R6880
Final Technical Report

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List of abbreviations

ADP	Aerial Digital Photography
BCHE	Bath College of Higher Eductaion
BSUC	Bath Spa University College
DFID	Department for International Development
GIS	Geographical Information System
GERMP	Ghana Environment Resource Mapping Project
IRNR	Institure of Renewable Natural Resources
KNRMP	Kumasi Natural Resources Management Project
KUMINFO	Kumasi NR Information System
M&E	Monitoring and Evaluation
NR	Natural Resources
NRI	Natural Resources Institute
NRM	Natural Resources Management
NRSP	Natural Resources Systems Programme
ODA	Overseas Development Administration
OECD	Organisation for Economic Country Development
OVI	Objectively Verifiable Indicators
PRA	Participatory Resources Assessment
PUDSI	Peri0Urban Demonstrator for Spatial Information
PUI	Peri-Urban Interface
RRA	Rapid Rural Assessment
RS	Remote sensing
SE	Socio-Economic
SEM	Socio-Economic Methodology
SL	Sustainable Livelihoods
SPOT	System Probatoire d'Observation de la Terre
UST	University of Science and Technology
VCS	Village Characterisation Survey

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1. Executive Summary

The formal Purpose of this project as defined in the original logical framework was:

> *"Improved methods of peri-urban natural resource information collection, storage, access and management developed and tested"*

To achieve this purpose the project had to develop appropriate and effective methods for natural resource and related socio-economic information collection and use which would promote and facilitate the involvement of target institutions and stakeholders (beneficiaries) in setting the sustainable development priorities.

To these ends, the project collected and integrated a large variety of input data: SPOT panchromatic imagery, specially-commissioned high-resolution aerial digital photography (ADP), and qualitative and quantitative information from field surveys including results of Participatory Resource Assessments (PRA). It developed methods of integrating elements of all of these in a GIS-based system, which also included a simple modelling demonstration capability. The use of high resolution imagery in the field for rapid rural mapping, the combined collection of natural resource and socio-economic information, and the use of photographic images for stimulation of local participation in natural resource assessment and planning was also investigated in detail.

Methods for rapid, efficient and combined collection of important socio-economic and natural resource information were developed and tested in a series of field visits.

Some of the project outputs have contributed to other research projects and are being adopted by a number of proposals in technical development and other projects.

2. Background

2.1. The demand, nature, importance and impacts of the researchable constraint

Previous work (Holland et al., 1996) has identified serious constraints to the management of peri-urban natural resources which have resulted largely from non-availability, inaccessibility and lack of co-ordination of relevant data. Invariably, everyone from local stakeholders to regional organisations lack up-to-date and comprehensive information regarding developments taking place and their possible effects on natural resources in their environments. They have therefore not been able to control or direct development in the most efficient, safe and sustainable way. Thus there is a need to develop and test effective tools and methods for natural resource and socio-economic information collection, management and use by a wide range of users including local target institutions and beneficiaries. This in turn should educate, enable and empower them to make better assessments and management decisions about the characteristics and rate of peri-urban development, and to examine the possible effects of such development on the overall efficiency, productivity and sustainability of their particular areas of interest.

Remote sensing surveys, supported by fieldwork, are often used very cost-effectively to obtain a large amount of information quickly about some natural resources. However, because of the highly spatially variable nature of the urban and peri-urban areas, imagery of very high spatial resolution is required to map information pertinent to natural resource management, of the sort still not generally available from satellite-based sensors (Barr et al., 1996). As part of previous work in Kumasi, Bath Spa University College, BSUC, (previously Bath College of Higher Education (BCHE)) carried out a trial airborne survey of a segment of the peri-urban zone using digital cameras imaging in the red and near infrared wavebands and at pixel ground resolutions of 10 cm and 25 cm. The resulting images and mosaics were used successfully in interpreting broad categories of vegetation type, including oil palm, plantain, row crops, cultivated land, buildings (including foundation work), and all classes of road. In many cases the imagery was far more reliable and more generally accepted than the existing paper maps, by surveyors, planners and the local village dwellers themselves. Even with simple visual interpretation techniques, airborne surveys using digital camera equipment of this sort showed considerable potential: first in providing valuable direct and inferred information about the extent and quality of a number of natural resources, and second in promoting interest and valuable discussions amongst several people concerned with the development of the peri-urban interface area (Curr et al., 1996). Such a system would have even more potential application if it was made cheaper, more controllable and more accessible to larger numbers of users, including local target groups and institutions.

