National Malaria Control Centre
Ministry of Health, Zambia

Using Geographic Information System Technology for Indoor Residual Spray Area Mapping

A Training Manual

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Glossary of Key Words

Arc: a line connecting a set of points.

Data: raw collection of facts.

Database: an organized, integrated collection of data.

Database management system: a set of programs for features drawn and characterized with scale and direction to represent the real world.

Geographic information system (GIS): a system of capturing, storing, checking, integrating, analyzing, and displaying data about the earth that is spatially referenced. It is normally taken to include a spatially referenced database and appropriate application software.

Global positioning system (GPS): a system for providing precise location which is based on data transmitted from a constellation of 24 satellites

Layer: a logical separation of mapped information according to a theme.

Line: a geographic feature defined by connecting at least two points.

Personal digital assistant (PDA): a portable, handheld computer.

Polygon: a multi-sided figure representing an area on a map.

Raster: an area partitioned into a set of grid cells with each assigned an attribute which corresponds to the majority of the area in that cell.

Theme: a group of features exhibiting common characteristics.

Vector: a means of coding geographic features by storing explicit coordinates.

Personal Digital Assistant Glossary:

Backlighting: a function that allows the display screen to glow from behind, making it easier to read in the dark.

Beam: the transmission of information between two PDAs by way of the infrared port. Data can also be beamed to a printer.

Bluetooth: a short-range wireless connection that allows the exchange of data from your PDA to your mobile telephone, computer, or printer.

Infrared (IR) port: a sensor that allows you to beam data between two PDAs.

Palm: an operating system for PDAs or PDA hardware created by Palm Incorporated.

Pocket PC: a Windows-based operating system created by Microsoft.

Stylus: a pointing device shaped much like a pen. The stylus is used to point to data on the screen or to write directly to the screen.

GPS Glossary:

Almanac: a file which contains positional information for all of the GPS satellites. The almanac is used by the GPS receiver to determine which satellites to track and can also be used for mission planning.

Attribute: a characteristic which describes a feature. Attributes can be thought of as questions which are asked about the feature.

Course acquisition (C/A) code: the standard code used by most GIS-level receivers. It is also known as the civilian code.

Carrier: the signal that carries the C/A Code from the satellite to the GPS receiver.

Differential correction: the technique of comparing GPS data collected in the field to GPS data collected at a known point. By collecting GPS data at a known point, a correction factor can be determined and applied to the field GPS data.

Dilution of precision (DOP): an indicator of satellite geometry for a unique constellation of satellites used to determine a position. Positions tagged with a higher DOP value generally constitute poorer measurement results than those tagged with lower DOP.

Ephemeris: the predicted changes in the orbit of a satellite that are transmitted to the GPS receiver from the individual satellites.

Ephemeris errors: errors which originate in the ephemeris data transmitted by a GPS satellite. Ephemeris errors are removed by differential correction.

Feature: the object which is being mapped for use in a GIS system. Features may be points, lines or areas.

Featuring: the process of collecting GPS and GIS information simultaneously.

Ionosphere: part of the atmosphere that is ionized by solar radiation. It plays an important part in atmospheric electricity and forms the inner edge of the magnetosphere. It has practical importance because, among other functions, it influences radio propagation to distant places on the earth.

Latitude (parallels of): a set of imaginary circles that are perpendicular to the earth's polar axis. Latitude describes position in terms of how many degrees it is north or south of the equator (0° latitude).

Longitude (meridians of): a set of imaginary circles around the earth that pass through the north and south poles. Longitude describes position in terms of how many degrees it is east or west of the prime meridian (0° longitude), which runs through Greenwich, England.

Multi-path error: the interference to a signal that has reached the receiver antenna by multiple paths; usually caused by the signal being bounced or reflected. Signals from satellites low on the horizon will have high multi-path error. Receivers that can be configured to ‘mask out’ signals from such satellites can help minimize multi-path.

Navigation: the process of travelling from one place to another and knowing where you are in relation to your desired course.

Position: an exact, unique location based on a geographic coordinate system. Marine navigation is based on the latitude/longitude coordinate system.

Satellite constellation: the group of GPS satellites from which data are used to determine a position.

Troposphere: the lowest portion of the earth's atmosphere. It is the densest layer of the atmosphere and contains approximately 75% of the mass of the atmosphere and almost all the water vapour and aerosol.

Value: descriptive information about a feature. Values can be thought of as the answers to the questions posed by attributes.

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1. Background

Indoor residual spraying (IRS) is one of the primary malaria prevention strategies in Zambia and is now supported in 15 target districts, representing mainly urban and periurban areas (Figure 1). IRS activities have been carried out since 2003, originally in 5 districts, then moving to 8 districts in 2004. The current 15 districts include Kabwe (Central Province); Chililabombwe, Chingola, Kalulushi, Kitwe, Luanshya, Mufulira, and Ndola (Copperbelt Province); Chongwe, Kafue, and Lusaka (Lusaka Province); Solwezi (North-Western Province); and Kazungula, Livingstone, and Mazabuka (Southern Province). Collectively these districts represent roughly 34% and 33% of the total population and total households, respectively, in Zambia. IRS plays a significant role in preventing malaria among a large proportion of the Zambian population. In combination with insecticide-treated nets (ITNs), these represent the main malaria transmission prevention strategies used throughout the country.

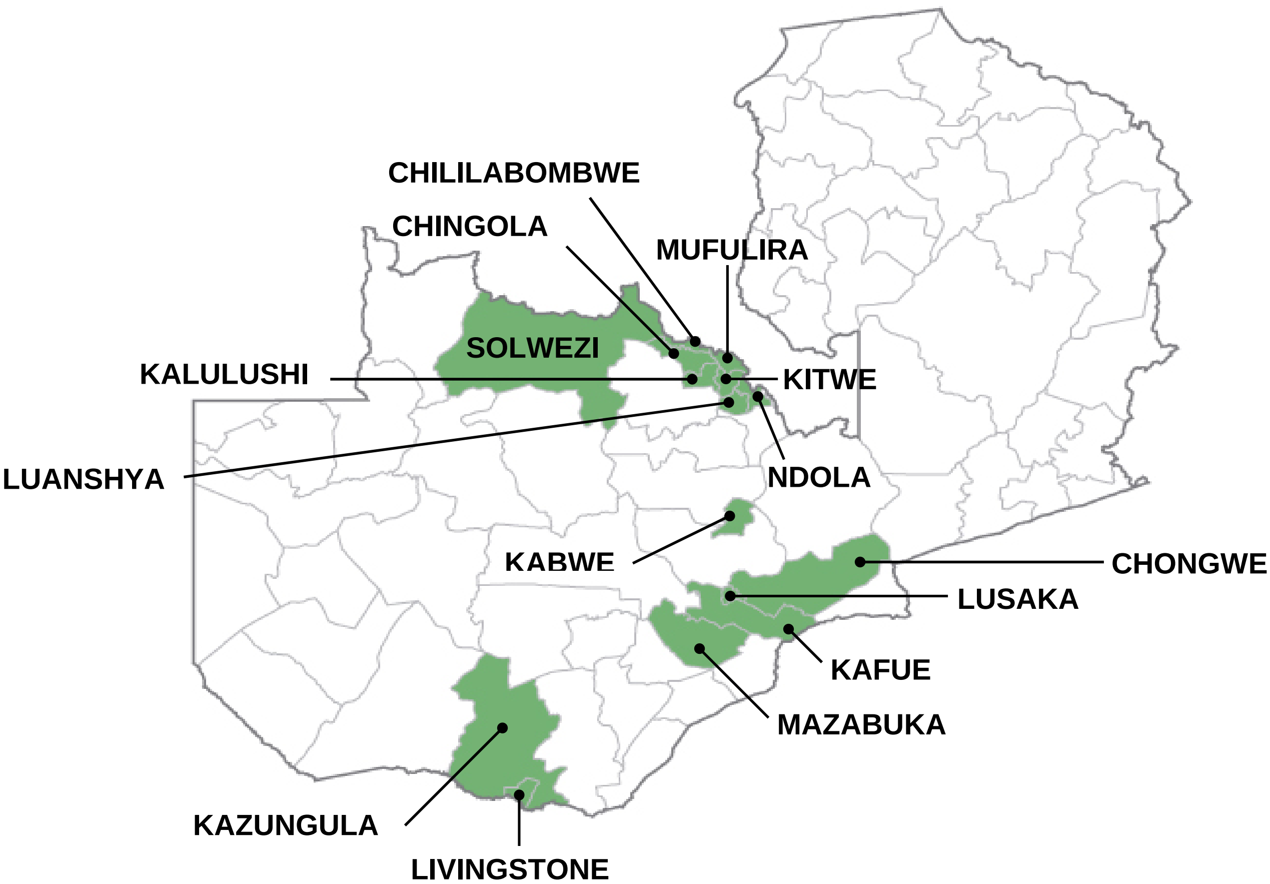


Figure 1. Districts targeted for IRS.

IRS activities are conducted annually and include district-level planning and budgeting for targeted areas, assessment of spray structures (to determine formal, informal and overall structure counts as well as volumes of insecticides needed), training of spray teams, IRS campaigns, and supervision and monitoring of spray activities. Post-campaign activities include reporting and attending the annual post-spray campaign national meeting of all 15 IRS districts to share experiences and lessons learned.

For monitoring and evaluating IRS, clearly defining IRS-targeted and -eligible households is important for several reasons. First, through the planning process, enumerating IRS households makes it possible to quantify the allocation of spray personnel, streamline the spray schedule, and estimate the duration of spray activities. As IRS activities are scaled up within each district, monitoring the changes to the targeted denominators will result in overall increases in resources necessary for conducting IRS activities. Second, according to the *National Malaria Strategic Plan 2006-2011*, IRS and ITN mass distribution efforts are designed to be mutually exclusive activities. Zambia is working to achieve high coverage rates of both interventions for optimal health impact. Households not targeted for IRS are therefore targeted for ITN mass distribution and net retreatment campaigns. Finally, in conjunction with studies to evaluate the impact of malaria interventions on malaria-related burden or within vector populations, careful delineation of spray areas and populations is necessary for determining the scale of expected impact for each intervention and for the nation as a whole.

Integrating geocoded information from global positioning systems (GPS) for malaria monitoring and evaluation activities has been done successfully elsewhere.[1] This has mainly been for IRS monitoring, geocoding target areas, and using geographic information systems (GIS) to manage large amounts of information for spray operations. Mozambique and South Africa IRS activities associated with the Lubombo Spatial Development Initiative Malaria Control Programme have also been a model for IRS monitoring and evaluation activities using GIS.[2]

Application of geocoding to future IRS plans

Strengthening the national malaria control programme by incorporating GIS/GPS mapping systems enhances Zambia's National Malaria Control Centre (NMCC) capacities to plan, manage and report on its intervention activities such as IRS, ITNs, or integrated vector control measures. Geocoding of household structures will be used in the overall planning of IRS activities and will be used to assist in making key decisions on a range of issues.

Quantifying insecticides

The most obvious use for geocoding structures is the quantification of insecticides. Rather than using general estimations or guesswork in counting structures, geocoding provides accurate counts of structures because structures are physically counted. Because the actual number of formal and informal structures and rooms are known, the estimates of insecticides to be used both in formal and informal structures can be improved. Knowing IRS

[1] Booman M, Durrheim DN, La Grange K, Martin C, Mabuza AM, Zitha A, Mbokazi FM, Fraser C, Sharp BL. Using a geographical information system to plan a malaria control programme in South Africa. Bull World Health Organ. 2000;78(12):1438-44. Epub 2003 Nov 17.
[2] http://www.malaria.org.za/lsdi/home.html

clusters, their size and relative position, as well as their distances from a defined station, can have an impact on the overall planning of the spraying exercise.

The district geocoding data collected to date in Zambia will be used to cross-check insecticide volumes ordered for the current spray season and in the next spraying season to quantify the amount of insecticides that will be needed. The geocoding results also will be used to compare the amounts of insecticides that will have been purchased for the districts that were still geocoding and could not, therefore, supply the actual data to support the purchase of insecticides. So far, geocoding has shown that there are more structures that need to be sprayed in the districts than have been estimated previously. This is evident from the fact that during the previous season, some districts ran out of insecticides while some districts received more insecticides than they needed.

Distributing spray operators

Geocoding structures provides a spatial view of the structures on the ground. When displayed in map format, this can be a planning guide for supervisors as it can help them distribute spray operators much more efficiently. In the coming spray season, large-sized maps that will have been geocoded for use during spraying will be printed and distributed to all the districts. These maps will be used by the supervisors to plan how to distribute the spray operators by looking at the densities of geocoded points. This will also help them prioritize areas to spray and coordinate with spray personnel.

Helping spray operators to plan

Maps can also prove useful to spray operators. If the spray operators are able to relate what is presented on the map to what is actually on the ground, they will have a better picture of what is expected of them in terms of the extent of the work that is needed to be carried out. Instead of using sketch maps, large-scale printed maps of spray areas can be given to spray operators as a checklist of structures to be sprayed.

Planning a range of malaria interventions

The spatial view of structures on the ground will also help visualize which areas need spraying and which areas require other interventions. IRS is known to be much more effective in areas that are densely populated. Geocoding, therefore, will help identify and eventually isolate these areas, and decisions can be made on the best intervention measures to undertake.

