National Malaria Control Centre
Zambia Ministry of Health

Geocoding Structures for Indoor Residual Spray Mapping in Zambia

Efforts in Chingola, Kabwe, and Solwezi Districts

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Introduction

The purpose of this document is to describe early efforts in Zambia in conducting geocoding in three districts (Chingola, Kabwe, and Solwezi) to map household IRS needs. Developed for those involved in national malaria control planning, the report describes the process of training enumerators, conducting field work, collecting and downloading data, and working with these three districts to produce relevant maps and information products used in planning for IRS activities. It also outlines the ways in which using geocoding can strengthen national malaria control programmes.

Zambia's *National Malaria Strategic Plan 2006-2011* calls for the rapid scale-up of effective malaria control interventions throughout the country. 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. IRS activities have been carried out since 2001, originally in five districts, then moving to eight districts in 2003. The current 15 districts include: Kabwe (Central Province); Chililabombwe, Chingola, Kalulushi, Kitwe, Luanshya, Mufulira, Ndola (Copperbelt Province); Chongwe, Kafue, Lusaka (Lusaka Province); Solwezi (North-Western Province); Kazungula, Livingstone, and Mazabuka (Southern Province). Collectively these districts represent roughly 34% and 33% of the total population and total households, respectively, in Zambia. As an intervention, 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 support for malaria transmission prevention strategies under the National Malaria Strategic Plan.

IRS is coordinated through the NMCC and operationally administered through the District Health Offices and City Councils, with the support of partners. Annually, IRS activities routinely include district-level planning and budgeting for targeted areas, enumeration of spray structures (to determine formal, informal and overall structure counts as well as volumes of insecticides needed), training of spray teams, community sensitization, IRS campaigns, supervision, and monitoring and evaluation. Several pre- and post-IRS campaign activities are coordinated by the NMCC and include understanding district implementation needs, ordering supplies and insecticides, developing IRS advocacy and communication materials, collecting and reporting on district information for determining operational coverage, and attending an annual post-spray campaign meeting of all 15 IRS districts and relevant stakeholders to share experiences and lessons learned.

At the district level, understanding the scope of areas targeted for spraying is critical for all subsequent spray activities. Clearly defining IRS targeted and eligible households is important for several reasons. First, through the planning process, enumerating IRS households provides quantifiable allocation of spray personnel needs, scheduling and 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 hopes to achieve high coverage of both interventions for optimal health impact. Targeted households and people not receiving IRS are therefore targeted for ITN mass

distribution and net re-treatment 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 in the district.

Examples of this use of GIS to support decision-making in IRS for malaria control have been documented elsewhere. For IRS monitoring, geocoding targets households and uses GIS to manage large amounts of information for spray operations. Mozambique and South Africa have been models for monitoring and evaluation activities.[1]

Background

To assist the Zambia National Malaria Control Programme (NMCP) with scaling up IRS activities in 15 districts, the concept of geocoding households using hand-held PDAs, was introduced into the national and district level spray program in 2006-2007 through a series of steps coordinated through the NMCC and partners. The timeline in Table 1 outlines the key steps.

Table 1: Review of geocoding activities

Date	Activity
Aug. 2006	Reviewed plan for geocoding structures at the 2006 post-spray review meeting in Ndola.
Sep. – Oct. 2006	Drafted plan for training districts in use of PDAs, GIS and software.
Dec. 2006 – Jan. 2007	Recruited personnel for backstopping activities.
Jan. – Feb. 2007	CDC developed PDA software for IRS household enumeration.
Feb. – Mar. 2007	Trained IRS district focal personnel and information officers.
Mar – Apr. 2007	Districts submitted plans and budgets for geocoding enumeration exercise.
May – Jun. 2007	Enumerated Solwezi, Chingola, and Kabwe district targeted spray.
Jun. 2007	Made trip to MRC, Durban, South Africa to coordinate the IRS information system development discussions.
Jun. – Aug. 2007	Enumerated additional 8 districts' targeted spray areas.
Sep. 2007	Spray activities to commence; remaining 4 districts to be geocoded in 2008.

A post-spray review meeting was held in Ndola, Copperbelt Province, in August 2006 to discuss the need for counting structures using geocoding. This included a review of the PDAs, global positioning (GPS) units and related equipment, as well as an introduction to the term GIS and a review of the benefits of using this type of information system for data collection for IRS campaigns. In September and October

[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.

2006, a plan was developed to train the 15 IRS districts on the use of PDAs and GIS for enumeration of households and mapping of the 15 districts. This plan was circulated among partners, and support for the activity was initiated. The plan outlined the need for additional staff and equipment for geocoding structures as well as technical support from knowledgeable personnel in basic concepts of GIS, PDAs, and geocoding.

With the help of HSSP and MACEPA, additional staff was identified in November 2006 to January 2007 to help NMCC coordinate the trainings at the district level and carry out the enumeration with the support district IRS focal points. The focal points for backstopping the IRS information system development and GIS component had the necessary strengths in GIS, handling large data sets, and monitoring and evaluation.