Another challenge in peri-urban assessment, planning and development is the complex interrelationship between natural resources and other factors, some of which are much more difficult to quantify or map (e.g. accessibility to resources or markets, population, ownership and management, population awareness, etc.). This means that a reliable assessment of availability, quality and potential for development of natural resources can often only be inferred from a simultaneous examination of a wide range of different datasets, some of which are quantitative but many of which are in a qualitative form (e.g. imagery, sketch maps, rapid rural appraisal (RRA) notes, photographs, etc.). Computer-based geographic information systems (GIS) when implemented properly, allow effective amalgamation and simultaneous examination of a wide range of data sources and types. Concurrently with the work of BSUC (Curr et al., 1996), and the review carried out by the Universities of Manchester and Nottingham (Barr et al., 1996), Geographic Data Support (GDS) developed a prototype information system with a simplified GIS interface which incorporated a wide range of digital datasets (including ADP) in a system (called PUDSI) that allows non-expert users to browse simultaneously diverse datasets of relevance for different areas of interest at user-selected scales. The integration of a variety of relevant qualitative and quantitative datasets in a user-friendly system showed enormous potential for illustrating important peri-urban development patterns and processes and their possible effects, especially if the knowledge of experienced managers in relevant disciplines could be integrated into it.

The use of GIS to manage and analyse data related to peri-urban research is becoming more common. Indeed, under another NRSP project (R6799), an integrated information system for peri-urban natural resource systems research (called KUMINFO) has been installed at two locations in the UK and at a local target institution: the Institute of Renewable Natural Resources at the University of Science and Technology, Kumasi, Ghana. Furthermore, there have been several other initiatives in Ghana involving the use of computer-based mapping and GIS, mostly at the national level (GERMP), but some with case studies planned at regional and even local level (e.g. district planning exercise, Ghana 2000). Such initiatives follow a pattern common in the development process in most countries: centralised information systems designed and installed, mostly for the anticipated use of planners and decision-makers only at the governmental level. However, one of the most common failings of such centralised “top-down” RS/GIS projects in the past has been their lack of regard of the needs of users at the local “grassroots” level (Falloux, 1989), where most of the important actions are actually taken. The real and sustainable success and effective utilisation of environmental information systems must lie in the establishment of a sound two-way (positive feedback) co-operation between governmental level planners and grassroot-level “customers” (Hedberg, 1991).

Rapid and participatory rural appraisals (RRA’s and PRA’s) (Chambers, 1990) are common means of obtaining information and stimulating discussions about local users’ feelings, concerns and attitudes regarding their natural resources. Many of the recent innovations in participatory approaches have involved a shift from verbally-oriented methods (formal interviews and written assessments) to visually-oriented ones (participatory diagrams and visualisations), since everyone has an inherent ability for visual literacy, and the impact of visual methods on communication and analysis can often be very profound (Pretty et al., 1995). Much of the information incorporated or generated in a peri-urban information system such as PUDSI/KUMINFO (e.g. aerial photographs, soil suitability maps, road and other route maps, fuelwood resource availability maps, location and accessibility of markets, etc.) could contribute significantly to the interactive participation and self-motivation of local stakeholders. Similarly, the concerns, perceptions and decisions made during participatory assessments (if they could be accurately recorded and incorporated), should significantly enhance the utility, effectiveness and overall sustainability of the information system being established.