Objectives of incorporating GIS/GPS mapping into Zambia's National Malaria Control Programme

The objectives and activities involved in strengthening the national malaria control programme by incorporating GIS/GPS mapping system are as follows:

Objective 1: To enhance the capacities of the NMCC and District Malaria Control Programme to use GIS/GPS-based information collection and management activities

Activities:

- Develop a work plan to carry out training of trainers sessions and district training for GPS-based mapping.
- Establish a set of master trainers for training activities related to GPS-based mapping at district level.
- Conduct a master training session and pilot testing.
- Establish the district training team.
- Conduct the district training and piloting testing.
- Plan field visit to conduct training session.

Objective 2: Develop maps of different malaria intervention areas at the district levels

Activities:

- Investigate the availability of appropriate digital base maps for each of the intervention areas from relevant institutions.
- Collect and compile data with backup copies.
- Transfer data to the central level.
- Compile and create a database at the central level with backup.
- Check for data entry accuracies.
- Map the various boundary levels in each of the intervention areas.
- Upload data from PDAs into ArcView/ArcGIS.
- Build up initial map layers based on analytical needs of the NMCC.
- Integrate with existing city or other boundary files.
- Produce a plotter-based map for use in IRS planning and operations.

Objective 3: Develop maps of household-level intervention for IRS areas incorporating vector breeding sites within

Activities:

- Visit targeted spay areas for information gathering.
- Conduct onsite meeting with focal person on information integration.
- Conduct initial boundary trace of targeted spray areas.
- Collect relevant information from the district IRS teams.

2. Training Workshop Objectives and Introduction to Basic Principles of GIS

Training objectives

The overall objective of this training is to provide trainees with the knowledge and skills necessary to effectively use PDAs with GIS to conduct household enumeration and mapping in support of national IRS in Zambia. Specific objectives of the training are to: Objectives of this training:

i. Introduce participants to basic principles of GIS;
ii. Explain the rationale for geocoding IRS spray areas;
iii. Familiarize participants with HealthMapper software.
iv. Introduce participants to GPS, household enumeration with personal digital assistants (PDAs) and geocoding;
v. Explain to participants the software programmes used in GPS and PDAs;
vi. Explain data extraction from Navio and GPS2 programmes;
vii. Introduce participants to the map production process and the products that will be produced and shared with the districts;
viii. Explain PDA maintenance procedures and availability procedures for the complete household listing; and
ix. Conduct PDA/GPS field exercises in which boundary tracing and IRS household enumeration will be done.

Basic principles of GIS

Information (or data) is an intangible resource that, unlike other resources, is multiplied by sharing. Information is crucial to any planning and management activity. Challenges in incorporating information into planning and management include:

- Determining what information is needed for a specific task, finding out if it exists and where.
- Establishing how to obtain existing information and how to collect it if it does not exist.
- Understanding how to store this information in easily acceptable and referenced form.
- Knowing how to interpret the data into quality information.
- Determining who needs the information, when, and in what form.
- Disseminating it as needed or required.

If the above steps are formalised, institutionalised, and made sustainable, one can talk of an information system. Formalised means standardised, with explicit procedures and formats, which are flexible. Institutionalised means the information systems are integrated into a permanent organizational structure, independent of any critical individual input. Sustained means the information system receives ongoing support in the form of necessary resources (funding, staffing). The institutionalising of information flow provides a ground for an information management framework.

Information management framework

An information management framework is developed based on project and investment requirements and an analysis of spatial needs. The framework provides a system in which information is viewed in an organisation. This entails seeing information as central to the planning process of an organisation. Developing a robust information management framework is essential for effectively implementing project strategies.

As organizations develop information systems, issues of access to information and accountability as well as critical updates become important. While an information management framework is important, investment in information can be quite costly. A meaningful spatial analysis requires good quality data. The spatial analysis component itself makes extensive use of maps and GIS. With good data, effective strategies for implementing plans using this data become meaningful.

Health management information systems

A health management information system (HMIS) is a system of formalized steps for capturing, managing, and retrieving information relevant for health. It is a participatory tool for health planning and management, concentrating on the interaction between health and development activities. The HMIS uses GIS as a tool to handle and process spatial and non-spatial data. An HMIS makes a clear distinction between factual information and policy information. Factual thematic maps, such as geology, soil, or population density maps show quantifiable or ‘countable’ data. Policy maps show information about certain policy decisions such as national acts, laws and by-laws, global environmental standards or rules and conditions developed by stakeholders during working group processes. Policy maps can be classified as suitability and sensitivity maps.

<u>Setting up an HMIS</u>

A standard HMIS setup requires resources and equipment (high-end desk top computer, an A0 inkjet, scanners, digitizers, and GPS).

Developing an HMIS involves the following steps:
- System setup.
- Equipment.
- Mapping group.

Data inventory
- Identifying existing reference data and information.

Base mapping
- Topographic platform generation.
- Standardization.

Thematic data gathering and mapping
- Factual data gathering (expert information systems generation).

Suitability and sensitivity analysis (maps and databases)

- Interpretation of expert systems data and maps to compare with environmental standards (e.g., pollution determination).
- Drawing conclusions about conditions in the pilot study areas.

Information dissemination (public comments)

- Exhibitions.

System maintenance

- Updating.
- Training.
- Institutionalization.

3. Geographic Information Systems[3]

A geographic information system (GIS) is a system capable of holding and using data describing places on the earth's surface. It is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information.

In general, GIS is a four-dimensional information system. The dimensions are X, Y, Z, and A, where X, Y, and Z are earth location parameters according to international mapping principles, and A is the attributing factor describing elements located in X, Y, and Z.

Importance of GIS

Some of the major issues facing government today - economic development, tourism, health transportation issues, increasing population, improvement of service provision, and so on - have critical geographic dimensions. Local issues, such as why poverty is higher in some areas than others or why traffic jams occur, are all affected by geography. Mapping where a new subdivision will be located, for example, can give new insight into its effects on transportation networks, the local environment, and local service providers like schools.

When buying a new house you might look for properties close to a school, within a certain type of neighbourhood, under a certain price, and with a given lot size. When considering the impact of a disaster such as a chemical spill, you need to analyze hazardous material information and then link it with details about the people, properties, and infrastructure that have been or can be affected. The solution to these and many other types of problems often requires access to several types of information that can only be linked by geography. Only GIS technology makes it possible to store and manipulate information using geography and to analyze patterns, relationships, and trends in that information to help make better decisions.

How GIS works

GIS makes it possible to store information about the world as a collection of thematic map layers that can be linked together to show the spatial distribution of a particular geographic feature or phenomenon. The features or phenomena can be categorized and symbolized by using three basic symbol types: point symbols (such as symbols in public places layer), line symbols (such as symbols in sewer mains layer) and area symbols (such as symbols in zoning district layer). This simple, but extremely powerful and versatile concept, has proven to be invaluable for solving many problems, from tracking delivery vehicles, to recording details of planning applications, to modelling

[3] Portions of this chapter were originally published online at
http://www.seminolecountyfl.gov/pd/commres/gis/index.asp,
http://www.geoplan.ufl.edu/giseducation/giscomponents.html,
http://www.csupomona.edu/~library/publications/geography/gis/gis.html,

how a brush fire will move across a landscape. Figure 2 shows environmental map layering.

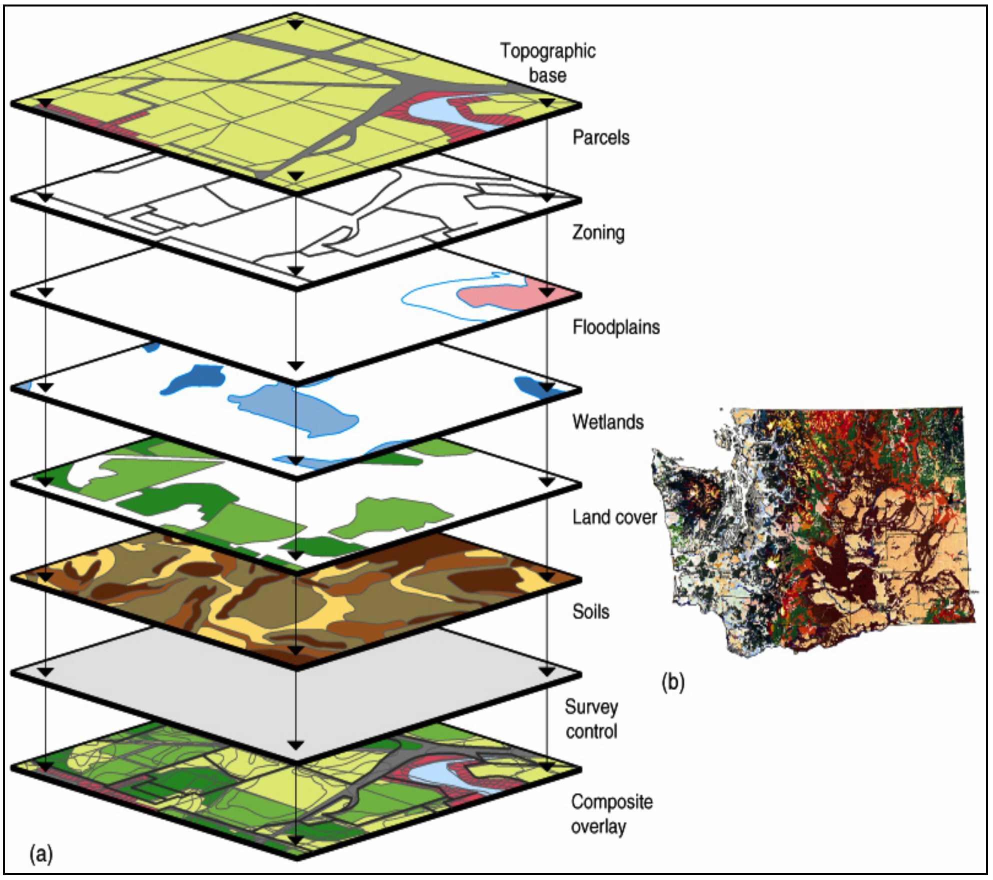


Figure 2. Environmental map layers produced by GIS.

Geographic information contains either an explicit geographic reference, such as a latitude and longitude or national grid coordinate, or an implicit reference, such as an address, postal code, census tract name, forest stand identifier, or road name. Implicit references can be derived from explicit references using an automated process called *geocoding*. These geographic references allow you to locate features (such as a house, business, a health facility or forest stand) and events (such as an IRS campaign or a chemical spill) on the surface of the earth for analysis.

Geographic information systems work with two fundamentally different types of geographic information—the *vector* model and the *raster* model. In the vector model, information about points, lines, and polygons is encoded and stored as a collection of x and y coordinates. The location of a point feature, such as a house, can be described by X and Y coordinates. Linear features, such as roads and rivers, can be stored as a collection of point coordinates. Polygonal features, such as sales territories and river catchments, can be stored as a closed loop of coordinates. The vector model is extremely useful for describing discrete features, but less useful for describing continuously varying features such as soil type or surface elevation data.

The raster model was developed to model continuous features. A raster image comprises a collection of grid cells rather like a scanned map or picture. Every cell can have a unique value. Both the vector and raster models for storing geographic data have unique advantages and disadvantages and modern GISs are able to use both models to effectively perform the most complex analytic tasks.

Common GIS tasks

In general, GIS performs six processes or tasks: input, manipulation, management, query, analysis, and visualization.

Input

Before geographic data can be used in a GIS, it must be converted into a suitable digital format. The process of converting data from analogue paper maps into computer files is called digitizing. Modern GIS technology has the capability to automate this process fully for large projects; smaller jobs may require some manual digitizing.

Today many types of geographic data already exist in GIS-compatible formats. These data can be obtained from data suppliers and loaded directly into a GIS.

Manipulation

It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make them compatible with your system. For example, geographic information is available at different scales (street centreline files might be available at a scale of 1:100,000; postal codes at 1:10,000; and census boundaries at 1:50,000). Before these can be overlaid and integrated, they must be transformed to the same scale. This could be a temporary transformation for display purposes or a permanent one required for analysis. There are many other examples of data manipulation that are routinely performed in GIS. These include projection changes, data aggregation (for example, to convert sales territories for census building blocks), and generalization (weeding out unnecessary data).

Management

For small GIS projects, it may be sufficient to store geographic information as computer files. There comes a point, however, when data volumes become large and the number of users of the data becomes more than a few, that it is best to use a database management system (DBMS) to help store, organize, and manage data. A DBMS is nothing more than computer software to manage a database--an integrated collection of data.

There are many different designs of DBMS, but in GIS the relational design has found most favor. In the relational design, data are stored conceptually as a collection of tables. Common fields in different tables are used to link them together. This surprisingly simple design has been so widely used mainly because of its flexibility and has very wide deployment in applications both within and without GIS.

Query
Once you have a functioning GIS containing your geographic information, you can begin to ask questions such as:

- Where are all the sites suitable for building new houses?
- What is the dominant soil type for oak forest?
- If I build a new highway here, how will traffic be affected?

Both simple and sophisticated queries utilizing more than one data layer can provide timely information to analysts and managers alike.

Analysis
GIS systems really come into their own when they are used to analyze geographic data. The processes of geographic analysis (often called spatial analysis or geoprocessing) uses the geographic properties of features to look for patterns and trends and to undertake 'what if' scenarios. Modern GISs have many powerful analytical tools, but two are especially important:

<u>Proximity analysis</u>
GIS is often used to answer such questions as:

- How many villages lie within 100 m flood zone of the main river?
- What is the total number of Villages within 10 km of this market centre?
- What proportion of the female population is within 500 m of the water well?

