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The use of remote sensing and geographic information systems in UNICEF's dracunculiasis (Guinea worm) eradication effort

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ABSTRACT

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Dracunculiasis (Guinea worm disease) is a parasitic disease which is endemic in 18 African and two Asian countries. It has a marked potential for eradication by a combination of water supply management, health education and controlled medical intervention. While data on the disease are, in many cases, both in short supply and unreliable, increasingly the tools of remote sensing and geographic information systems (GIS) are becoming important components of the eradication effort. In particular, remotely sensed data from LANDSAT have allowed the identification and location of remote and small settlements in dracunculiasis-endemic areas. When coupled with additional information available in remotely sensed data from LANDSAT, and when used in conjunction with a GIS containing digitized maps and field data collected from hand-held global positioning system receivers, the eradication effort has developed an epidemiological tool of potential power. While at first this system is finding uses in managing existing data in a unified inventory, the system shows potential for use as an effective management decision-making tool as the control effort moves from disease reduction to disease eradication. This paper will use a single province within one country, the Zou Province of Benin, to demonstrate the varied data sources involved in the system, the software and hardware components of the system, and to discuss the specific problems involved in using the system in the field. Of particular consideration, and of potential use to other similar programs, is a consideration of the management and implementation of the system. The paper concludes that a combination of remote sensing and GIS technologies offers the epidemiologist a new and important means by which to effectively implement solutions to public health management problems.

INTRODUCTION: UNICEF'S GUINEA WORM ERADICATION EFFORT

Dracunculiasis (Guinea worm disease) is a water-borne parasitic disease with an obligate human host, which is endemic in 18 African and two Asian

countries. The disease is estimated to affect between 1 and 3 million Africans annually. While it is rarely fatal, it is a very painful and debilitating disease, often crippling its victims for up to 2 months and in some cases causing permanent disability. The economic effect of the disease is considerable (Belcher et al., 1975), as also is the human impact, particularly on women and children (Nwosu et al., 1982; Watts et al., 1989). There is no available medical treatment. However, the disease is entirely preventable.

Approximately 85% of the known cases of dracunculiasis are in six countries: Nigeria Ghana, Benin, Togo, Burkina Faso and Mali, with the greatest number in Nigeria. There are also believed to be large numbers of cases in Sudan. Outside Africa, only Pakistan (less than 500 cases) and India (less than 8000 cases) are endemic. Well organized efforts in these two countries are likely to eliminate dracunculiasis from the Asian subcontinent before 1995.

Dracunculiasis can be prevented by the exclusive use of safe water. The 1 year incubation period presents an educational and epidemiological challenge. Nevertheless, dracunculiasis has a marked potential for complete worldwide eradication by the end of this decade. This goal is attainable because the disease is highly localized, with a marked preference for small, generally poor and rural villages that are remote from a formal health infrastructure (Edungbola and Watts, 1985).

Elimination of the disease requires advance knowledge of the village's geography. While drastic disease reduction is possible by simply providing a safe water supply, complete elimination requires a delicately balanced combination of water supply management, intensive health education and community mobilization. In the small and remote areas where financial constraints prevent the provision of safe water supplies, transmission of the disease can be interrupted using a combination of interventions administered through primary health care centers, primary schools, public health engineering departments, integrated child health services or other existing infrastructure.

The key element required for timely, cost-effective interruption of the fragile dracunculiasis life cycle and to complete elimination of the disease is the acquisition, management and dissemination of information. If UNICEF is to attain its health-impact goals for the year 2000, the same obstacles, and lack and misuse of information must be overcome in many other programs in addition to the dracunculiasis effort.

UNICEF, therefore, will use the dracunculiasis program to build an information management system for a target of 10 000 villages in West Africa as part of the dracunculiasis eradication effort. Interventions for this and other disease efforts will use the methodology and data from these 'least reached villages' to attack dracunculiasis, and to build an information infrastructure for other programs, such as malaria control and immunization. For the 10 000 villages, a basic survey system of a Village Children's Register will be estab-

lished and used to provide data. Data will be converted to information using two tools: (1) a management information system based in the field and the use of low-technology computerized tools, such as spreadsheets and database management systems, to ensure effective intervention delivery and support ongoing monitoring; (2) a geographic information system, based both in New York and at centers in the field, to track the disease, to identify targets, support decision making, and to provide overall systems management and planning.

SATELLITES AND GUINEA WORM

Data on dracunculiasis are usually both in short supply and unreliable. UNICEF's dracunculiasis program must, therefore, conduct its own case surveys as well as perform basic data collection in the field. Increasingly, the tools of remote sensing and geographic information systems (GIS) are becoming important components of the eradication effort. At the first stage, which can be called the inventory stage, the need is to locate affected villages, assess their characteristics in addition to disease rates and determine their suitability for inclusion among the 10 000 villages. At the recent Third African Regional Conference on Dracunculiasis (27–30 March 1990, Côte D'Ivoire), affected countries reported case counts and the status of their intervention efforts. Individual countries vary from having done nothing at all, to formulating national plans, to passive reporting, to conducting surveys, to conducting pilot interventions and in one case (Cameroon) to nearly eliminating the disease. A shared data-related problem, in addition to the lack of case surveys, means that for many countries there are no useful maps of remote and small settlements. The result is massive under-reporting in countries which rely on passive reporting only.