In January and February 2007, the PDA software for household enumeration was developed with the help of the Malaria Branch of the US Centers for Disease Control and Prevention (CDC), by Dr. Anatoly Frolov. The program relied on a combination of a household listing and sampling tool used previously by the CDC and the Zambian Ministry of Health in household survey enumeration and a new questionnaire designed specifically for IRS enumeration. The software was developed in Visual Basic using SQL Mobile running on Windows Mobile 5 operating system. PDAs used in the training and fieldwork were Dell Axim X51s and HP iPAQ 2495s. All PDAs were fitted with US GlobalSat SiRF Star III compact flash GPS units. Dell Axim X51s were equipped with extra long-life batteries and all PDAs had extra data storage drives and protective cases. A full list of the exact equipment and software used is included in Appendix A.

The training course content was produced, including presentation materials, pre- and post-evaluation surveys, and a training manual with step-by-step procedures for using the PDAs and software program. These materials are available in *Using Geographic Information Systems for Indoor Residual Spray Area Mapping: Training Manual* which can be obtained from the NMCC upon request or from the NMCC website (www.nmcc.org.zm).

In February and March 2007, all 15 IRS districts were trained in the use of PDAs for the enumeration and geocoding of IRS target structures (a report of the training activities and lessons learned is also available on the NMCC website). At the end of the trainings, districts were asked to submit plans and budgets for integrating the PDAs and geocoding into the annual enumeration of structures that districts perform in their IRS planning efforts. By mid-April, all 15 districts had submitted plans and budgets. These plans were reviewed by NMCC technical staff and standardized for personnel, supervision, and other costs. A summary of the trainings, plans, and other related materials can be found in the NMCC publication *Using Geographic Information Systems for Indoor Residual Spray Area Mapping: Training Report*.

Scheduling district enumeration was based on a limited number of PDAs and the size of the estimated target IRS structures to be enumerated. Fifty-seven PDAs were used for the exercise, which meant at most two or three districts could be enumerating simultaneously. The schedule was conveyed to district staff and

arrangements were made to begin the enumeration with Sowlezi and Chingola districts in May 2007, followed by Kabwe in June 2007.

Training Enumerators

Adequately training enumerators is essential to successfully using geocoding for IRS. It is important that the right cadres of enumerators are selected to ensure that both quality and quantity are maintained in the geocoding exercise. Local knowledge is also an essential part of the exercise to ensure that the operation is carried out using enumerators who are familiar with their area because there is a lot of interaction between the enumerators and the households.

Selecting the appropriate caliber of participants to involve in training was essential. To ensure that this was done well, the local communities were requested to come up with eligible candidates – preferably those with a minimum education of grade 12 (high school). The minimum in education was important because the candidates were expected to quickly become proficient in the use of (PDAs. In addition, these candidates would be expected to interview the households and write down any challenges that they would come across in the field. The DHMT provided advice on the best way to identify strong candidates, and the nominations were be done by engaging communities in the identification process with the help of neighbourhood health committees and local health centres in the areas where the operations were to take place.

The nominated candidates were requested to attend the training arranged at the agreed-upon location within the district. After the first day of training, the trainers were able to approve or excuse the candidates, in consultation with the district coordinators. One candidate, for instance, was dropped due to poor eyesight.

The training began with obtaining feedback from the candidates on their expectations of the training. The candidates had various expectations:

- To acquire knowledge on the use of handheld computers.
- To gain some background on how GPS works.
- To see the results of the geocoding.
- To participate fully in the exercises.
- To obtain a bicycle.
- To obtain an allowance.
- To obtain identity cards.

The trainings were done in two days. The first day was classroom-based and focused on theory, providing an orientation to the PDA, its maintenance, and the pretest questionnaire. The second day was meant for practical training and gave the enumerators an opportunity to collect live data and report any problems that they may have encountered both in using the PDAs and in their interaction with the community. The enumerators were given background information on the purpose of the exercise and its importance, requiring seriousness and attention to detail in terms of data collection. They were taught what a PDA was and what it was capable of doing. They were taken through the basic functions of the PDA that they would be expected to know. These included the following:

1. Switching the PDA on and off.
2. Accessing the settings option.
3. Adjusting the brightness.
4. Checking the battery power.
5. Updating the date and time.
6. Removing the PDA from the cover and inserting it in.
7. Slotting the GPS receiver in and out.
8. Resetting the PDA.
9. Identifying the GPS receiver indicator light.

Once the enumerators were comfortable with the above, they were introduced to the GPS2 program. This is the program that runs the IRS questionnaire. The questionnaire was explained to them in detail, and questions were answered during this time. This was important because any failure to understand the questionnaire and any failure to use it properly would render the whole exercise useless. At this stage, the critical point was to ensure that what was recorded onto the questionnaire was safely saved. It was therefore important to ensure that the GPS receiver and the PDA were communicating properly. Once this was understood, the enumerators were given the opportunity to try out the equipment outside the classroom and on the training grounds. They were put in groups and used the training structures for their exercises and tested the questionnaires and the GPS receivers themselves. This provided an opportunity to clarify any problems before collecting live data during the practical session.

Enumerators practicing using PDAs before beginning field exercises.

Geocoding Field Exercises

The geocoding field exercises were conducted once it was clear that the enumerators had grasped the basic principles of handling the PDAs. The enumerators were initially grouped in twos to ensure that whenever one had problems, the partner would provide assistance. That way, confidence among the enumerators would be increased. Facilitators and supervisors would also conduct random visits on enumerators to check if the recordings were being done as instructed. Meeting points were agreed upon, and transport would pick up the enumerators to deploy them to other sites.