To answer such questions, GIS technology uses a process called buffering to determine the proximity relationship between features.

<u>Overlay analysis</u>
The integration of different data layers involves a process called overlay. At its simplest, this could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, slope, and vegetation, or land ownership with tax assessment.

Visualization
For many types of geographic operation, the end result is best visualized as a map or graph. Maps are very efficient at storing and communicating geographic information. While cartographers have created maps for millennia, GIS provides new and exciting tools to extend the art and science of cartography.

GIS components

A working GIS integrates five key components: hardware, software, data, people, and methods (Figure 3).

Source: www.bgis.sanbi.org

Figure 3. The five key components of GIS.

Hardware
Hardware is the computer on which a GIS operates. Today, GIS runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations.

Software
GIS software provides the functions and tools needed to store, analyze, and display geographic information. Key software components are:

- A DBMS.
- Tools for input and manipulation of geographic information.
- Tools that support geographic query, analysis, and visualization.
- A graphical user interface for easy access to tools.

Data
Perhaps the most important component of a GIS is the data. Geographic data and related tabular data can be collected in-house or bought from a commercial data provider. Most GISs employ a DBMS to create and maintain a database to help organize, manage, and document data.

People
GIS technology is of limited value without adequately skilled people who manage the system and develop plans for applying it. GIS users range from technical specialists who design and maintain the system to those who use it to help them do their everyday work.

Methods

A successful GIS operates according to a well-designed plan and business rules, unique to each operation.

Related technologies

Geographic information systems are closely related to several other types of information systems but it is the ability to manipulate and analyze geographic data that sets GIS technology apart. Although there are no hard and fast rules about how to classify information systems, the following discussion should help to differentiate GIS from desktop mapping, computer-aided design, remote sensing, and DBMSs.

Desktop mapping

A desktop mapping system uses the map metaphor to organize data and user interaction. The focus of such systems is the creation of maps: the map is the database. Most desktop mapping systems have more limited data management, spatial analysis, and customization capabilities. Desktop mapping systems operate on desktop computers such as personal computers, Macintoshes, and smaller UNIX machines.

Computer-aided design

Computer-aided design (CAD) systems evolved to create designs and plans of buildings and infrastructure. This activity required that components of fixed characteristics be assembled to create the whole structure. These systems require few rules to specify how components can be assembled and they have very limited analytical capabilities. CAD systems have been extended to support maps but typically have limited utility for managing and analyzing large geographic databases.

Remote sensing

Remote sensing is the art and science of making measurements of the earth and its elements, using sensors not in touch with the earth. The sensors (such as camera films, or scanners) are attached on platforms such as satellites, aeroplanes, balloons, and human beings. The sensors collect data in the form of images. Remote sensing systems provide specialized capabilities for spatial data collection, manipulation, analysis, and visualization. Remotely sensed images are subjected to a geographical reference system, through a process called geo-referencing. After geo-referencing, the images are good source of GIS data input due to their pictorial characteristics.

Database management systems

DBMSs specialize in the storage and management of all types of data including geographic data. These systems are optimized to store and retrieve data and many GISs rely on them for this purpose. They do not have the analytic and visualization tools common to GIS.

How GIS can be used

Perform geographic queries

The ability of GIS to search databases and perform geographic queries has become an essential element in a range of workplaces. GISs have helped:

- Map, manage and locate utilities such as water, electricity, and telecommunication by, for example, locating the position of breaks in electrical circuits, water pipes, and telecom lines.
- Decrease the time taken to answer customer requests.
- Find land suitable for development.
- Search for relationships among diseases and source (such as cholera and households, or pit latrines and ground water)
- Search for relationships between crops and soils.

GIS can be used to answer questions such as:

Location	What is at a certain location?
Example	101 Shore Road (location can be described in many ways, such as by address or by longitude and latitude).
Condition	Where is a specific feature?
Example	Where are IRS-eligible structures?
Trends	What has changed over time?
Example	Are there more houses in a catchment area requiring IRS now compared to one year ago?
Patterns	What spatial patterns exist? How many IRS-eligible houses are in this village?
Modelling	What if certain variables change? If an additional district is added to the IRS catchment area how many more houses would need spraying?

All geographic features can be reduced to three basic types:

- *Point data* refers to a feature associated with a single location in space such as a household.
- *Linear data* describes a feature's location by a string of spatial coordinates such as railways, roads and streams.
- *Areas data* describes a feature by a closed string of spatial coordinates commonly referred to as a polygon.

Improve organizational integration

Many organizations that have implemented GIS have found that one of the main benefits is improved management of their own organization and resources. Because GIS has the ability to link data sets together by geography, it facilitates interdepartmental information sharing and communication. By creating a shared database, one department can benefit from the work of another because data can be collected once and used many times.

As communication increases among individuals and departments, redundancy is reduced, productivity is enhanced, and overall organizational efficiency is improved. Thus, in a utility application, the customer and the infrastructure databases can be integrated so that when there is planned maintenance, affected customers can be sent a computer-generated standard letter.

Improve decision-making

Decision-making can be improved tremendously with GIS. This is true as long as good databases have been put in place. With a good database, various queries and analyses that can positively contribute to the decision-making processes in an organisation are possible. There are several examples in which certain decisions can be carried out with the help of using this technological tool. Decisions on suitable waste disposal site selection are one such example. Geocoding of structures in areas where IRS is taking place can help make decisions on quantifications of insecticides as well as to decide which insecticide is suitable in different sites. Information obtained can best be presented in the form of maps and reports for decision-makers to visualise what is taking place on the ground. Good decision-making relies on quality data and has financial implications. For GIS to be a useful decision-making tool, data must be of good quality so that it can be processed into useful, reliable information.

Produce maps

Maps portray information that is generally easier to interpret than text because they are self explanatory. In the past, making maps involved complex manual cartographic approaches. Today, GIS software can be used to make quick useful maps on the desktop. For example, ArcGIS desktop (which contains a rich collection of symbols that can make map production process user friendly) and HealthMapper can be used to make maps addressing various themes. Figure 4 shows examples of maps of geocoded structures in Zambia's Solwezi District. Information on Zambia's GIS mapping processes and outputs can be seen in Table 4.

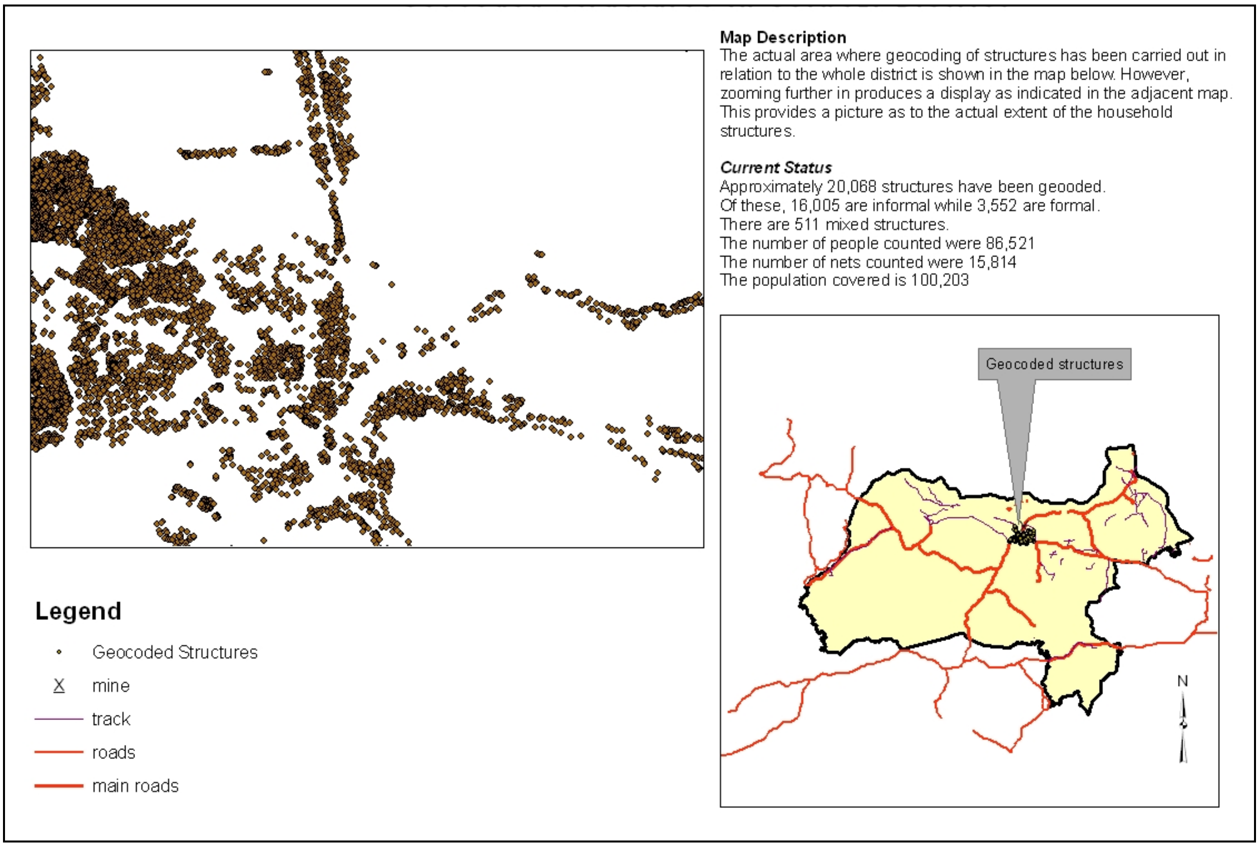


Figure 4. *Geocoded structures in Solwezi District.*

Sources of data

Data can be generated by various users including governmental agencies, academic groups, and the private sector. From a GIS perspective, the best data (and data source) to be used will depend on the task at hand. It is important to think about the data requirements before embarking on the GIS exercise.

Digital data availability in Zambia

Most geographic data in Zambia is obtained from institutions that are mandated to produce maps. However, such data may not be in digital form, although the Zambia Survey Department in Mulungushi House is actively involved in the production of digital topographic maps of selected areas. Other similar institutions include:

- Geological Survey Department
- Central Statistics Office
- Soil Survey Unit
- Electoral Commission of Zambia

The Zambia Association of Geographic Information System is an association of GIS professionals which has been trying to address issues of information sharing among individuals and institutions as well as addressing the issue of data standards.

4. Household Geocoding

An address is simply information used to describe a location. Unlike a coordinate value, an address describes how to reference a location based on existing features in your GIS database. For example, if you needed to locate the address 380 Independence Avenue, Lusaka, Woodlands, with the correct street data, it would not take you long to find the exact location. You might first find Lusaka, then find the suburb of Woodlands.

Just as you first narrowed your search to a specific region, found a particular feature, and finally interpreted a point, the computer is doing the same process to assign a location to an address when geocoding. Geocoding, therefore, is the process of assigning geographic identifiers (e.g., codes or geographic coordinates expressed as latitude-longitude) to map features and other data records, such as street addresses.

Address elements

Addresses have some specific characteristics. An address contains certain address elements and is presented in a range of formats. When geocoding, the address format is interpreted, address elements are identified, and these address elements are compared against elements in the reference data. An address element is an individual component in the address, such as the house number, the street name, and the postal code. Address elements help in the geocoding search, pinpointing an address to a particular location.

Address formats

Addresses can be presented in various formats. Below is one example of how addresses are presented in Zambia. Figure 5 indicates the house number followed by the name of the street. This is then followed by the street type. In this case, the house is in a close. This is a street that has a dead end. The fourth box in this example indicates the area or township where this house is located. This is followed by the name of the town and lastly the country.

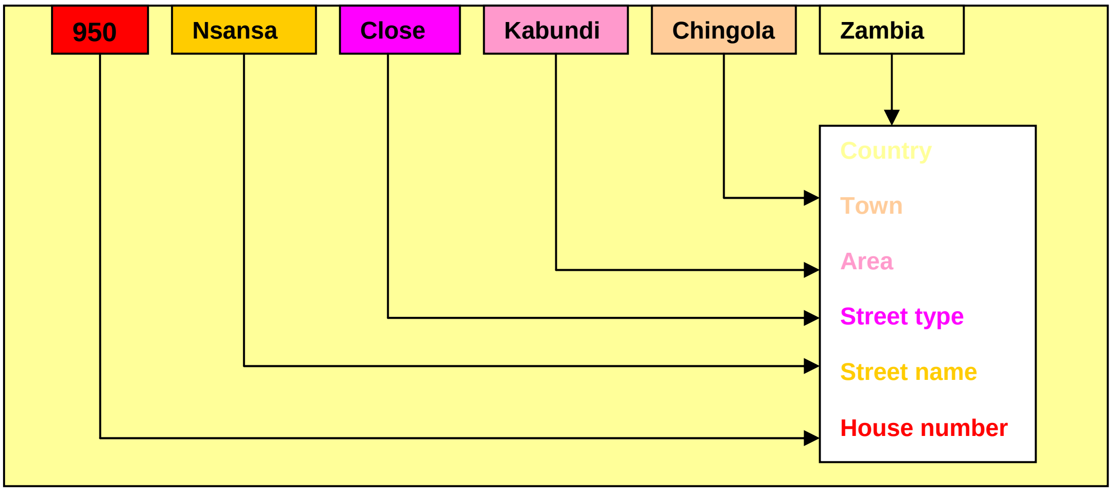


Figure 5. Geocoding using house numbers.

