was to design a centralized information service for programme managers to make educated and rapid decisions for famine interventions and policy. The system would respond to the information needs of government, nongovernment and intergovernment agencies for planning, targeting and policy-making in famine response programmes. It would serve as a centralized source where pre-selected information on sectors such as agriculture, meteorology or economy, in addition to health, would be quickly and easily available, thereby eliminating the need for planners to go to different specialized agencies for information.

The rationale for this study was based on four conditions dominating rapid and effective famine response action.

M. J. C. de Lepper et al. (eds.) The Added Value of Geographical Information Systems in Public and Environmental Health 189–199

First, resource constraints were getting increasingly serious with grave implications for continued international assistance for control of famine conditions in Africa. Second, while the health sector is focal in famine relief, the crisis is essentially a multisectoral problem and requires multidisciplinary data for rapid programme planning and resource allocation. Third, large quantities of data exist in specialized agencies of the larger United Nations family and in national archives. Most of these remained unused in emergencies, since the international databases are frequently in sophisticated forms that are inaccessible to the uninitiated and the national ones are non-standardized and non-computerized, making retrieval of selected information difficult. Finally, nongovernmental organizations were observed to frequently have regular data reporting systems that were not adequately processed or used either by themselves or by the governments with whom they work. These agencies formed a potentially important repository of local data.

It was also increasingly recognized that, in planning health care services for famine conditions, where rapidity of decision-making is critical, information from several sectors besides health is required and, furthermore, available for use in digested forms that allow interpretation and analysis by health specialists. The study therefore addressed essentially the issue of information for rapid response planning in situations of mass displacements or acute local food shortages. Based on field experiences, five additional sectors besides health were selected as being relevant. These were demography; agriculture; logistics and infrastructure; socioeconomic; and environment and meteorology.

The specific objectives of the study were:

(i) to conceptualize and design a ready-to-use information system for transfer to the national health authorities or the relief and recovery management unit;
(ii) to identify and develop image-, graphic- and map-linked databases for quick interpretation and operational decision-making.

This chapter focuses on the second objective, its experience in the application of geographical information system (GIS) techniques.

13.2 Data aspects

13.2.1 Database design

The structure of the system was defined by country blocks. Information by category, as available, was collected for each country and any additional information generated by special survey and studies generated by other bodies was appended in the informational annexes to the country data block. These annexes were restricted to only the surveys dealing with food, nutrition and health. The system was not designed to create any new sources of information but rather to enhance the utilization of information held in existing databases. The project therefore examined databanks and information systems of the United Nations agencies and allied bodies and found that many useful sources of information and databases were frequently unknown and even less utilized by most of the implementing agencies. A very small proportion of the potential users, including national governments showed any knowledge of the internationally maintained systems and databases and fewer acknowledged ever requesting or receiving any information from them. Several databases were examined, including both electronically maintained and data on cards, reports and other forms of hard copy. Certain countries had better data reporting than others and the variability was significant. This was problematic for standardization of data format across countries. In addition, specific sectors had better data collection systems than others.

Meteorological, ecological and climate databases provided the best quality information in terms of reliability, coverage, accuracy and time series. The Climate System Monitoring (CSM) databases of the World Meteorological Organization (WMO), initiated as a response to the occurrence of significant climate anomalies over the last decades, provided useful information when associated with adverse socioeconomic effects. The WMO databases carried synthesized information on climate anomalies, rainfall variability and vegetation data by small geographical areas. It had available time-series data for the past 110 years on African rainfall. The data, however, were technical in nature and were not divided by the political and administrative boundaries of the countries. Similarly, the soils and temperature databases of Africa held by the United Nations Environment Programme were also reliable sources. Both sets required some interpretation and adjustment to be classified most meaningfully by international and national boundaries.

The health sector information, on the other hand, was disappointing in both coverage, quality and continuity. Physical resources, such as hospitals, dispensaries, health centres and skilled personnel enumerated in the data source agencies, were the only items with relatively regular reporting. However, a major caveat in these items was that hospitals and health centres were frequently inoperative in reality and therefore, the value of this data was questionable for rapid response planning. For crisis management and long-term planning, data on the existence and functioning capacity of institutions in affected areas can be key to efficient response. Several sample surveys on nutritional status and incidence of nutritional deficiency diseases were available, but no official figures were reported on an ongoing basis. Continuous nutritional data collection in this field was generally undertaken only by large nongovernmental organizations, which did this as an incidental by-product of their principal activities.