As the enumerators became accustomed to using the PDAs and the area they were working in, they started geocoding individually and this increased the number of structures that each individual was able to geocode. An average of 60 structures each day was recorded individually. Several enumerators could manage up to 80 structures. On one or two occasions, individual records of over 100 were recorded. At the end of the field exercises, enumerators assembled to share experiences. These included experiences with the PDAs, in interacting with the households, and among the enumerators themselves. Experiences shared were used to improve on the next day's activity as well as to assist those who were still finding some problems to adjust themselves.

Downloading Data to the Computer and Charging PDAs

Data captured onto the PDAs was downloaded onto a district IRS focal computer at the end of each day. This was done one PDA at a time and it was a task best carried out by the supervisor after the end of each geocoding exercise, preferably in the evenings. This was made possible using two different pieces of software which district staff were trained to use during the district training activities prior to the enumeration role out. The first is Micosoft ActiveSync which makes it possible for both the computer and the PDA to communicate. The second is the IRS2007 program which picks the data from the PDA data files and converts it to a Microsoft Access database and stores this onto the computer. There are two ways that data can be downloaded onto the computer.

1. **Copy data from all the other PDAs onto one PDA that is called the master PDA**. This can be done using beaming procedure outlined in the Training Manual, a process in which infrared is used between two PDAs to communicate and therefore exchange data. Once this has been done, the master PDA is then used to transfer the data copied from all the PDAs. This is done using the IRS2007 program.

2. **Connect each PDA to the computer** without first going through the process of beaming. The IRS2007 program is used to download data from each PDA.

Once downloaded onto a computer, the data was available in Microsoft Access format and was available for importing into any GIS software, such as WHO's HealthMapper, to produce point features representing geocoded structures. A few queries were developed in MS Access to test the quality, completeness and extent of

the information collected by each enumerator. Feedback was given to the district officers and supervisors if any noticeable errors or quality issues were detected.

PDAs were recharged daily at the end of the field exercise. The Dell Axim X51 PDAs had a long-life battery that kept them running for approximately eight hours as long as the PDA had initially been fully charged. The HP iPAQ 2495s, on the other hand, still had their original batteries, and experience in the field revealed that they ran out much more quickly than their cousins. The district supervisors ensured that the PDAs were fully charged on a daily basis. This was a taxing exercise because it takes each PDA one to two hours to charge, and many PDAs were being used. Equipment such as adapters, charger cables, and multiple plug extensions were supplied to the districts during the entire exercise.

Mapping Targeted Structures

Downloaded data was displayed in a GIS program and maps were developed. Examples of the maps produced for Solwezi, Chingola, and Kabwe (Figures 1, 2, and 3, respectively) are included below. Point data taken during the enumeration of structures is presented as a series of dots and is overlaid with existing district boundary files, roads, forest and other information where available.

Figure 1.