Figure 6 is similar to the one above, except that plot numbers rather than house numbers are used.

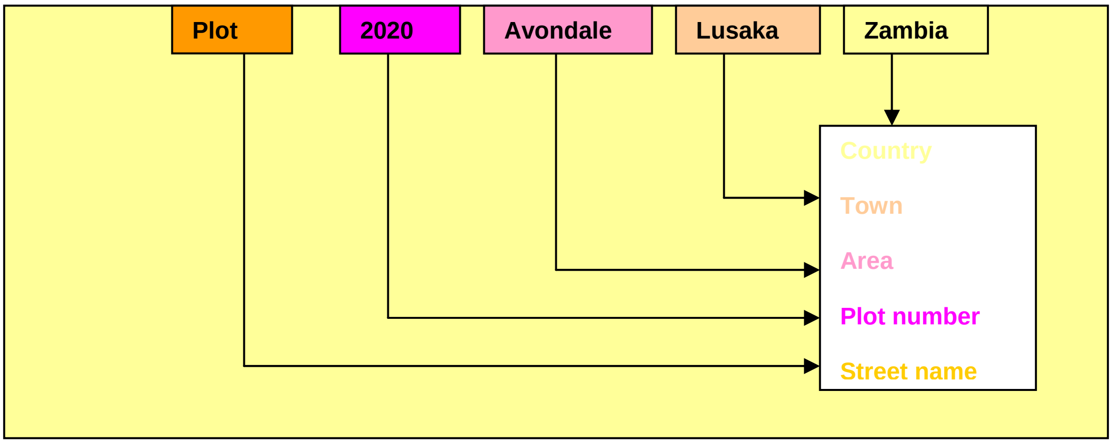


Figure 6. Geocoding using plot numbers.

These two examples show how both addresses consist of several elements within the address that can be used to identify a particular house. The presentation format of the address in the form can easily be identified by the people living within that particular area. The challenge comes in situations where the numbers are not in order. This is true particularly with plot numbers and there are many such cases in Zambia.

Geocoding process

Initially, the geocoding process requires two major types of information—reference data and address data. Reference data refers to a GIS feature class containing the address attributes on which a search is based. For example, when searching for house number addresses, the reference material must contain the street names, house number ranges, or address attributes of the specific parcels. In assessing if the reference data that you have will work for your geocoding process, there are a few considerations that you need to make. These considerations are based on the extent and resolution of the data.

Beyond determining if the data has a spatial coverage that includes all of the features to be geocoded, it is important to consider if the reference data has information at the detail that will make the search meaningful. For example, to geocode individual addresses, it is essential that reference data have information at this level of detail.

5. Global Navigation Satellite Systems

Global positioning system is the name given to a constellation of 24 satellites orbiting the earth and transmitting signals that enable a GPS receiver to locate its position on the ground. The accuracy of the location is dependant on several factors, some of which include the delay in the signal sent from the satellite as well as the actual position of the satellite itself.

Information from the GPS is obtained when communication has been established with at least three satellites. Once this communication has been established, the latitude and longitude can then be calculated using travel time. Similarly, altitude of the position in question can be calculated, except that for altitude a minimum of four satellites are required in order to obtain reliable results.

In determining a location, the GPS uses the principle of trilateration. This involves the calculation of relative positions using geometry in which the positions of three or more satellites are used to determine the actual position of the GPS receiver. Once the positions of the GPS satellites are known, the next thing is to know the distance between the each of the satellites and the GPS receiver.

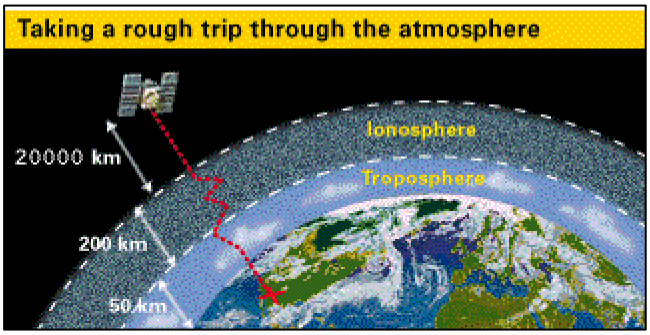
Just like any other equipment that provides real-time accuracy, these satellites are monitored continuously. The path of the satellites can also be predicted accurately. As a result, it is possible to determine the position of the satellites at any given time in the future. Any indications of possible deviations in the course of its orbit are immediately corrected.

The GPS error budget

The GPS system is assumed to be as accurate as possible. Despite this, errors are still there. These errors can cause a deviation of about 50 to 100 metres from the actual GPS receiver position. There are several sources for these errors, the most significant of which are discussed below.

Atmospheric conditions

As a GPS signal passes through the charged particles of the ionosphere and then through the water vapour in the troposphere, it gets slowed down a bit (Figure 7). The ionosphere and troposphere both refract the GPS signals. This causes the speed of the GPS signal in the ionosphere and troposphere to be different from the speed of the GPS signal in space. Therefore, the distance calculated from ‘Signal Speed x Time’ will be different for the portion of the GPS signal path that passes through the ionosphere and troposphere and for the portion that passes through space.

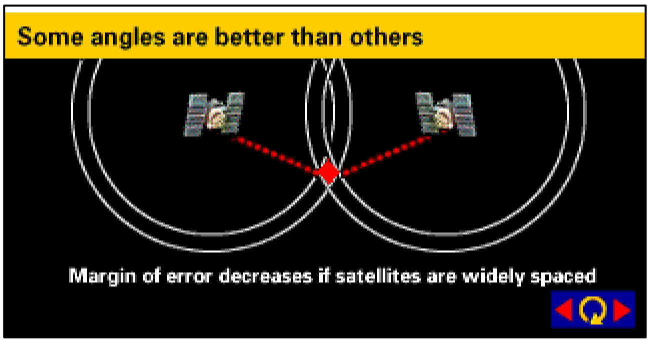


Source: http://www.trimble.com

Figure 7. GPS signal passing through earth's ionosphere and troposphere.

Ephemeris errors/clock drift/measurement noise

GPS signals contain information about ephemeris (orbital position) errors, and about the rate of clock drift for the broadcasting satellite. Distortion of the signal by measurement noise can further increase positional error (Figure 8). The disparity in ephemeris data can introduce 1 to 5 metres of positional error, clock drift disparity can introduce up to 1.5 metres of positional error, and measurement noise can introduce up to 10 metres of positional error.



Source: http://www.trimble.com

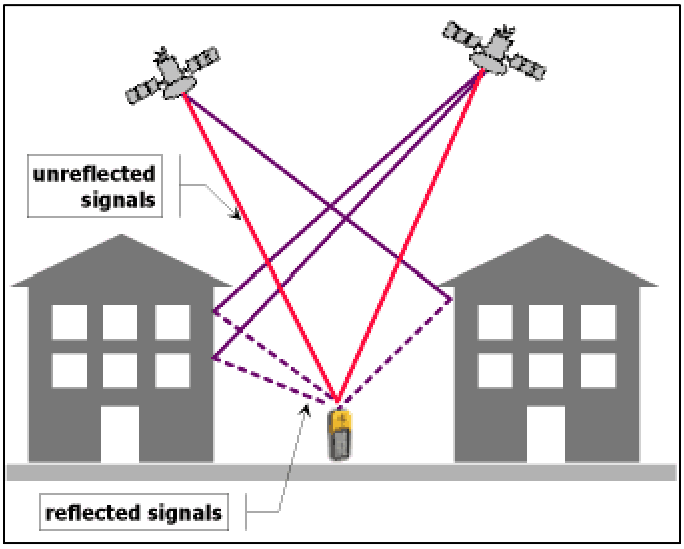
Figure 8. Influence of angles on the margin of error.

Selective availability

Ephemeris errors should not be confused with selective availability, which is the intentional alteration of the time and ephemeris signal by the US Department of Defence. Selective availability can introduce up to 70 metres of positional error. Fortunately, positional errors caused by selective availability can be removed by differential correction.

Multi-path error

A GPS signal bouncing off a reflective surface prior to reaching the GPS receiver antenna is referred to as multi-path error. Because it is difficult to completely correct multi-path error, even in high-precision GPS units, it is a serious concern to the GPS user (Figure 9). See page 24 for more information on this subject.



Source: http://www.kowoma.de

Figure 9. Multi-path error caused by GPS signal bouncing off a surface.

The most common sources of errors in GPS positions are listed in Table 1. These errors collectively are commonly known as the GPS Error Budget:

Table 1. GPS error budget

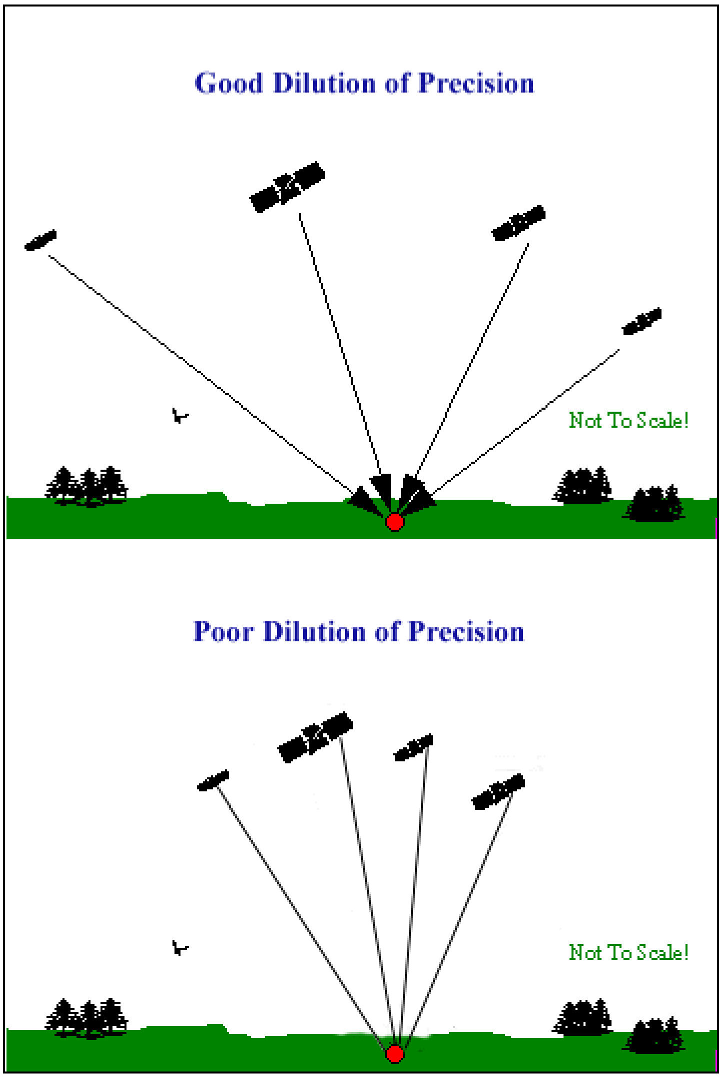
Source	Uncorrected Error Level
Ionosphere	0-30 metres
Troposphere	0-30 metres
Measurement noise	0-10 metres
Ephemeris data	1-5 metres
Clock drift	0-1.5 metres
Multi-path	0-1 metre
Selective availability	0-70 metres

Measuring GPS accuracy

As discussed above, there are several external sources which introduce errors into a GPS position. While the errors discussed above always affect accuracy, another major factor in determining positional accuracy is the alignment, or geometry, of the group of satellites – or constellation – from which signals are being received. The geometry of the constellation is evaluated for several factors, all of which fall into the category of dilution of precision, or DOP.

Dilution of precision

DOP is an indicator of the quality of the geometry of the satellite constellation (Figure 10). A computed position can vary depending on which satellites you use for the measurement. Different satellite geometries can magnify or lessen the errors in the error budget described above. A greater angle between the satellites lowers the DOP and provides a better measurement. A higher DOP indicates poor satellite geometry and an inferior measurement configuration.



Source: http://www.cmtinc.com

Figure10. Satellite geometry affects dilution of precision.

Some GPS receivers can analyze the positions of the satellites available, based upon the almanac, and choose those satellites with the best geometry in order to make the DOP as low as possible. Another important GPS receiver feature is to be able to ignore or eliminate GPS readings with DOP values that exceed user-defined limits. Other GPS receivers may have the ability to use all of the satellites in view, thus minimizing the DOP as much as possible.

Using differential GPS to increase accuracy

As powerful as GPS is, some 50 to 100 meters of uncertainty is not acceptable in many applications. How can we obtain higher accuracies? A technique called differential correction is necessary to get accuracies within 1 to 5 meters, or even more accurate with advanced equipment. Differential correction requires a second GPS receiver, called a base station, collecting data at a stationary position on a precisely known point (typically it is a surveyed benchmark). Because the physical location of the base station is known, a correction factor can be computed by comparing the known location with the GPS location determined by using the satellites.

The differential correction process takes this correction factor and applies it to the GPS data collected by a GPS receiver in the field. Differential correction eliminates most of the errors listed in the GPS error budget discussed earlier. After differential correction, the GPS error budget changes (Table 2).