Archival data were also uneven in coverage over time and quality varied. The cholera and yellow fever data transferred from cards filed on the weekly epidemiological reports were perhaps the only regular incidence data to be reported to WHO by province. The data were considered to be underreported and the magnitude of this underreporting was unknown. The problem became aggravated when the data were compiled by different agencies. Estimates differed for the same disease according to the source (government, nongovernmental or international) and, on occasion, delayed reporting caused inexplicable increases in the incidence of diseases that were not due to the extension of the reporting period.

13.2.2 Data quality

Data limitations are a primary consideration in interdisciplinary approaches to analysis. While they should not block exploratory research, it is essential to examine well the caveats such that they can be accounted for in the development of applications. Limitations become additionally problematic when data from different sectors have to be worked into a GIS application. For example, the denominators of indices differ as well as time and space units. Some examples of these limitations are described below.

The comparability of the statistics in Africa, both temporal and spatial, was mainly limited by the use of non-comparable definitions. For example, in agriculture, under traditional African conditions, it is not always clear what would be the main occupation of the individual. Persons can be occupied in different occupations at different times of the year, creating definitional ambiguities especially for risk assessment. In certain countries of the region, farmers frequently work away from their holdings during a large part of the year, for example, on plantations, in mines or nearby towns. Furthermore, the fact that a man can have several wives who independently cultivate separate pieces of land although the land may customarily belong to the head of household creates problems for both demographic and agricultural information.

In general, the problem in this project was more the lack of usability of data rather than their inaccessibility. In other words, much of the data existed, but processes to reformulate them in ways that could be entered in models or images were complicated. In addition, conceptual (between sectors) and numeric compatibility were also problematic. For example, time intervals of data that are of critical importance were at different scales for epidemiological data compared with ecological or climate data. This meant aggregated scores had to be developed to standardise time frames between variables. Similarly, health data was often hospital-based, which imposed certain limitations in its interpretation. The population or geographical area it represented was not compatible with data from other sectors that were more precise. Economic or environmental data, on the other hand, tended to be population-based and were not subject to the same constraints.

The data also suffered from limitations due to their selectivity. Hospital statistics, although an accurate source of diagnostic information, present a serious bias arising from selectivity in relation to factors such as location, type of disease, provision of health facilities, age and sex and socioeconomic status of the patient. The population served was frequently unknown. It was therefore not possible to generalize the hospital data to a community or a geographical unit. These statistics could give an inaccurate appreciation of the prevalence of morbidity, if extrapolated. They could, nevertheless, measure the relative distribution of diseases in the areas covered and be treated as valuable adjuncts to mortality statistics, suggesting priorities for provision of more medical facilities and efficient medical care.

For purposes where rapidity is the primary objective, timeliness of statistical information is *sine qua non*. But this can be maintained almost only at the expense of accuracy, while improvements in quality require more time and increase the cost of the information.

13.3 A GIS for famine management: technical aspects

Like most computer-based information systems, CISFAM had a series of basic features: data capture, storage and retrieval, analysis, output and display. Data capture involved putting information into the computer and organizing it in memory. The key element was how GIS software handled each piece of information. Retrieval, the reversal of storage, recovered ordered data from the memory and searched information with certain characteristics (e.g., all hospitals less than 20 km from a paved road or with maternity wards) for use in the development of maps or in estimating risk. A special feature of CISFAM was its capacity to analyse as well as display the results in images. This involved the retrieval of data files or parts of them in any combination and analysing them to generate composite maps. These display possibilities would help planners manipulate and prioritize needs for resource allocation by changing risk factors and therefore shift priority emphasis on the maps.