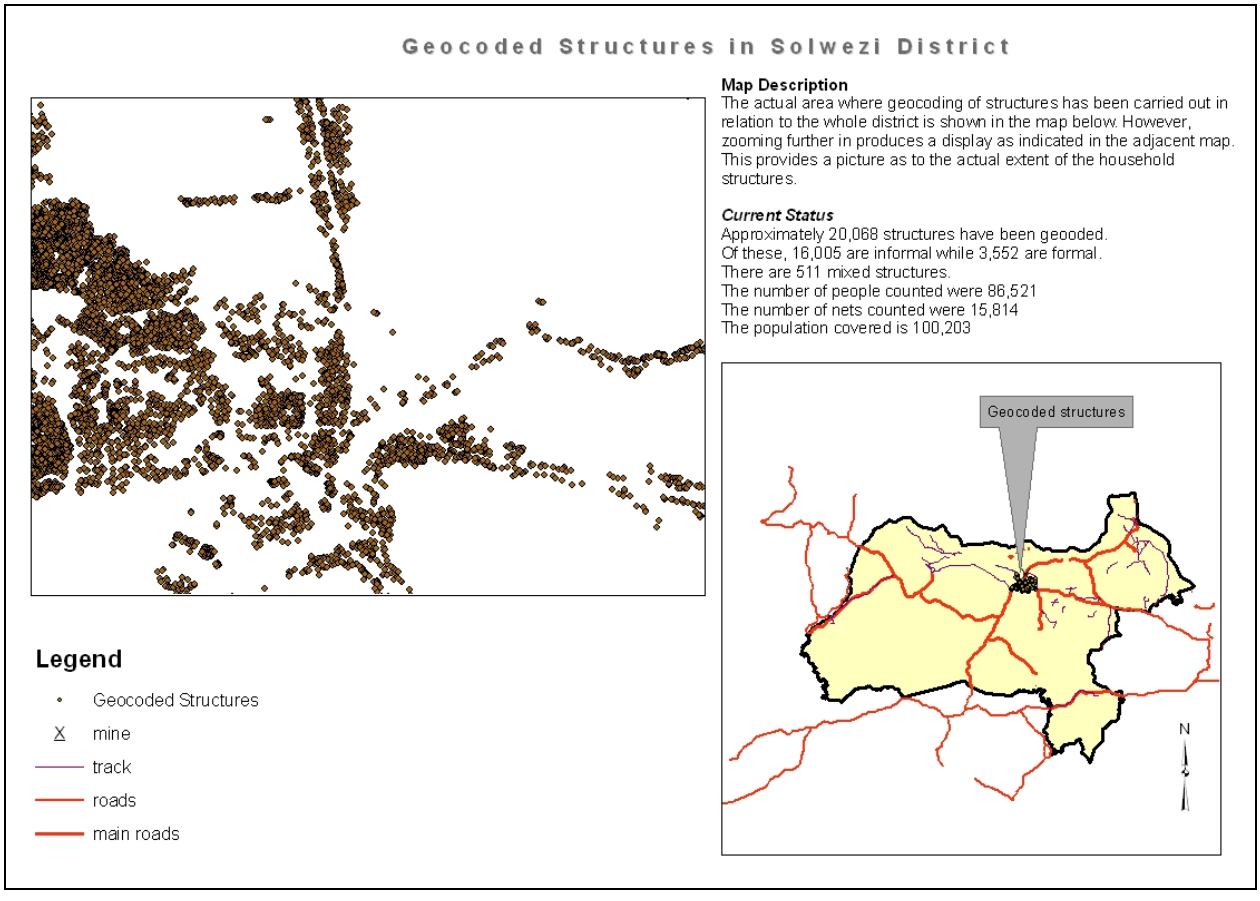


Figure 2.