Table 2. GPS error budget with differential

Source	Uncorrected	With Differential
Ionosphere	0-30 metres	Mostly removed
Troposphere	0-30 metres	All removed
Signal noise	0-10 metres	All removed
Ephemeris data	1-5 metres	All removed
Clock drift	0-1.5 metres	All removed
Multi-path	0-1 metres	Not removed
Selective availability	0-70 metres	All removed

By eliminating many of the above errors, differential correction allows GPS positions to be computed at a much higher level of accuracy.

Types of GPS receivers and levels of accuracy

There are generally three types of GPS receivers available: course acquisition (C/A) code, carrier phase, and dual frequency receivers. Each of them offers different levels of accuracy and has different requirements to obtain those accuracies.

<u>C/A code receivers</u>

C/A code receivers are used in Zambia for IRS geocoding. They typically provide 1- to 5-metre GPS position accuracy with differential correction. C/A code GPS receivers provide a sufficient degree of accuracy to make them useful in most GIS applications.

C/A code receivers can provide 1- to 5-metre GPS position accuracy with a processing time of 1 second. Longer processing times (up to 3 minutes) will provide GPS position accuracies consistently within 1-3 metres. Recent advances in GPS receiver design will now allow a C/A code receiver to provide sub-meter accuracy, down to 30 centimetres.

Carrier phase receivers

Carrier phase receivers typically provide 10- to 30-centimetre GPS position accuracy with differential correction. Carrier phase receivers provide the higher level of accuracy demanded by certain GIS applications.

Carrier phase receivers measure the distance from the receiver to the satellites by counting the number of waves that carry the C/A code signal. This method of determining position is much more accurate; however, it does require a substantially higher occupation time to attain 10- to 30-centimetre accuracy. Initializing a carrier phase GPS job on a known point requires an occupation time of about 5 minutes. Initializing a carrier phase GPS job on an unknown point requires an occupation time of about 30 to 40 minutes.

Additional requirements, such as maintaining the same satellite constellation throughout the job, performance under canopy, and the need to be very close to a base station limit the applicability of carrier phase GPS receivers to many GIS applications.

Dual-frequency receivers

Dual-frequency receivers are capable of providing sub-centimetre GPS position accuracy with differential correction. Dual-frequency receivers provide survey-grade accuracies not often required for GIS applications.
Dual-frequency receivers receive signals from the satellites on two frequencies simultaneously. Receiving GPS signals on two frequencies simultaneously allows the receiver to determine very precise positions.

GPS and canopy

GPS receivers require a line of sight to the satellites in order to obtain a signal representative of the true distance from the satellite to the receiver. Therefore, any object in the path of the signal has the potential to interfere with the reception of that signal. Objects which can block a GPS signal include tree canopy, buildings, and terrain features.

Further, reflective surfaces can cause the GPS signals to bounce before arriving at a receiver, thus causing multi-path error. This problem can be caused by a variety of materials including water, glass, and metal. The water contained in the leaves of vegetation can produce multi-path error. In some instances, operating under heavy, wet forest canopy can degrade the ability of a GPS receiver to track satellites.

There are several data collection techniques which can mitigate the effects of signal blockage by tree canopy or other objects. For example, many GPS receivers can be instructed to track only the highest satellites in the sky, as opposed to those satellites which provide the best DOP. Increasing the elevation of the GPS antenna can also dramatically increase the ability of the receiver to track satellites.

Unfortunately, there will be locations where GPS signals simply are not available due to obstruction. In these cases, there are additional techniques which can help to solve the problem. Some GPS receivers have the ability to collect an offset point, which involves recording a GPS position at a location where GPS signals are available while also recording the distance, bearing, and slope from the GPS antenna to the position of interest where the GPS signals are not available. This technique is useful for avoiding a dense timber stand or building.

GPS for GIS

Although the main importance of GPS is to determine a location on the surface of the earth, describing what is at the location is the major importance in GIS, as it is this that is mapped. The mapped objects are referred to as features, and are used to build a GIS. It is the power of GPS to precisely locate these features, which adds so much to the utility of the GIS system. Without feature data, a coordinate location is of little value.

Feature types

There are three types of features which can be mapped: points, lines and areas. A point feature is a single GPS coordinate position which is identified with a specific object. A line feature is a collection of GPS positions which are identified with the same object and linked together to form a line. An area feature is very similar to a line feature, except that the ends of the line are tied to each other to form a closed area.

Describing features

As stated above, a feature is the object which will be mapped by the GPS system. For example, it is possible to map the location of each house on a city block and simply label each coordinate position as a house. However, the addition of information such as colour, size, cost, and occupants will provide the ability to sort and classify the houses by these categories.

These categories of descriptions for a feature are known as attributes. Attributes can be thought of as questions which are asked about the feature. Using the example above, the attributes of the feature house would be colour, size, cost, and occupants.

Logically, each question asked by the attributes must have an answer. The answers to the questions posed by the attributes are called values. In the example above, an appropriate value (or answer) for the attribute (or question) colour may be blue. Table 3 illustrates the relationship between features, attributes and values.

Table 3. Relationship between features, attributes, and values

Feature	Attribute	Value
House	Colour	Blue
	Size	3 BDR
	Cost	$118K
	Occupants	5

By collecting the same type of data for each house which is mapped, a database is created. Tying this database to position information is the core philosophy underlying any GIS system.

Exporting GPS data to a GIS system

To be used, GPS data must be exported into the GIS system. This results in a GIS layer created for each feature that has been captured. The feature may be in form of point data, line data, or polygons. In the IRS programme being carried out in Zambia, data on structures is collected using GPS-enabled PDAs. The GPS data is automatically from the PDA to the computer and saved in MS Access. Any GIS software can then convert this data into layers (see Figure 2).

In this manual, description will be restricted to the GlobalSat BC-337 Compact Flash (CF) GPS receivers (Figure 11), the type currently being used with the Dell X5 Axim and HP PDAs. The CF GPS receiver plugs into the Axim's X51 CF slot or the HP’s CF slot and draws power directly from the PDA. This type of receiver is the most portable but will drain the battery from the PDA quickly. Larger capacity batteries can be obtained separately to solve this problem.

Source: www.mobiletopsoft.com

Figure 11. Compact Flash GPS receiver.

Advantages of GPS navigation

The advantages of GPS can be seen from the broad applications that rely on GPS today, such as navigation. Today delivery trucks can be monitored as they deliver cargo from one point to another and so locations of delay can be identified. In the context of malaria control, GPS makes it possible to accurately quantify and identify the position of household structures and health facilities. The relative position of these structures from each other, and the way they are clustered, can assist in planning spray activities, for example. Their relative position with regards to the health facilities can help define catchments areas.

6. Overview of Personal Digital Assistants

A PDA is a computer that can fit in the palm of your hand. Also called palmtops, pocket computers, palm pilots, or handhelds, PDAs are meant to be an extension of your computer that can be carried with you so that you have access to many things available on your desktop computer, such as email, web browser, various software applications, planner, address book, memo pad, and multimedia applications. PDAs also can include a mobile phone, camera, GPS system, and software applications that are tailored to specific professions.

Types of PDAs

As the capabilities of PDAs continue to grow, the devices are in a constant state of change. PDAs come in a wide range of capabilities as well as price. A basic organizer that stores contact information and provides a daily calendar costs approximately US$50; a high-end PDA that provides advanced features such as wireless access, expansion slots, cameras, and more costs much more.

Basic PDA

The two main types of PDAs are the Palm and the Pocket PC and they are quite similar. The amount of internal memory in the PDA determines the number of names, phone numbers, and information it can store. The most basic PDA is able to provide:

- An address book in which you can store names, addresses, phone numbers, and e-mail addresses.
- A memo pad where you can take notes.
- A daily calendar where you can store appointments and other information.
- An alarm clock with appointment reminders.
- A calculator.

Mid-range PDA

In addition to added memory, most mid-range PDAs today also include wireless and multimedia functions. They generally have colour screens with crisper text. The screen may also support landscape formatting. Other features found in a mid-range PDA may include:

- A faster processor.
- Wireless networks that enable you to access the web or corporate networks.
- Support for data networks providing connectivity to Smart phones.
- Support for MP3 files.
- A memory card slot for use with digital cameras.
- An additional memory slot for adding memory at a later date.
- Rechargeable batteries and a cradle.
- Ability to retain data when batteries run out.

High-end PDA

A high-end PDA will give you even more memory, a higher screen resolution, and a faster processor. Other features you may find on a high-end PDA that are not generally found on lower-priced PDAs include:

- Digital camera and video recorder.
- Global positioning system card and receiver that, along with mapping software, allow you to pinpoint your location and get directions.
- Bluetooth capabilities.
- An MP3 player.
- A mobile telephone.
- Keyboards for quick and easy typing or data entry.

PDA accessories

Added accessories can make your PDA easier to use. Some examples include:

Cases: There is a wide variety of PDA cases to protect your PDA from being damaged. If you are especially hard on your electronics, you may want to consider one of the metal or rubber cases.

Chargers: Most PDAs come with wall chargers, but you can buy car chargers if you are on the road a lot.

Keyboards: Adding a keyboard to your PDA is an option you may want to consider if you want to send e-mails or do a significant amount of note taking. There are several keyboards that can be plugged into the PDA if your PDA does not come with a built-in keyboard.

Headphones: Many models come with standard stereo jacks, allowing you to connect headphones to your PDA. Some of the higher-end models are able to block outside noises so that you only hear what is being played from your PDA.

Software: There is a wide variety of software packages available for PDAs. You can purchase software for creating documents, spreadsheets, and slide shows. There is software to track business expenses and mileage. There are also several mapping programs that make it possible to map destinations.

7. Overview of Desktop and PDA Software for GIS

There are several types of software that can be used with desktop computers and PDAs for GIS.

Software for the desktop computer

Software that can be used with the desktop computer includes:

HealthMapper: This is GIS software developed by the World Health Organization (WHO) for recording disease events and for viewing and creating maps and geographical data.

IRS2007.Desktop: A software developed by the US Centers for Disease Control (CDC) for extracting GPS and household-listing data from PDAs for enumeration of IRS areas.

ActiveSync: ActiveSync acts as the gateway between a Microsoft Windows-powered PC and Windows Mobile powered device and allows you to synchronize geocoded data collected from the applications on the PDA as well as Microsoft Outlook information, Microsoft Office documents, pictures, music, videos and applications to and from your device.

Pre-install tools: The training CD comes with additional software that may be required to install on your desktop computer in order to run either the IRS2007.Desktop or the ActiveSync software. These include:

- dotnetfx.exe: This is a .NET Framework 2.0. It may be already installed by Windows Update or other application.
- MDAC_TYP.2.8.1.exe or newer: Required for a functioning of SQL Server Mobile part on desktop. It may be already installed by another application.
- Sqlsupport.msi: This is a desktop portion of SQL Server Mobile.

During the installation of IRS2007.Desktop, you may receive error messages that indicate you must install these tools.

Software for the PDA

There are several types of software that can be used with your PDA, including:

GPS2: This software is developed by the CDC for collecting GPS and household-listing data from PDAs for enumeration of IRS areas. GPS2 is loaded with the IRS household list form for complete IRS listing, determination of formal and informal structures, and population counts.

Navio: This proprietary software, similar to GPS2, is used to collect geocode data using the PDA with a GPS unit. Navio allows for trip mapping using subsequent rapid interval geocoding.

8. Using the PDA to Perform IRS Household Listing

The Dell Axim X51 contains two programs, GPS2 and Navio, that are useful for geocoding IRS spray areas. The next few pages will guide you through the use of these two programs to record geocoded information for digitizing the spray areas.

Enumerating households

Start the PDA

The PDA is turned on by clicking on the 'Power' button next to the Dell logo in the top middle part of the front PDA screen.

Run the GPS2 program

From the 'Start' menu, select GPS2. This will activate the program for collecting geocoded information. Figure 12 shows how the control panel will then appear. Only two of the four buttons are accessible, 'Collect' and 'Beam' ('Select' and 'Navigate' are only accessible after you enter at least one household in the listing).

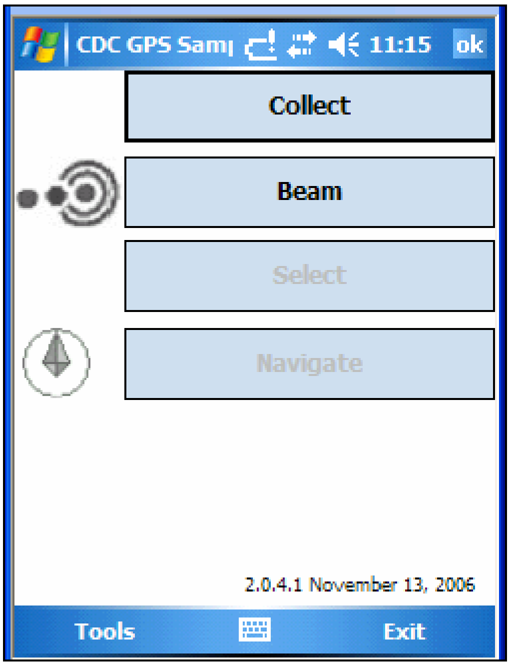


Figure 12. Control panel appearance after activating GPS2.