2.2. Previous and related research

To date, there have been very few cases of RS/GIS and RRA/PRA used in a combined or synergistic manner. RS/GIS has tended to be dominated by physical scientists and technical specialists, with little evidence of local social benefits from the application of RS/GIS technologies. In the past RS/GIS has been generally associated with highly centralised, top-down management applications that require extensive or comprehensive quantitative data sets. This has discouraged participatory approaches, which may be seen as more qualitative and much more point-specific. Thus RS/GIS, even when operationalised for large-scale mapping at local level, has failed to incorporate socio-economic parameters such as land and resource rights, resource use and farming systems, and it has not been able to depict or record socio-economic trends. The problems are further compounded (or maybe caused) by limited practical collaboration between social scientists and RS/GIS practitioners, a lack of documentation or analysis of existing practice, plus a tendency for practitioners to be distracted by the power and appeal of the technology itself, as a tool for mapping and analysis of data, rather than the application of GIS outputs in a practical resource management context (Quan et al, 1999).

However, local impacts of poverty, deprivation and vulnerability do have a pronounced spatial dimension, at least in terms of people's varying access to basic infrastructure, markets, water and other natural resources, educational and health services. Therefore GIS should be able to assist in at least understanding and perhaps modelling the distribution and nature of poverty, possible solutions and priorities for intervention at the regional planning level. At the local level, maps and imagery relating different sets and depictions of spatial data, can help people understand their own situations in the wider regional context. Then the scope and opportunities for location-specific or area-wide action, including the planning and trade-offs which may need to be made amongst differing stakeholder interests, may be more fully appreciated (Quan et al, 1999).

As a result there are now more calls for GIS to be accountable economically, politically, socially and ethically and for GIS operators to be concerned about the ends to which the data manipulation are put. With more recent decentralised, participatory and people-oriented development approaches there is a growing interest in using GIS in bottom-up transformation through representation of local voices (Weiner et al, 1995). In some circumstances GIS has even been used to support improved, more participatory land use planning, where local groups have been empowered by maps and information about their location in relation to surrounding areas, assisting them in conflict resolution, in negotiations for more equitable natural resource access and in methods to sustain traditional land use in the face of external pressures (Bird, 1995, Weiner et al, 1995, Harris et al, 1997)

Stakeholders	**Level**	**Decision Aiding Tools**	
Development/National/	Top Level	RS/GIS	
Research Funding		High technology	
Organisations		Macrodata	
		Physical Maps	
Regional Planners	Regional Level	Areal	
		Perceived, conventionally	
Town and Country Planners		High-level, extractive,	
		Areally comprehenxive and	
Planning Committees		Summarising	
		Objective	
NGO's	Local level	Quantitative	**BOTTOM-UP**
		Indirect	RRA/PRA
Village Chiefs and Elders		**TOP-DOWN**	Participatory
			Local, macrodata
Village Development			Mental maps
Planning Committees			Indigenous knowledge
			Location-specific
			Subjective
Vilage inhabitants			Qualitative
Individuals	Micro level		Sometimes anecdotal

Table 1. Top-down RS/GIS versus bottom-up RRA/PRA surveys

Several studies have looked at the use of remote sensing (in the form of aerial photography and satellite imagery) in rural development planning (Chambers, 1990, Ford and Lelo, 1991, Carson, 1987, Hutchinson and Toledano, 1993, Sandford, 1989, Dewees, 1989, Mearns, 1989, Mather 1999). In general, they all found that rural dwellers were very adept at interpreting aerial photographs of their own areas. The new perspective on their environment stimulated participation and discussion among all groups, and proved powerful as a facilitation tool. In some cases (e.g. Mather 1999) they proved to be a useful means of identifying poor and marginalised groups and involving them in discussions of their resource base (e.g. fuelwood resources, charcoal burners, etc). However, most studies pointed out the dangers of possible knowledge distortion or imposed "interpretations" by outsider experts with the introduction of external information (images or maps). The interface and methods adopted when the external information is presented to the insiders, and the insiders' knowledge as presented to the outsiders is critical.