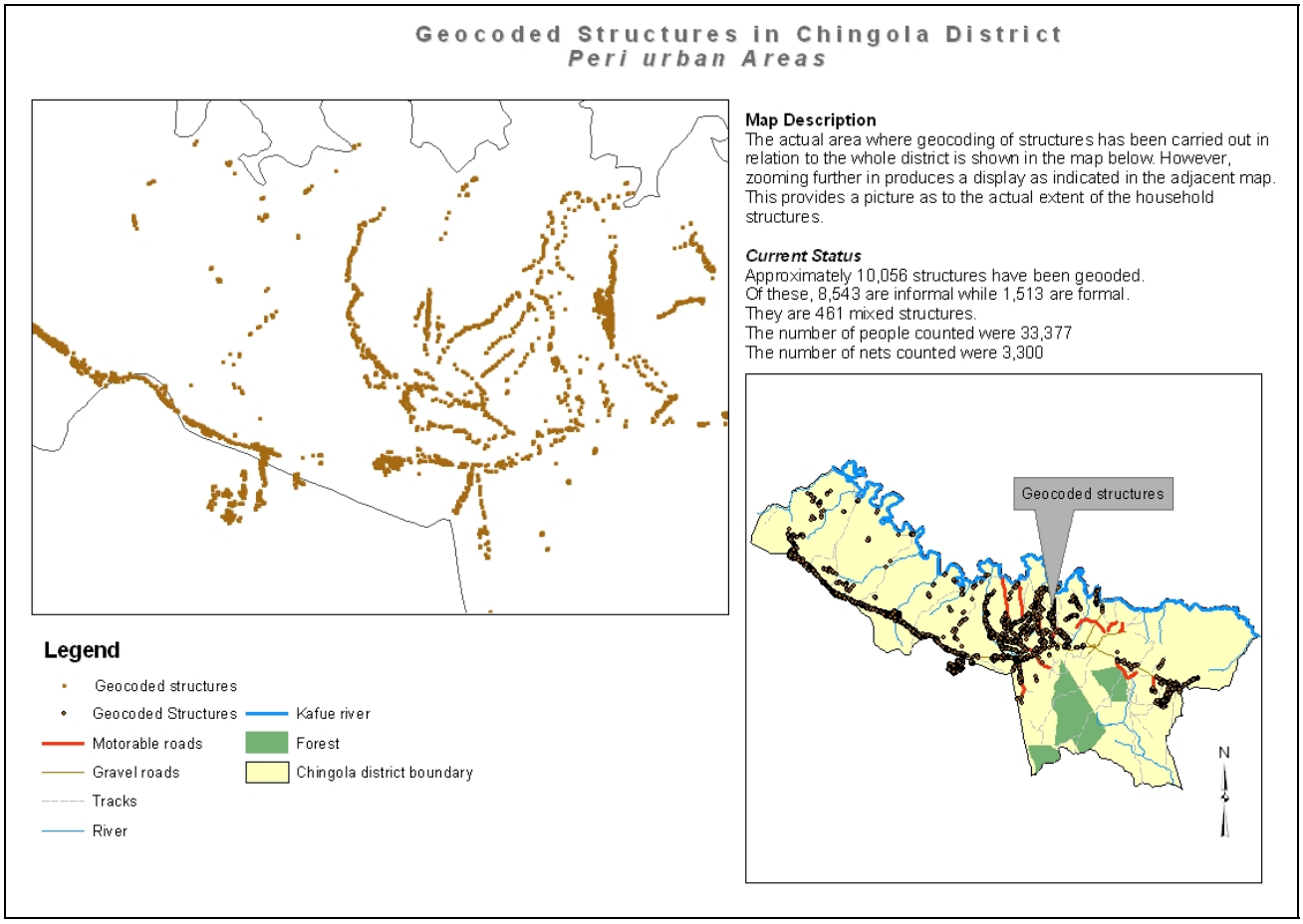
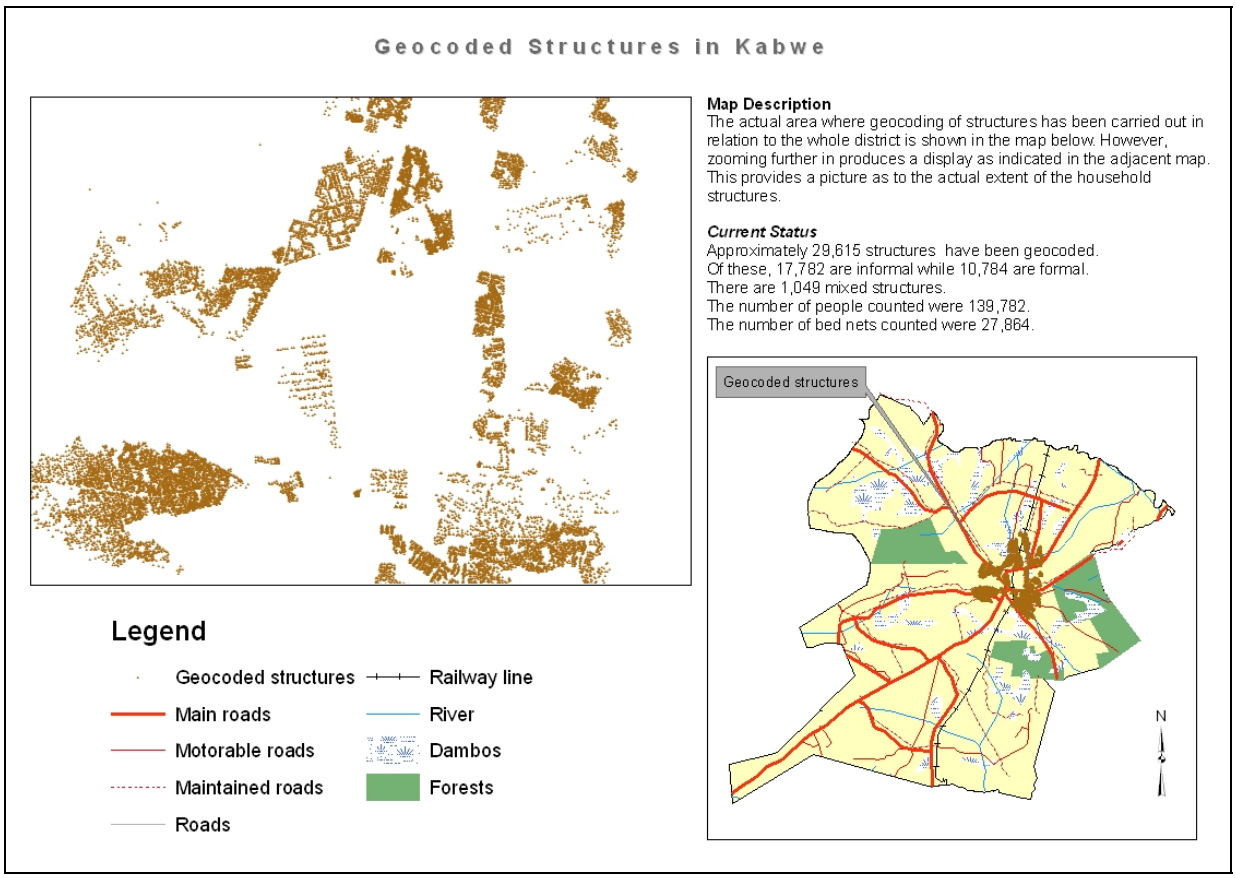

Geocoded Structures in Chingola District
Peri urban Areas
Map Description
The actual area where geocoding of structures has been carried out in relation to the whole district is shown in the map below. However, zooming further in produces a display as indicated in the adjacent map. This provides a picture as to the actual extent of the household structures.
Current Status
Approximately 10,056 structures have been geooded.
Of these, 8,543 are informal while 1,513 are formal.
They are 461 mixed structures.
The number of people counted were 33,377
The number of nets counted were 3,300
Geocoded structures
Legend
Geocoded structures
Geocoded Structures
Motorable roads
Gravel roads
Tracks
River
Kafue river
Forest
Chingola district boundary
N

Figure 3.