Begin household listing

Walk to the first household. To begin the household listing using the PDA, select 'Collect'. The next screen appears (Figure 13). The keyboard can be minimized by clicking on the keyboard icon in the middle of the bottom blue task bar. This screen allows for at least 3 fields to recognize the household. Enter something meaningful in the 'Village Name/EA' field, such as 'Chainda' to represent the area where you are currently listing households.

Next enter a house number, such as 4356. It is better to label the household with a meaningful number that can be used to identify the house again at a later date. The button 'last+1' will allow rapid repeat entry.

The 'Status:' field has a green square as in Figure 13 below. The green square indicates the GPS unit is reading the signal correctly. The 'Status:' field may also appear as red or black. If this happens, the GPS unit needs to be reset in the port on the top of the PDA.

The 'Comment' field is another field for entering household-specific information. Enter something meaningful like the head of the household's name, for example, 'Joseph Banda'.

The 'Exclude point from sampling' field should NOT be checked.

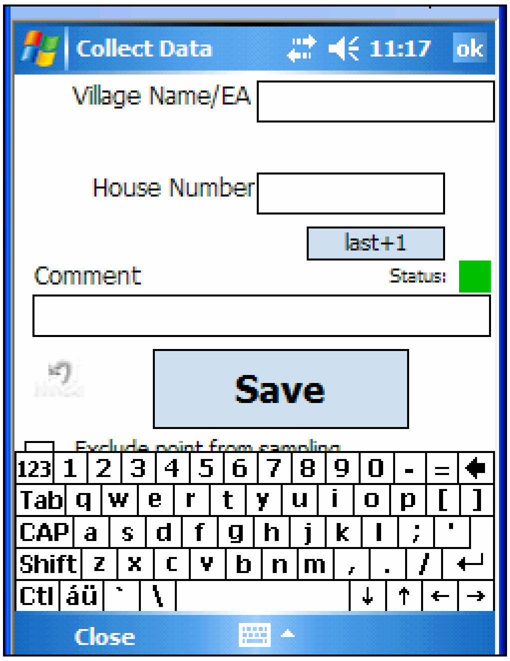


Figure 13. The status field.

Once all three fields have complete information, click 'Save' to save the record. You will receive a notification that indicates 'Saved successfully'.

Once the 'Save' procedure is complete, the screen below (Figure 14) appears with the IRS household listing details. Complete all information for the household. The number of unplastered rooms is calculated automatically from the difference between the total number of rooms and the total number of plastered rooms. If the household respondent does not know how many nets are available in the household, check the 'Do not know' box.

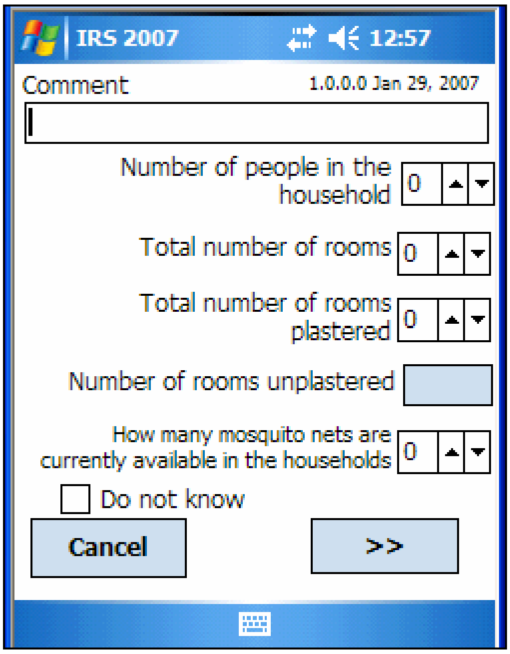
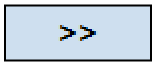


Figure 14. IRS household listing details.

Once the information is complete, click on the 

button.

The last screen (Figure 15) provides additional information about where the house is located. Select the province and then select the district in which the listing is being conducted. Once selected, click 'Save' to save the record.

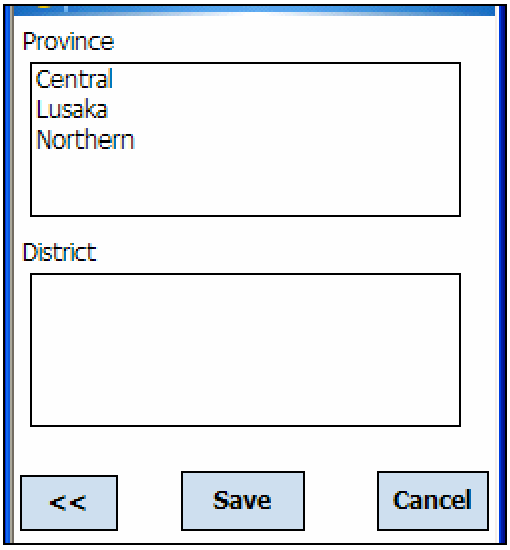


Figure 15. Additional location information.

The program returns to the 'Collect Data' screen. DO NOT HIT SAVE AGAIN. Click 'Close' in the bottom left corner (Figure 16).

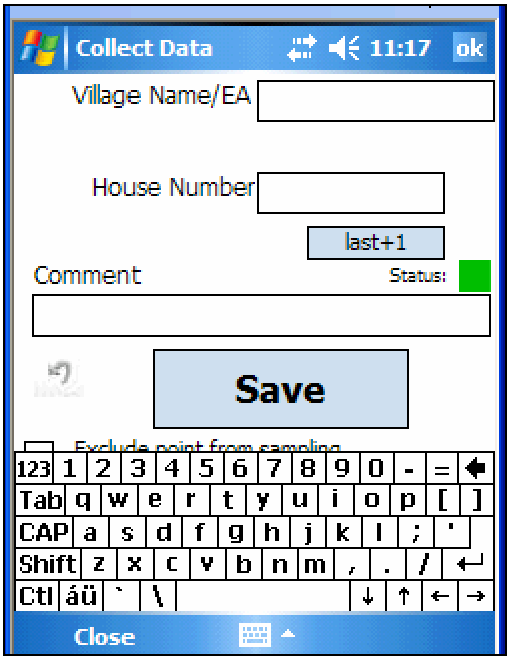


Figure 16: Collect Data screen (click 'Close').

Now that you have entered your first household, the control panel has four buttons that are accessible as shown in Figure 17 below.

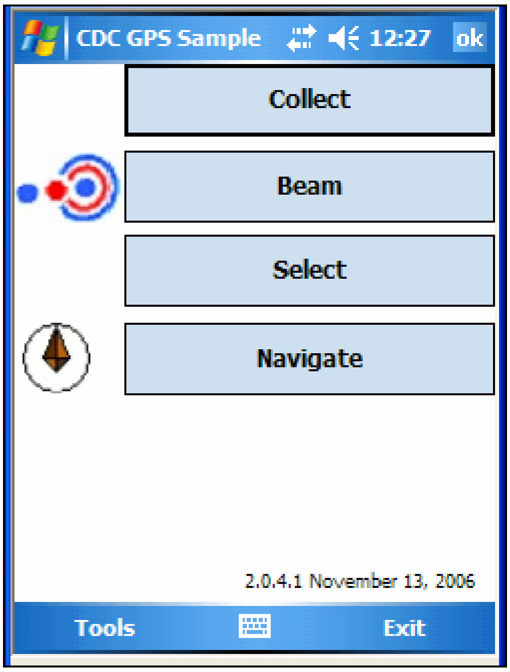


Figure 17. Control panel after first household entry completed.

You can repeat all the steps above to enter more household listing information until you have completed the listing for the day.

The other three buttons are for beaming data between PDAs ('Beam'), survey sample selection ('Select'), and navigation back to households listed ('Navigate').

Beaming data between PDAs

Beaming data in and out allows data from other PDAs to be shared between enumerators.

This screen is accessed by selecting the 'Beam' button from the main screen. The primary functions of this screen are to transfer and receive data from another PDA using GPS2. The GPS2 program transfers data using the infrared port and combines the transferred data with the current database.

The signal icon to the left of the 'Beam' button on the main screen can be used to determine if the infrared beam function is active on both PDAs (Figure 18, below left). The icon becomes colourful when another infrared device, not necessarily a PDA, is detected.

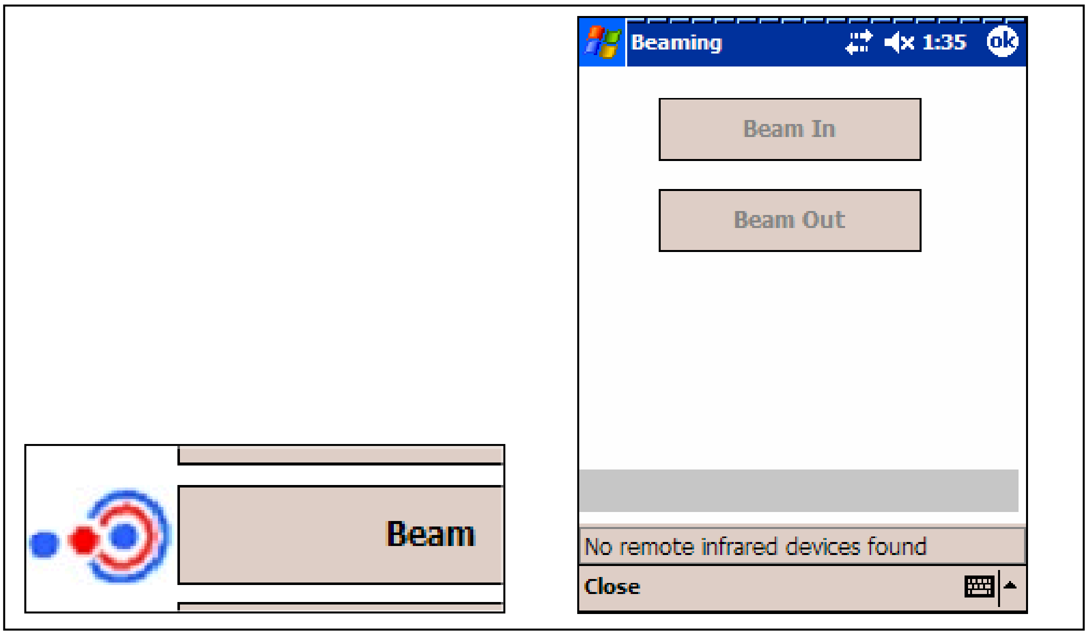
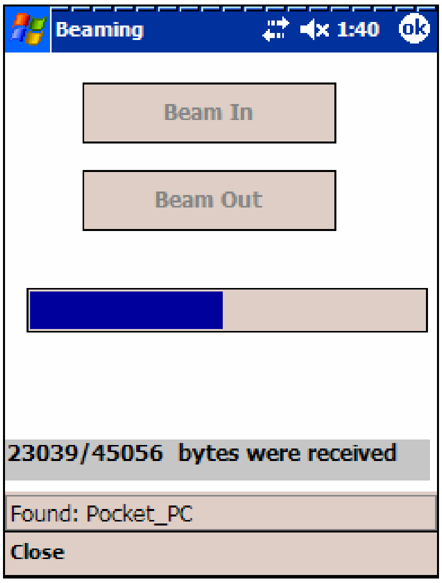


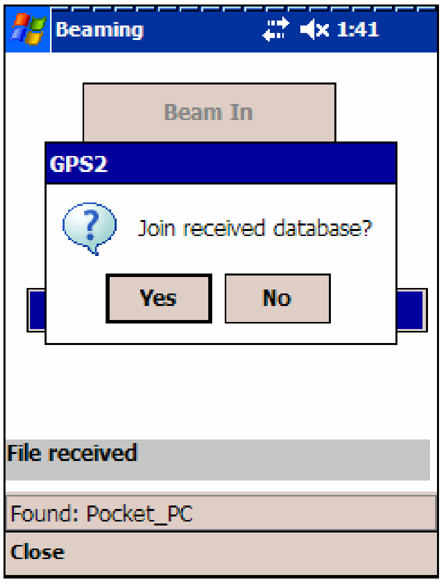
Figure 18. Activated beam icon (left); no infrared device detected (right).

When the 'Beam In' and 'Beam Out' button text is black, another infrared device is detected. When the button text is grey, no infrared device is detected (above right).

To transfer data between PDAs, the receiver must press the 'Beam In' button before the transmitter will press the 'Beam Out' button. The transfer process will start automatically after pressing these buttons (Figure 19).



Transfer progress is shown.



Screen after successful transfer.

Figure 19. The transfer process.

Selecting households for sampling

The 'Select' button is used for selecting households for the second-stage sampling during a household survey, such as the National Malaria Indicator Survey. This will not be used during the IRS household listing.

Navigating back to listed and selected households

From the control panel, click on 'Navigate'. The navigation screen (Figure 20) allows you to see all the households listed. So far, we have only entered one household, House Number 4345 where Joseph Banda lives in Chainda.