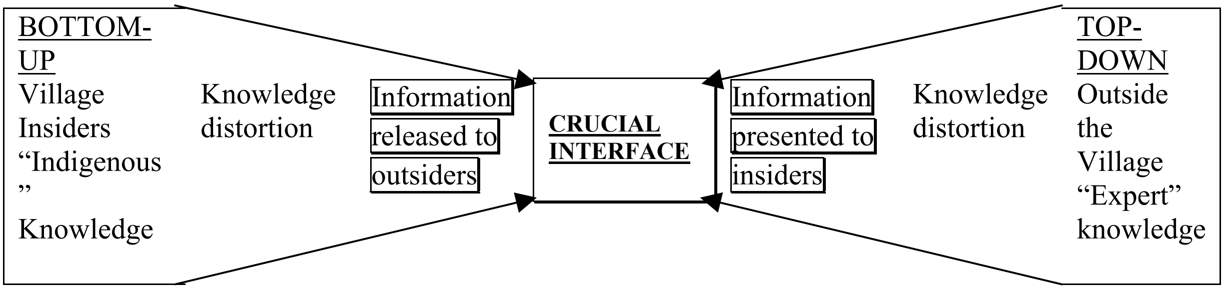

Figure 1. Interface between external and internal information..

In general though, most previous work on the use of aerial photography in participatory approaches, found that :

- Aerial photography provided a new and stimulating perspective for local dwellers, often revealing details or measures of features which they had not seen, or not appreciated, from the ground. The visual nature of the imagery was readily interpretable by most people;
- Aerial photography can be used to speed up the process, and increase the number, of transects which are carried out in RRA or PRA exercises. This follows the "Yellow Pages" process (let your fingers do the walking);
- Aerial photography as a tool for village level natural resource planning was effective in several places (Nepal, Ethiopia, Kenya);
- A laptop computer can be used to overlay natural resource and socio-economic resource data onto a physical aerial photograph as an aid to participatory village resource level planning, and offers the facility for zooming and roaming digital data. There was, however, a danger of the equipment itself proving to be a distraction;
- "Social" or "mental" maps developed by individual members of a village enables the natural resource data reflected on the aerial photograph to be interpreted more accurately; and
- A positive and productive relationship can be developed between RS/GIS and PRA.

One suggested methodology for transferring indigenous knowledge into objective information could include a method of developing a navigational map which merged the mental images in the mind of the villagers with the image maps produced remotely.

Insiders Knowledge of the area		KNOWLEDGE LEVEL		Scientific knowledge of RS/GIS
	Mental sketch map of area	INFORMATION LEVEL	Aerial image map of the area	
		DATA LEVEL		
		Image map of the area overlaid with local information (including local names and references for particular features).		

Figure 2. Image Map of area overlaid with local information (including local names and references for particular culturally important features).

Other NRSP funded projects which ran concurrently with this project and with which we have had considerable interaction include:

- Project R6799, the Kumasi Natural Resources Management Project (led by NRI), which carried out a number of important research projects in the Kumasi peri-urban region related to contributing towards the sustainable livelihoods of people in that area, based on improvements in the management and productivity of natural resources. Part of this project was the implementation of a comprehensive GIS system (KUMINFO) within the Institute of Renewable Natural Resources at the University of Science and Technology (1997 – 2000), the aim of which was to aid research and planning.
- Project R7330, Peri-urban natural resources management at the watershed level, Kumasi, Ghana, led by Dr. Duncan McGregor at Royal Holloway University of London (1999 – 2001)
- A project led by Dr. Julian Quan at NRI, entitled “Issues and methods in the joint application of GIS and participatory enquiry in natural resources research” (1998 – 2000).

We have also provided data and information to a number of other projects carrying out research in the peri-urban Kumasi area.