Geocoded Structures in Kabwe
Map Description
The actual area where geocoding of structures has been carried out in relation to the whole district is shown in the map below. However, zooming further in produces a display as indicated in the adjacent map. This provides a picture as to the actual extent of the household structures.
Current Status
Approximately 29,615 structures have been geocoded.
Of these, 17,782 are informal while 10,784 are formal.
There are 1,049 mixed structures.
The number of people counted were 139,782.
The number of bed nets counted were 27,864.
Geocoded structures
N
Legend
Geocoded structures
Main roads
Motorable roads
Maintained roads
Roads
Railway line
River
Dambos
Forests

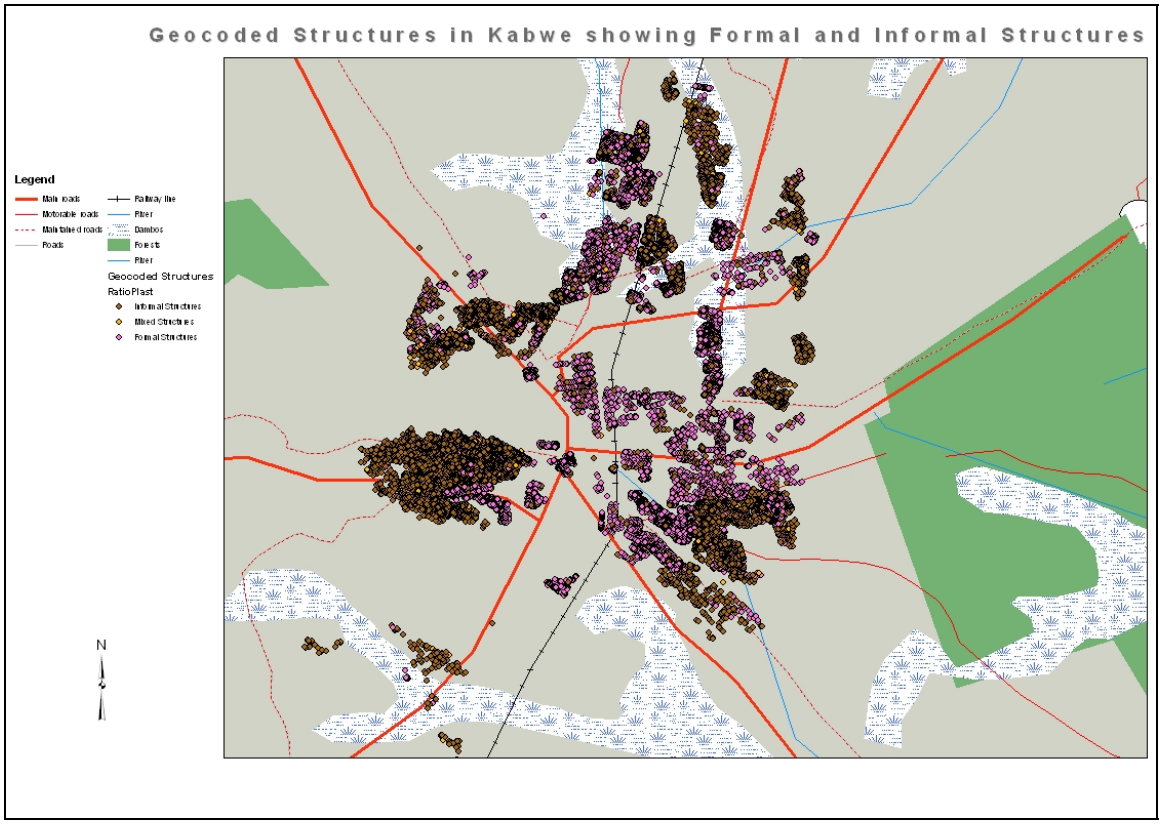
Application of Geocoding to Future IRS Plans

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. Figure 4 shows the actual location of formal and informal structures in Kabwe and their relative position to each other. The 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.

Figure 4.



The numbers that have been collected so far in the districts that have had their structures geocoded 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 will be printed and distributed to all the districts that will have been geocoded for use during spraying. 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.