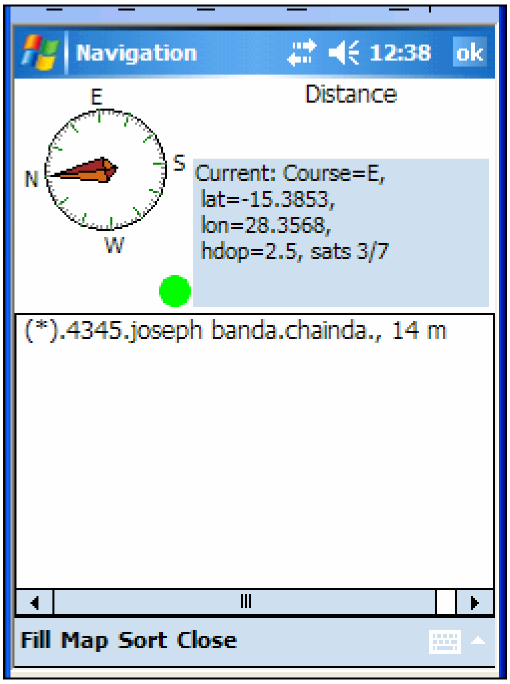


Figure 20. The navigation screen.

9. Data Extraction from GPS2 Programmes

There are eight steps to extracting geocoded information from the PDA to the computer.

Step 1: Ensure ActiveSync is installed on your desktop computer.

ActiveSync was provided in the training CD. Go to the Software folder, find the ActiveSync41.exe file in the ActiveSync folder and double click on it. Follow the installation instructions. The PDA must be able to be connected to complete the installation of ActiveSync. You must restart the computer when the installation is complete.

Step 2: Install Microsoft Framework .NET 2.0.

Microsoft Framework .NET 2.0 was provided in the training CD. In order for the IRS2007.Desktop application to run on a desktop computer, please ensure that the latest version of Microsoft Framework .NET 2.0 is installed. Go to the Software folder, find the dotnetfx.exe file in the Framework.NET2.0 folder and double click on it. Follow the installation instructions. You must restart the computer when the installation is complete.

Step 3: Install IRS2007.Desktop on your desktop computer.

IRS2007.Desktop was provided in the training CD. Go to the Software folder, find the SetupIRS2007.Desktop.msi file in the CDC_IRS folder and double click on it. Follow the installation instructions. An icon will be placed on your desktop to enable you to launch the program.

Step 4: Connect the PDA to the computer with the cable.

The PDA must now be connected to your computer using the USB cable. The cable fits into the bottom of the PDA. After connection, ActiveSync application should begin automatically. Once ActiveSync is running and the PDA is recognized, proceed to the next step.

Step 5: Launch the IRS2007.Desktop program.

Find the desktop icon for IRS2007.Desktop and double click on it. The program opens to the screen shown in Figure 21 below.

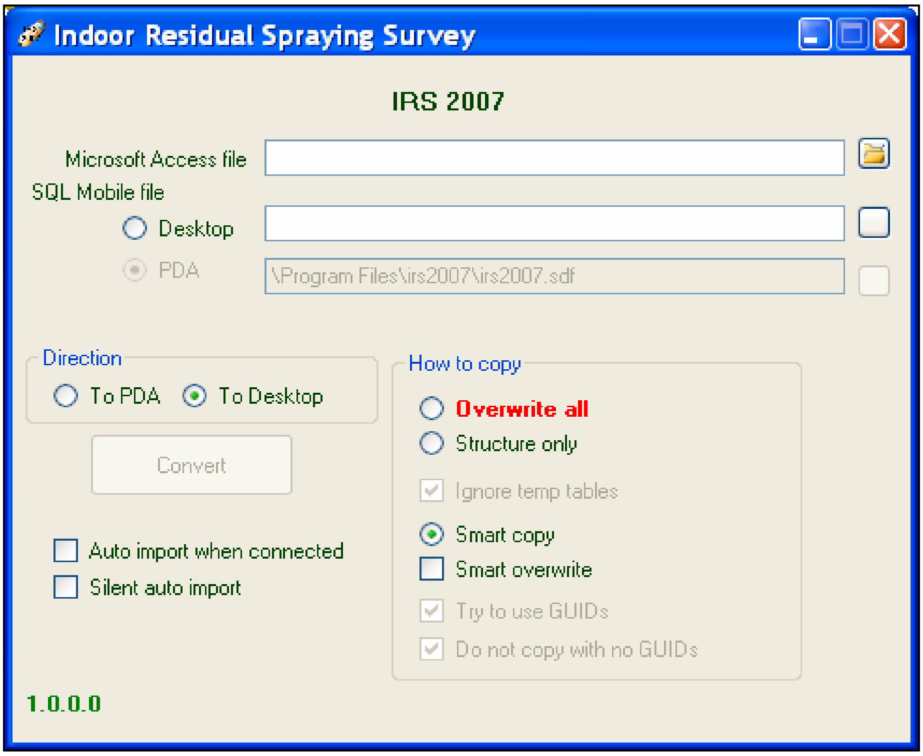


Figure 21. The IRS2007.Desktop screen.

Step 6: Specify the location of the data files.

In order to extract data from the PDA, two files' names must be specified: 1) the location of the MS Access .mdb file where IRS household-listing data will be placed on the desktop computer, and 2) the location of the file on the PDA that contains the IRS household listing data recorded during the listing exercise.

Figure 22 below shows the location of the MS Access .mdb file where IRS household listing data will be placed on the desktop computer as C:\Data\testdata.mdb. If this is the first time the C:\Data\testdata.mdb is used, or if the file C:\Data\testdata.mdb does not yet exist, the program will create the file.

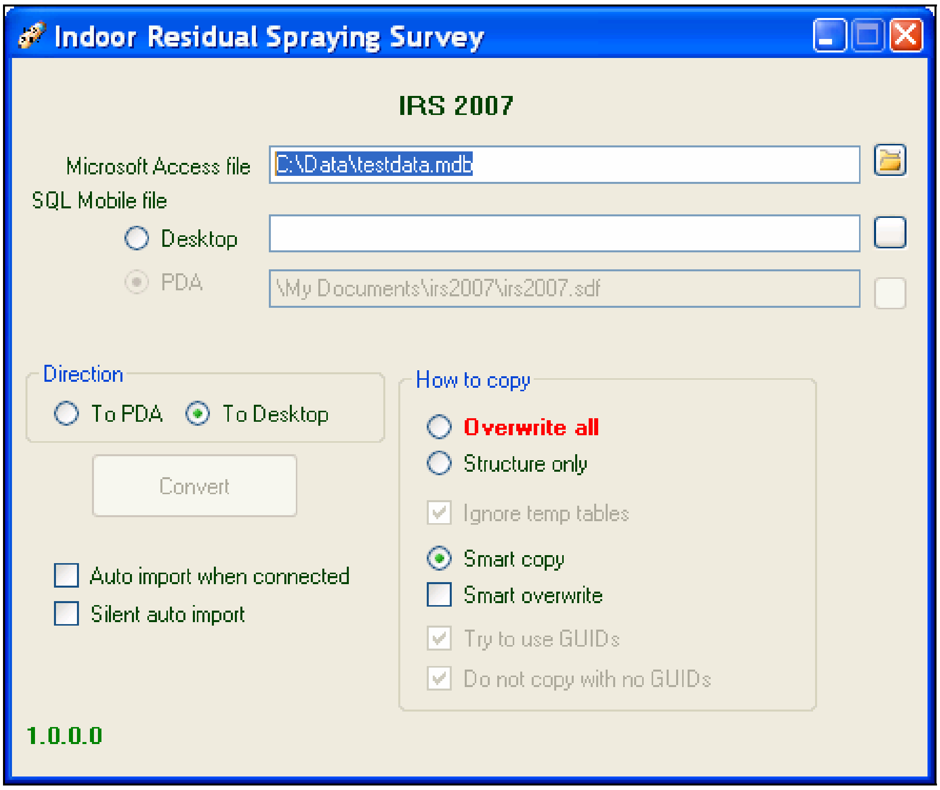


Figure 22. The MS Access .mdb file.

When the PDA is connected, the SQL Mobile file is set to extract data from the default location on the PDA (Figure 23). The default location is \MyDocuments\irs2007\irs2007.sdf. If the file has been saved to another location on the PDA, use the drop-down arrow to locate it.

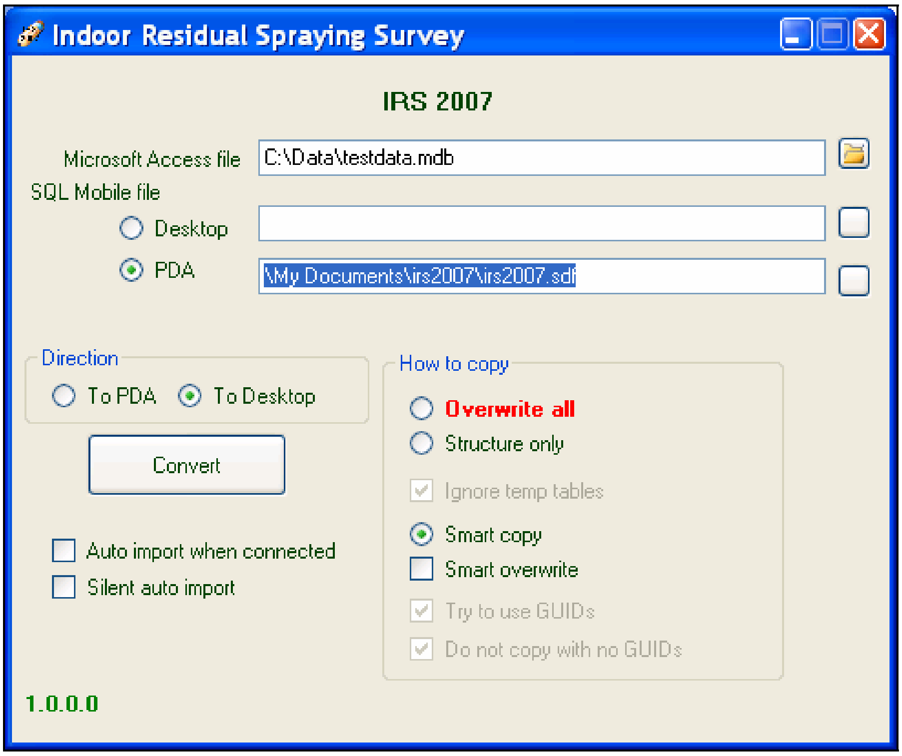


Figure 23. The default location on the PDA.

All other parameters on the IRS2007.Desktop program should be left as presented in the figure above to transfer data from the PDA to the desktop computer to ensure that data are extracted and imported correctly each time the PDA is connected.

Step 7: Convert the data into an MS Access file

Next you will need to click the 'Convert' button. Once the data are extracted and the new MS Access .mdb file is created, a message will appear in the bottom of the screen as in Figure 24.

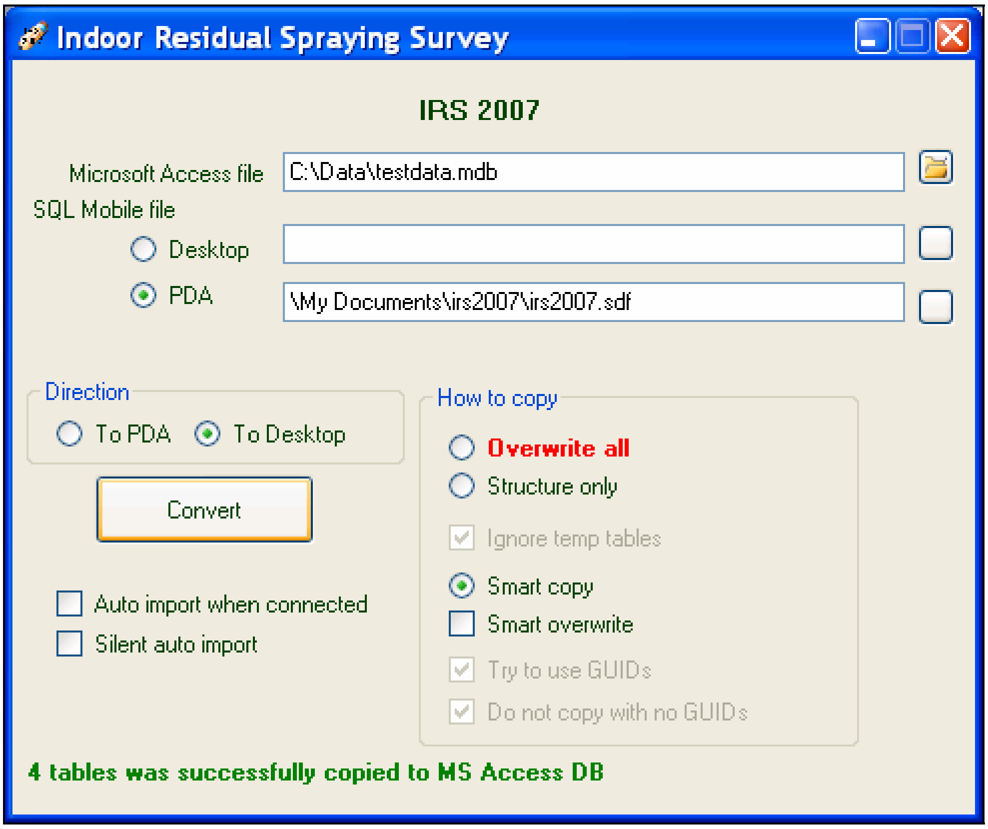


Figure 24. Successful creation of the new MS Access .mdb file.

Step 8: Convert the MS Access file in MS Access 97 for importing into HealthMapper

The final step before the file is ready to use in HealthMapper is to convert the MS Access file into a MS Access version 97. HealthMapper relies on MS Access 97 for reading data into the data management tool because the application was designed to meet the needs of a variety of data management systems in countries where WHO operates.