As a solution to this problem, the eradication effort has used two satellite-based technologies to assist in locating settlements. First, remotely sensed data from LANDSAT have allowed the identification and location of remote and small settlements in dracunculiasis-endemic areas. In a pilot test of the technology, a LANDSAT 5 Thematic Mapper image covering parts of Benin and Nigeria, was acquired. Using Benin national maps, air photographs and other sources, this image was georegistered to latitude and longitude using control points common to both the map and the image. Selecting the control points was not simple, since the lack of paved roads, locational errors on the maps and the heterogeneity of the image made point identification difficult. The greatest accuracy was attained when river features were used as a control, in spite of the fact that rivers on the image were frequently dry or covered with dense forest canopy. The georegistered image was classified by supervised classification and a maximum-likelihood classifier, using the Earth resources data analysis system (ERDAS) GIS and image-processing software. By selecting a more settled section of the image in which to identify settlements, a

settlement classification accuracy of approximately 90% was attained. Settlements as small as 30 m × 30 m on the ground could be detected and classified. The ERDAS image was used in conjunction with digitized map data in ARC/INFO via the ERDAS LIVELINK software, as described below.

A second use of satellite technology in the effort was the use of hand-held global positioning system (GPS) receivers in the field. Field operatives were able to visit more villages in the pilot study area, equipped with these battery-powdered units. GPS is a system consisting of a constellation of 21 satellites in unique orbits such that four satellites are above the horizon at all places and all times. The satellites contain atomic clocks, and transmit an encoded signal containing time and orbital information. GPS receivers receive and decode these signals, and use the information to compute the location of the receiver. Before 25 March 1990, the nominal accuracy of the hand-held GPS technology was 20–40 m. On that date, the Department of Defense, which owns and operates the GPS system, turned on 'Selective Availability', a random-number code modifier, which degraded the nominal accuracy to 100 m, although early reports indicate that actual accuracy may now be only 200 m. Even at this level, case counts and surveys for villages which do not exist on maps can be placed on small-scale national maps as a result of using GPS with some degree of reliability. Field surveys using this technology are now in progress and are likely to expand in the near future.

DEPGIS

A GIS has been designed and tested for use as part of the data-management component of the dracunculiasis eradication effort. Known as DEPGIS, and located in New York at Hunter College (City University of New York), the system is designed to be applied both to individual nations and to all affected nations, and uses off-the-shelf software and hardware. DEPGIS consists of several computer programs for use with maps and digital map data, all of which operate in the MS-DOS microcomputer environment. Components of the system have been tested successfully on IBM, Compaq and Toshiba microcomputers. Software components of the system include AutoCAD by Autodesk, Tralaine and ATLAS* GRAPHICS by Strategic Locations Planning, ERDAS and LIVELINK by Earth Resources Data Incorporated, ARC/INFO by Environmental Systems Research Institute and the MAGELLAN GPS software by Magellan Inc.

Data entry into the system is by capture from LANDSAT imagery via LIVELINK, by GPS data stored either on disk from the MAGELLAN receivers directly or from spreadsheets such as DBaseIII-plus and Excel, and by digitizing maps using AutoCAD software and Calcomp or Altek digitizing hardware (Fig. 1). Data-management components of the system include spreadsheet capability in ATLAS*GRAPHICS and a relational database management system within the INFO part of ARC/INFO. The system is capable of producing

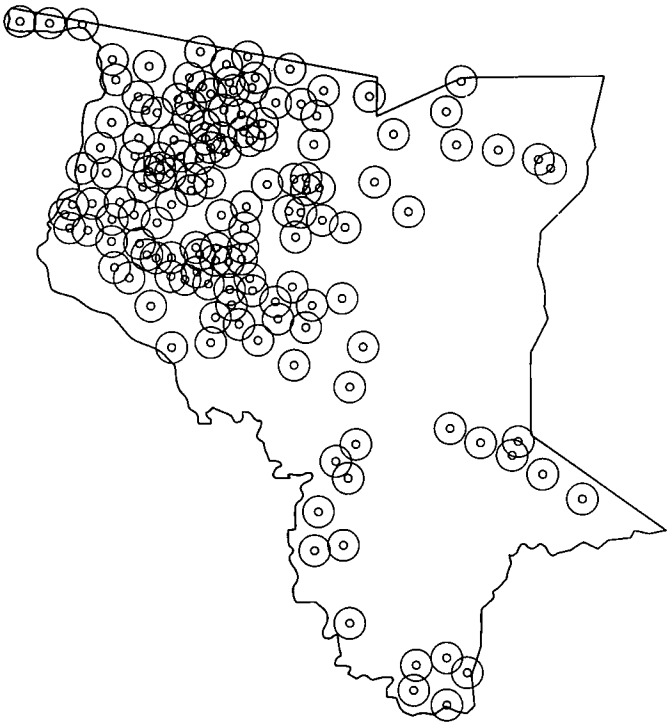

Fig. 1. Savanes region of Benin showing the location of schools; circles of 0.5 and 3 km radius about each school. School proximity reinforces the benefits of clean water in Guinea worm eradication.