The GIS aspect of the project depended on two basic techniques of data use: overlays and statistics. In consultation with the staff of UNEP-GRID, two main directions were identified for exploration. One was overlaying data planes for composite images. For example, for any defined area, datasets could be overlaid in an electronic version of stacking maps with different information for the same area. The greater the number of datasets, the greater the number of possible comparisons. For example, in a study of malaria control, the software would compare water distribution, health centres, domestic animal distribution and endemic malaria incidence by overlaying these datasets one by one. In emergency health planning, this had special implications in pinpointing vector-breeding sites, location of displaced population camps or temporary food or health care distribution points as well as arable land area and firewood availability.

The second was the potential of spatial modelling techniques using composite databases of numerical and image data. For example, certain diseases with biological, environmental and human spatial parameters were modelled to reproduce a multidimensional distribution of the disease over the area of interest.

13.4 Experimental application of GIS technology to health planning: the case of Senegal

One of the most important developments in affordable computer technology has been the emergence of GIS, and today, many types of GIS are currently in use. For CISFAM, the GIS system used integrated tabular (i.e., vital statistics) and thematic (i.e., ecological) maps with digital satellite data (i.e., vegetation) in a geographicalal context that allowed analysis of physical, biological, economic and social information on visual planes. The feasibility of linking these different types of data was tested by developing a model for detailed estimation of population density in Senegal.

In the absence of data, the development of a population density dataplane for Senegal was undertaken using a model with specified parameters that were hypothesized to determine the population distribution. Appropriate coefficients were estimated by regression analysis using a combination of extrapolated data and data from countries with similar ecological conditions. Thus, relative distance from roads according to the type of road, relative distance to a city or town according to its size and administrative importance, presence of water sources, climate and topography were all considered using different techniques in the model. The latitude and longitude of major transportation routes and 118 towns in Senegal were digitized from 1 500,000 scale maps obtained from the Institute Géographique National, Paris. Each of the towns was assigned a rank from one (village) to five (metropolitan area), based upon the relative size of each. The Earth Resources Laboratory Application Software (ELAS) was used at UNEP/GRID to develop six raster or gridded cell (pixels) dataplanes generated at 30 seconds of latitude and longitude resolution (approximately one square kilometre) one for the transportation network and one for each of the five ranked town sizes. Dataplanes for distances away from each town and road were then developed using the ELAS overlay DIST. Topography, climate, desertification and surface water distribution were introduced as satellite images. The final estimated population density dataplane was generated by the summation of each of these distances indexed through tables with different weights for the roads and relative size of towns as contained in the following chart using the ELAS overlay DBAS. Hypothesized coefficients of influence of other variables were included in the model. The iterations were made successively, as a function of constraints to produce topographic distributions of the variables of interest. The results are shown in Maps 13.1, 13.2 and 13.3.