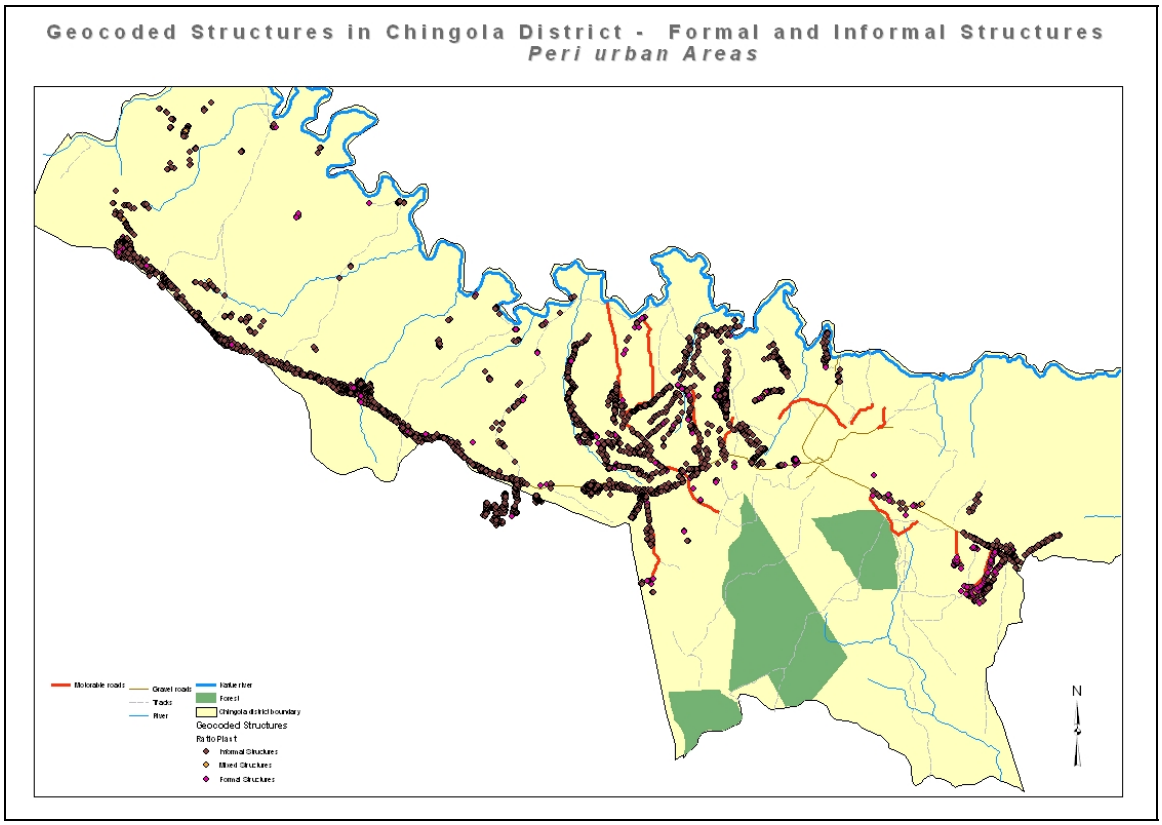
Helping spray operators to plan

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 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. The map of Chingola (Figure 5) shows structures that are densely clustered together, indicating high populations and also structures that are highly isolated.

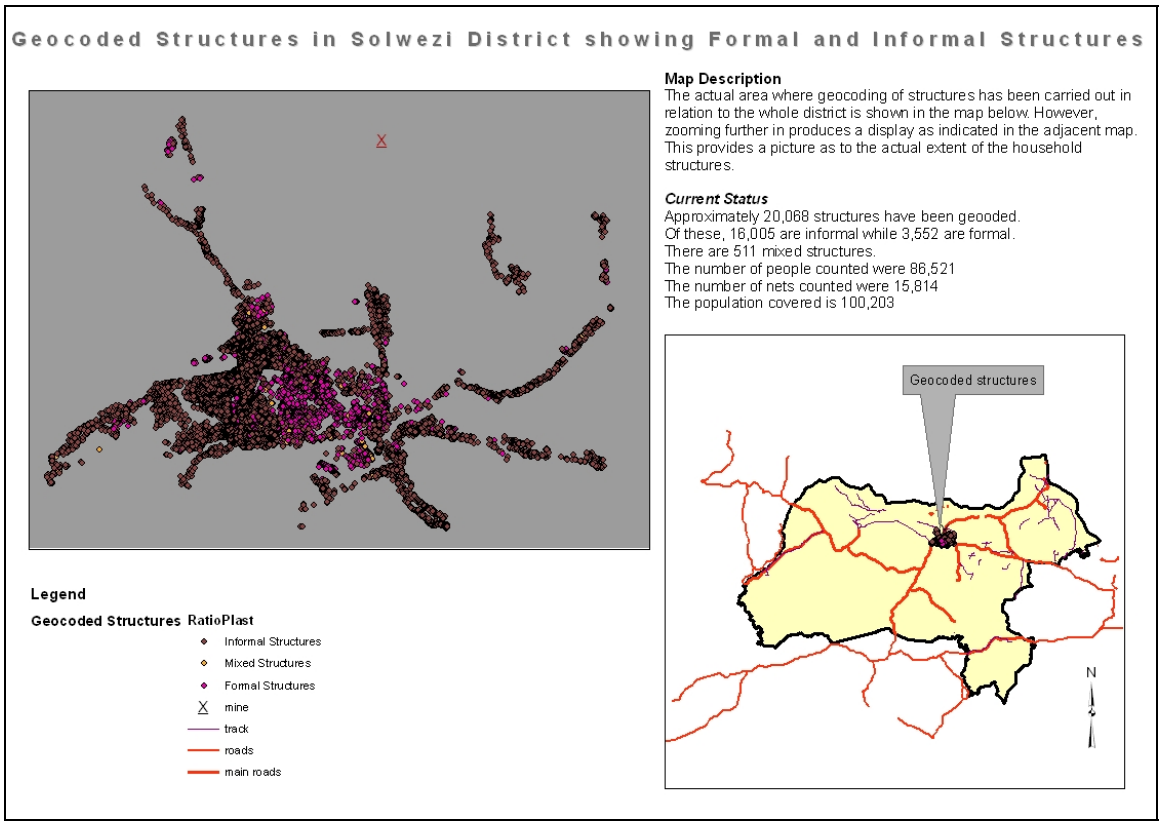
Figure 5.



The position of the geocoded structures relative to the whole district provides a good picture of how the nets are distributed in the district. Currently, districts with IRS intervention are excluded from mass distribution of nets, yet IRS activities are only taking place in specific areas of the district. A map clearly shows these areas. Spatial analyses will be done to see to what extent geocoding can assist the inclusion of non-IRS areas for mass distribution of nets within IRS districts. Therefore, households and targeted people not receiving IRS can now easily be targeted for ITN mass distribution and net re-treatment campaigns

The map of Solwezi (Figure 6) shows the extent of IRS in the district. The cluster clearly shows that a very large portion of the district is not covered by IRS. A spatial display such as the one shown will make this deficiency be quickly noticed and appropriate actions taken.