maps and graphics, performing analyses, and routine data management and searches. Figure 1 shows some examples of output from DEPGIS. The ATLAS*GRAPHICS software can accept data in ARC/INFO format via a translation module. Therefore, field data from spreadsheets and other sources can be mapped using ARC/INFO, the graphic and statistical databases passed on to ATLAS, and the resultant data sets transported to the field on laptop computers. The addition of a digitizer and plotter makes these smaller field data sets suitable for operational activities in the field, and for use in the management information system also under development.

THE ZOU PILOT STUDY

During the last few months, a pilot data set for DEPGIS has been developed. The area chosen, the Zou Province of Benin, was data rich in the sense that a computerized record of field activities, particularly well drilling, had been developed. To build on this data set, maps were acquired and digitized, and a LANDSAT image purchased and processed. The Zou data are particularly well suited for point-based query, since the attributes are assigned to

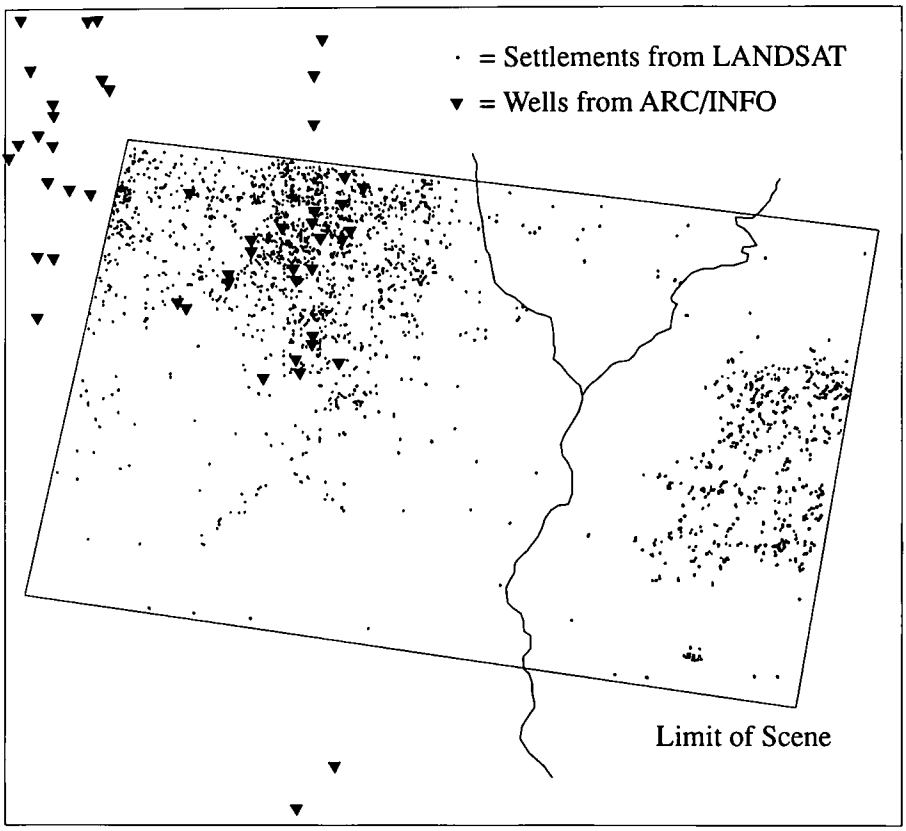

Fig. 2. Distribution of settlements (derived from LANDSAT-TM) and wells (from ARC/INFO) in the Dassa area, Zou Province, Benin.

water wells and drill holes. Variables include the type of well, the condition and type of the pump, the dates of well drilling, dracunculiasis incidence and other village statistics such as population. The satellite image was able to show many settlements not marked on the maps and for which field data are available (Fig. 2). While no GPS data have yet returned from the field, the additional level of detail that this will add to the data base will make this one pilot area perhaps the most data-rich part of West Africa.

CONCLUSIONS

Our experience in the integration of information for effective use against dracunculiasis shows that a combination of remote sensing and GIS technologies, coupled with the additional sophistication that computerization and GPS bring to the field, offers the epidemiologist a new and important means by which to effectively implement solutions to public health management

problems. There is an excellent chance for dracunculiasis to be completely eradicated by the target date of the year 2000. If this feat is accomplished, the dracunculiasis eradication program has hopefully established a benchmark for effective management of epidemiological data and information. Furthermore, GIS and remote sensing will have proven themselves as worthwhile tools for a better response to human needs.

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