The following steps are necessary to convert the file to MS Access 97:

- Open MS Access (Figure 25 below shows MS Access 2003 format).
- Close any open databases.
- From the 'Tools' menu, find 'Database Utilities', 'Convert Database' and select 'To Access 97 File Format…'.

- Select the database file that was saved in Step 7 above, testdata.mdb as the Database to convert from.
- Click ‘Convert’ then specify the name of the database to save as in MS Access 97.

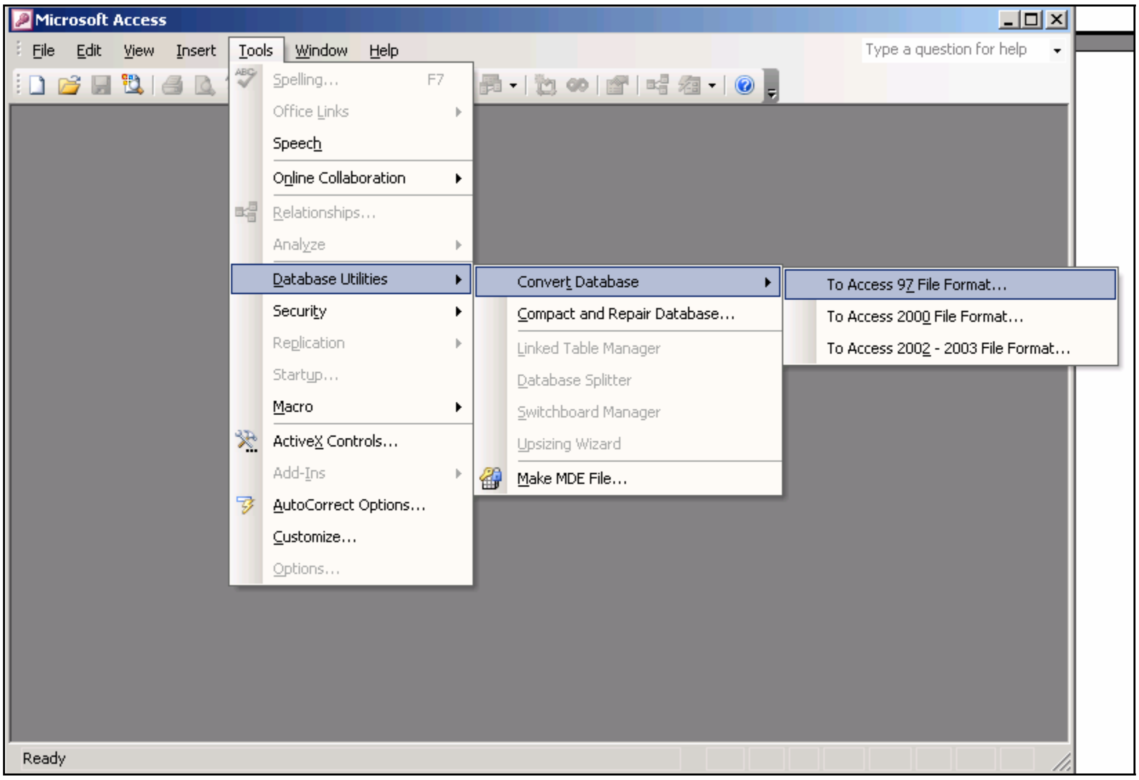


Figure 25. MS Access 2003 format.

You are now ready to use this data in HealthMapper to view the data.[4]

[4] The Zambia National Malaria Control Programme has extensive plans for using GIS/GPS for mapping households. An overview of these plans can be found Table 4.

Table 4. Zambia IRS/GIS Mapping Processes and Outputs

No	Map Description	Inputs	Map Production Process	Sources for Inputs	Contact Points
1	**National map areas** showing provinces and districts participating in IRS.	Zambia base topographic map 15 district administrative boundaries	Start HeathMapper software (see manual for details) Load Zambia base map Load the 15 districts	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa
2	**Provincial IRS maps areas** showing where IRS activities are taking place.	Zambia base topographic map 15 provincial administrative boundaries Rainfall distribution	Start HeathMapper software (see manual for details) Load Zambia base map Load the provincial boundaries	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa
3	**District IRS map areas** showing which areas have been sprayed in a district.	Zambia Base topographic map 15 district administrative boundaries Health facilities Population Land use Rainfall distribution	Start HeathMapper software (see manual for details) Load Zambia base map Load the district boundaries Load GPS points for health facilities Add district population figures to the district shape file Add land use layer Add district rainfall figures to the district shape file	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa

No	Map Description	Inputs	Map Production Process	Sources for Inputs	Contact Points
4	**District map showing HHs sprayed.**	Zambia base topographic map District base maps Health facilities Population Land use Rainfall distribution HHs sprayed (PDA point data) Type of chemical Quantity Location name	Same as Map 3 but with: Point data showing HHs sprayed Add type of chemical sprayed data to the district shape file Add name of location, compound, suburb to the district shape file	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa
5	**District malaria prevalence map** showing areas where malaria is likely to occur.	District topographic base maps Population	Load HealthMapper Add population figures to the district table Add a table with malaria pre-deposing factors	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa
6	**District malaria map showing population at risk** within a 5, 10, 20 km radius of a health facility, river, IRS HHs sprayed.	District topographic base maps Population	Same as Map 5. Create a buffer 5, 10, 20 kms	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa

No	Map Description	Inputs	Map Production Process	Sources for Inputs	Contact Points
7	**District map showing species of mosquitoes in IRS Map areas**.	District topographic base maps District topographic Base maps IRS map areas Species of mosquito	Same as Map 6. Add mosquitoes attribute data to the shape file	HealthMapper provided by WHO but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa
8	**District map showing areas the type of chemical used to kill mosquitoes.**	District topographic base maps IRS map areas HHs sprayed Type of chemical Species of mosquito	Same as Map 7. Add attribute data to the shape file with type of chemical used	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa
9	**District map showing the malaria prevalence and chemical used.**	District topographic base maps IRS map areas HHs sprayed Type of chemical Incidence of malaria	Same as Map 8. Overlay map 5 & 8	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia bBase map provided by NMCC.	J. Miller B. Chirwa
10	**Map showing mortality rates in IRS map areas in select age groups (under 5, 5-10, etc.).**	District topographic base maps IRS map areas HHs sprayed Type of chemical Mortality rates	Same as Map 9. Add attribute table showing mortality due to malaria to the shape file	HealthMapper provided by WHO, but NMCC will preload your PCs. Zambia base map provided by NMCC.	J. Miller B. Chirwa

10. PDA Equipment, Maintenance, and Troubleshooting

Equipment list

When you receive PDAs to use for household enumeration, each PDA will have all of the equipment listed below. It is your responsibility to ensure all the equipment is kept up and in good working order.

- Dell Axim X51
- GPS Unit
- SD card
- USP cable
- Power cable
- Outer box
- Stylus (one on the outer box and one hidden inside the PDA)

Charging the battery

The Dell Axim X51 comes with a long-life battery. When fully charged, it can last about 4-6 hours. Under most conditions, this is enough charge to last one full working day as long as the PDA is turned off when not in use.

Fully charging the battery is essential to keep it in good working condition. PDAs come with recharge cables which are inserted into the bottom of the PDA. The electrical plug for the cable fits a standard US electrical outlet, so adapters or matching extensions will be provided.

Backing up data on the SD card

Backing up data is essential during all field work. From the Control Panel, the backup procedures are accessed through the Tools menu in the bottom left corner of the screen. There are two options for data backup: ‘Simple’ and ‘Select File’ (Figure 26).

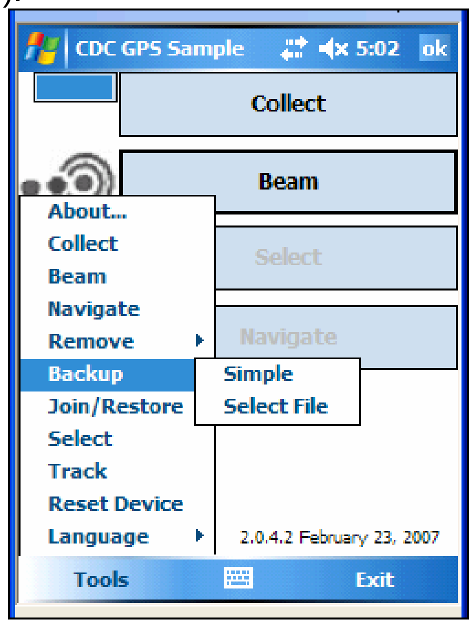


Figure 26. Data backup

Simple backup will copy the collected points in the database to another file. The file name of the backup file consists of the most recently used village name, date, and time stamp, and IRS listing information. Several file locations can be used for storing backups. Also, it is possible to append collected points into an existing file.

Every day at the end of data collection, a full backup of household listing data is recommended. This is done by using the 'Select File' option. When you are ready to do a full backup, choose the Select File' option. The screen below (Figure 27) appears.

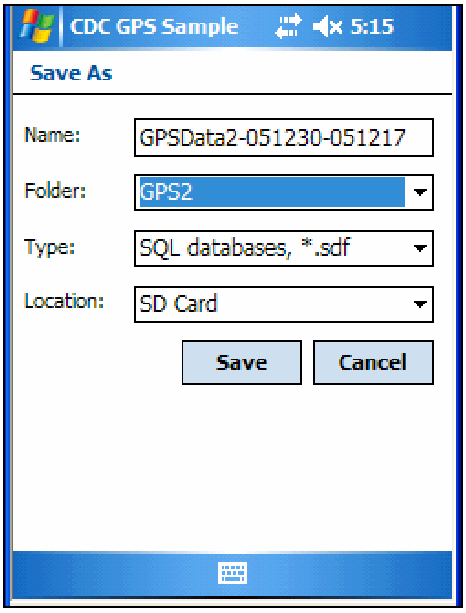


Figure 27. Options for backing up data.

This screen allows you to choose a few options for backing up data. For the full backup at the end of the day, it is recommended that you name the file something meaningful and that you save the data to the 'Location: SD Card' as in the example above.

Once these parameters have been entered, click 'Save'. A message will indicate the backup was successful and then you will be returned to the 'Control Panel'.

Troubleshooting tips

The GPS is not getting a signal

The x51s lose their signal occasionally. It seems to be associated with the PDA going to power save mode. The easiest thing to do is simply shut down the GPS program for a few seconds and then restart it.

If that does not work, shut down the GPS program, take the GPS unit out of the PDA, wait a few seconds, reseat the GPS unit in the PDA and then restart the GPS program.

If that does not work, reset the device (in the GPS program, click ‘Tools’ in the bottom left corner and then ‘Reset Device’)

One way to prevent this is to occasionally press the backlight (button 4) to prevent it from going to power save mode.

Note that if the GPS is not getting a signal while you are mapping, it should give you two warnings indicating that the point is not valid and asking if you want to continue. You should click ‘No’ to either one of those warnings and make sure you get a valid GPS signal. In most PDAs, it seems to record the household without the GPS data but it is not clear that that is true in all cases. The biggest problem this creates for the team is that they will not have the GPS data to guide them back to the houses selected for interview.

GPS data does not show up when I go to the navigation screen.

Each time the GPS program is started, it asks if the existing data should be cleared from the database. If you are starting a new enumeration area, then press ‘Yes’. If you are continuing with the same enumeration area, then press ‘No’.

If you accidentally clear the database, there are several options. If this happens after beaming, the easiest thing to do is to beam the data back from another PDA.

If it happens before beaming, then do the following:

Go to ‘Tools’ and click on ‘Join/Restore’.

This will bring you to a screen with two buttons. Click on ‘Open File’ and then every *.sdf file on the PDA will be listed.

There will be a gray bar in the middle of the screen with a list of files under it. On that gray bar, there will be a column for ‘Date’ –click two times on this.

There will be an arrow pointing down next to the word ‘Date’ (if the arrow is pointing up, tap one more time). The first two files may be ‘RBM2006’ or ‘GPSData2’ (often only the ‘GPSData2’ file is there).

Click on the third file (second file if only ‘GPSData2’ is at the top of the list). That will bring you to back to the screen with two buttons.

Click on ‘Join/Restore’. That will bring in the most recent database. To check it, click on ‘Tools’, then ‘Remove’ then ‘By Date’. The list of dates should have the GPS data from the previous day.

After we beam our files together, the list of selected houses does not appear the same.

They are the same but the houses get sorted differently on each PDA. They are sorted by date and time, but the houses collected on your own PDA will show up at the top of the list.

Online resources

http://www.aximsite.com/articles/link.php?id=22#Outlook
Information on Axim PDAs.

www.activeangler.com/articles/how-to/articles/capt_matt/gps.asp
GPS overview.

http://www.cmtinc.com/gpsbook/index.htm
Introduction to GPS for GIS and TRAVERSE.

http://www.tinystocks.com/gps.html
Information on Navio software.

http://www.seminolecountyfl.gov/pd/commres/gis/index.asp,
Introduction to GIS.

http://www.geoplan.ufl.edu/giseducation/giscomponents.html,
Components of GIS.

http://www.csupomona.edu/~library/publications/geography/gis/gis.html
Introduction to GIS.

http://www.microsoft.com/windowsmobile/activesync/default.mspx
Information on ActivSync software.

http://www.who.int/gisresource.
Information on HealthMapper software.