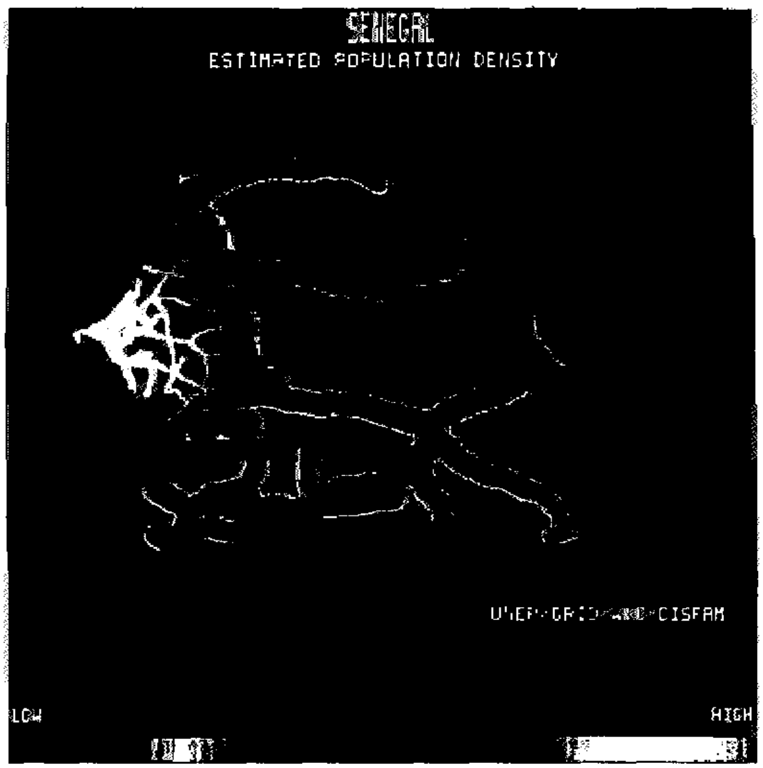
13.5 Conclusions

CISFMA was founded on the concept of management information systems for health. Although this concept is no longer controversial, a certain fuzziness exists about the elements and purposes of such systems. Data of many kinds are fed into a management information system, but unless selectively compiled and processed, they convey little other than standard archival data. The value of data and statistics in a management information system is judged by their usefulness in programme evaluation and policy formulation.

Today, technology can almost certainly be counted on to cut down the costs of producing and collecting figures (e.g., processing). However, it should be recalled that data compilation is only the start of a whole chain of processes, which include interpretation of the data collected and statistical analysis and research, all of which are entirely dependent on the basic conceptualization of the initiative and on human ingenuity for interpretation. The reconciliation of the needs for international comparability and hence conformity with the standards laid down by the international agencies and the specific domestic needs of an individual country can pose difficulties. This requires a certain amount of ground work in standardization and common definitions and criteria between the collaborating agencies.

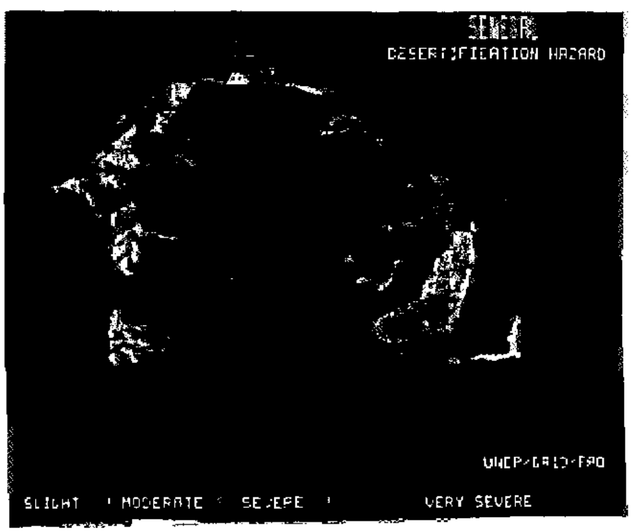
The importance of multisectoral data needs for the health sector underscores the interest in using image-processing techniques. Currently the problem is not so much that data from the different health-related sectors are unavailable. On the contrary, there is a very large number of existing databases. What is more, the issue is the underexploitation of this data. The digestion of the different data into formats that are interpretable by health policy-makers would constitute an extremely efficient tool towards the better use of resources. Today, the technically difficult formats in which specialized geographical, meteorological and ecological data are maintained and the discipline-specific terminology pose major stumbling blocks to interdisciplinary use.

Map 13.1: Estimation of population density; the UNEP/GRID model applied to Senegal, integrating major cities and transportation routes



Map 13.2: Modelled distribution of health care accessibility in Senegal

Map 13.3: Desertification hazard in Senegal



In addition, the constraint on monitoring health is not the inability to provide reliable and relevant indicators. This can be done with a degree of confidence. The key element is the appreciation on the part of international and national policy-makers of the importance of collecting and using relevant data to monitor conditions and plan programmes and the will to use tools, techniques and materials that are already available to them.

It is clear that spatial modelling is a feasible alternative to the use of sector-specific information in discrete or purely statistical format. A propitious marriage between statistical modelling and geographical techniques for image-processing can produce extremely powerful and attractive results. These products can not only facilitate the planning and optimization of health care services but provide the potential for risk analysis of communities for health conditions related to environmental as well as non-environmental characteristics. The composite visual presentation of what would otherwise be disparate collection of large datasets, has significant advantages for policy making They provide convincing material for policy-makers to take decisions. The problems of data compatibility between those drawn from the health sector and those collected from remote-sensed mechanisms can be difficult but not insurmountable. Estimated data can be used successfully, as proved by this experiment. Their use requires preliminary analysis (such as a system of equations) to estimate the coefficients of parameters that are expected to influence the variable of interest The software and computer requirements today are also no longer prohibitive in cost. However, a constructive framework wherein scientists from different disciplines can work together is essential. Also essential is a large measure of creativity and imagination, since the terrain is so far practically untouched, as disciplines tend to work within their boundaries.