Figure 6.



Clarifying expected impact of malaria interventions

Careful delineation of spray areas and populations will help determine the scale of expected impact for malaria interventions on malaria-related burden or within vector populations. Further, enumerated spray structures can be sampled for surveying rapidly, since enumeration provides a full geocoded dataset of households. Surveys on the actual extent of spray activities, quality of spray services, and heath-related impact will guide the program's evaluation efforts.

Understanding risk exposure

Superimposing layers of water bodies and geocoded structures will help in the analysis of the risk of the population to exposure to the vector. During the wet season, mapping of these water bodies will be done, and data on larvae collected from these points, together with the map layers of geocoded structures, will help establish the extent of the risk of the population to malaria.

Clarifying intervention cost effectiveness

In running any programme, cost-effectiveness is one of the important considerations. The relative distribution of the structures from each other as well as their relative densities (clusters) can provide the first step in determining the distance at which IRS becomes less cost effective than bednets. Such a study is planned and will provide input in effectively coming up with strategies for future IRS activities.

Analysizing catchment areas

The layer for geocoded structures will be overlaid with the layer for health facilities. This will be useful for analyzing catchments areas. In addition, it will enable the closer investigation of areas where geocoded structures fall outside the boundaries of the IRS districts.

Lessons Learned

Several important lessons were learned from training district enumerators, field work management, and data collection.

- Training of enumerators on using PDAs can be done within a maximum of two days. The first day should be restricted to theory and to practicing the features of the PDA. The second day should be field exercises.

- Counting structures poses a challenge. This is true in particular for multi-story buildings. A standard way of geocoding these according to the limitation of the software program should be adopted.

- Communication in the field is a challenge. A practical way of communicating while in the field is needed. When teams are spread over large areas and some teams need to be shifted, mobile communication becomes handy.

- Public address systems are important as they prepare the community for this exercise. T-shirts and ID cards have been found important and acceptable by the community.

- Level of literacy of enumerators is important. People from within the community who have recently finished school have proved worthwhile. They have been found active, interested, and willing to walk long distances and work more hours.

- Constant interaction and regular meetings among enumerators, facilitators and supervisors proved to add to the efficiency of the exercises as problems would be solved on site.

- Frequent daily sending of data for quality control ensured that corrections were made before significant errors in data collection occurred.

- Incorporating Environmental Health Technicians (EHTs)/supervisors in the whole exercise provided transfer of skills to the heath facility.

- Transport in far-flung areas is important. In urban areas, enumerators can be dropped off and picked up from established points as they are able to walk short distances.

Next Steps

With the completion of the enumeration activity in three initial districts, the activities are continuing according to the established schedule until the spray activities get underway in August/September 2007. It is expected that at least 11 of the 15 spray districts will be fully enumerated by September 2007. The remaining districts will be enumerated at the conclusion of the spray activities in early 2008.

Those districts that have been fully enumerated will be provided with large-scale maps of their districts. These maps will initially be useful for coordinating spray activities in 2007 as district activities commence.

In June 2007, NMCC staff held a joint meeting with the Medical Research Council (MRC), in Durban, South Africa, to discuss the development of the complete database tool, available for national- and district-level monitoring, evaluation and reporting, that will incorporate the full dataset that is developed from all districts' enumeration efforts. MRC South Africa has been working to develop a tool, based partially on WHO's HealthMapper and other in-house modifications, to assist the South Africa Ministry of Health in IRS activities. This database tool includes a data entry, queries and logical steps, tabulated results and reports to assist districts in processing enumerated data to optimize the data collected. Further, this tool will assist both districts and the NMCC in coordinating spray activities as efforts are scaled up. The tool is being tested with household data in June/July 2007 and is expected to be implemented during the latter half of 2007 to district level. As spray activities are scaled up, this tool will be important in supporting effective management, monitoring, and evaluation of IRS, generating data to help sustain progress, and ultimately providing evidence of impact to support ongoing investment.

Appendix A: PDA Equipment and Accessories

Hardware	Notes
Dell Axim X51 or HP iPAQ 2495 (PDAs)	1 per enumerator (should get a few extra)
Long-life battery (2200) (for Dell Axims)	1 per PDA
SD Card (at least 256MB)	1 per PDA
CF GPS Unit	1 per PDA
Otterbox 1900 series	1 per PDA
1900 Tall GPS POD Kit050 (To protect GPS)	1 per PDA
1900 Screen-Saver Replacement Kit Kit060	3 per pack
1900 Latch Replacement Kit Kit069	Clips break on occasion, so have extra available.
# of extra styluses (for IPAQ 3800 series)	These are large styluses to fit in the Otterbox case (3 or 4 per pack).
Software	
Visual CE Professional by Syware	1 copy needed per computer to write or synchronise data.
GPS2 or newer version (free from CDC)	CDC developed household listing/sampling software.
IRS2007 or newer version (free from CDC)	CDC developed IRS enumeration questionnaire.
MSActivesync (free)	1 copy needed per computer to synchronise data.
WHO HealthMapper v 4.2 or newer version (free from WHO)	WHO developed basic desktop GIS tool for viewing data and mapping.