In the final analysis, it still remains to be demonstrated, on a larger scale than was possible in the CISFAM study, that these tools may be used fruitfully for health planning. A series of specific applications in selected health problem areas, undertaken within the same conceptual base, would advance significantly what is today a nascent idea, still in the domain of theoretical discussion

References

Carter, D., G.W. Heath, G. Hovmork & H Sax (1989). Space applications for disaster mitigation and management. *Acta Astronomatica*, **19**: 229-249.

Friedman, M (1990). Putting the data to work. *Dev Forum*, **18**: 12-13.

Graeme, T. (1986) Satellite imagery: a broader view of the earth and its resources. *UNDRO News*, 11-16.

Hugh-Jones, M. (1989). Applications of remote sensing is essential to the identification of the habitats of parasites and disease vectors. *Parasitol Today*, **5**: 244-251.

Linthicum, K.J., C.L. Bailey, G.F. Davies & C.J. Tucker (1987). Detection of rift valley fever viral activity in Kenya by satellite remote sensing imagery. *Science*, **235**. 1656-1659.

Paul, C.K. & A.C. Mascarenhas (1981). Remote sensing indevelopment *Science*, **214**: 139-145.

UN Environment Programme. Putting the data to work.

Wortman, Sterling (1980). World food and nutrition: the scientific and technological base. *Science*, **209**: 157-164.

Debarati Guha-Sapir
WHO Collaborating Centre for Disaster Epidemiology
Department of Epidemiology
University of Louvain
School of Public Health
EPID. - U.C L. 30 34
Clos Chapelle-aux-Champs 30
B-1200 Brussels
Belgium

Library of Congress Cataloging-in-Publication Data

The Added value of geographical information systems in public and environmental health / edited by Marion J.C. de Lepper and Henk J. Scholten and Richard M. Stern.
p. cm. -- (GeoJournal library ; v. 24)
Includes bibliographical references and index.
ISBN 0-7923-1887-0 (hb. : acid free paper)
1. Environmental health--Data processing. 2. Public health--Data processing. 3. Geographic information systems--Economic aspects.
I. Lepper, Marion J. C. de. II. Scholten, H. J. (Henk J.)
III. Stern, Richard M. IV. Series.
RA566.A33 1994
614.4'2'0285--dc20 93-39559

ISBN 0-7923-1887-0

Published by Kluwer Academic Publishers,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Kluwer Academic Publishers incorporates
the publishing programmes of
D. Reidel, Martinus Nijhoff, Dr W. Junk and MTP Press.

Sold and distributed in the U.S.A. and Canada
by Kluwer Academic Publishers,
101 Philip Drive, Norwell, MA 02061, U.S.A.

In all other countries, sold and distributed
by Kluwer Academic Publishers Group,
P.O. Box 322, 3300 AH Dordrecht, The Netherlands.

The views expressed in the publication are those of the contributors and do not necessarily represent the decisions or the stated policy of the World Health Organization or of Kluwer Academic Publishers B.V.

Printed on acid-free paper

Printed in the Netherlands

Contents

PART III : ANALYSIS OF SPATIAL INFORMATION

PART IV : APPLICATIONS OF GEOGRAPHICAL INFORMATION SYSTEMS IN PUBLIC AND ENVIRONMENTAL HEALTH

PART II : THE COMPONENTS OF GEOGRAPHICAL INFORMATION SYSTEMS

PART VI : IMPLEMENTING GEOGRAPHICAL INFORMATION SYSTEMS

PART VII : TOWARDS A HEALTH AND ENVIRONMENTAL GEOGRAPHICAL INFORMATION SYSTEM FOR EUROPE