3. Project Purpose

The formal Purpose of this project as defined in the logical framework was:

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To achieve this purpose the project had to develop appropriate and effective methods for natural resource and related socio-economic information collection and use which would promote and facilitate the involvement of target institutions and stakeholders (beneficiaries) in setting the sustainable development priorities.

To these ends, the project collected and integrated a large variety of input data: SPOT panchromatic imagery, specially-commissioned high-resolution aerial digital photography (ADP), and qualitative and quantitative information from field surveys including results of Participatory Resource Assessments (PRA). The project developed methods of integrating elements of all of these in a GIS-based system. Various tools and interfaces were also developed for the GIS system to enable simple data investigation and demonstrate modelling for some applications.

Two years after the project started, the new Labour Government's White Paper on "Eliminating world poverty: A challenge for the 21st century" set a new agenda for DfID and the UK aid programme. In 1999 it led the NRSP to modify its research goals to encompass a poverty alleviation focus. Previous research on the PUI had been guided by priorities set by the previous government's aid policy which was very much geared to productivity and productive potential increases in the peri-urban interface. The shift in direction was reflected in a new goal defined as "Livelihoods of poor people improved through sustainability enhanced production and productivity of RNR systems". In response to this shifting emphasis and the new overall goal, this project began to concentrate more of its efforts at the local level identifying improved method of information provision rather than collection, as a way of local empowerment for stimulation of local level participation in peri-urban natural resource allocation and management (particularly land).

The use of ADP in the field for rapid rural mapping, the combined collection of natural resource and socio-economic information, was investigated in detail. Its acceptability and interpretability was examined in a number of locations, as was its effect on engaging local dwellers in discussions and decision-making about their natural resource bases.

Unfortunately the original logframe outputs and objectively verifiable indicators (OVIs) were poor- they consisted mostly of "hard outputs" including:
- a literature review in various aspects related to the project
- a stratification map and report showing locations for detailed ADP acquisition
- preliminary RRS results and report
- photomosaic map and associated field data for parts of Kumasi

- a prototype GIS system with simple user interface and modelling demonstration capability
- reports on most appropriate image acquisition systems, transfer of image acquisition and GIS transfer, and new and appropriate technologies.

With the change in emphasis, and in hindsight, the OVIs should have been:
- Appropriate methods of high-resolution imagery acquisition assessed and tested
- Directions of peri-urban growth mapped, quantified, documented and related to socio-economic phenomena
- Issues in the use of recent high-resolution aerial photography in local level evaluation of natural resource issues assessed
- Contribution of RS/GIS in stimulating local participation in planning and allocation of natural resources assessed
- Possible take-up of improved methods by appropriate target institutes evaluated.

Despite the poor design of the original logframe, and although not strictly compliant with logframe guidelines, it is still possible to demonstrate how the project has delivered against the original Purpose.

First, the processed 1994 SPOT imagery compared with the 1972/3 topographic maps illustrated and quantified the direction and magnitude of urbanisation in the region of Kumasi, which had not been appreciated previously. The magnitude of change in area from agriculture to built area was highly correlated, and therefore reflected, a number of socio-economic conditions in the peri-urban villages. This allowed a useful stratification of the peri-urban villages. The results from this work have been used in several other projects. Second, the ADP acquired for a large part of Kumasi has proved to be an invaluable resource for this project, and several others as well. The development of methods for processing and use of the ADP in local level assessment and action research is also significant, and a methodology for the combined rapid collection of natural resource and socio-economic data (termed rapid rural mapping) has been developed and shown to work effectively. Third, a simple GIS interface for combining a variety of both qualitative and quantitative datasets and employing them in simple modelling demonstrations has been developed and tested. It has been installed at one of the target institutions in Ghana, where it is proving to be a valuable resource for a number of other projects and the development of several project proposals including technical co-operation appeals.

4. Research Activities

4.1. Assessment of low-cost image acqusition systems

Previous work by Bath Spa University College (Geotechnologies group) (previously known as Bath College of Higher Education (BCHE)), carried out a trial airborne survey of a segment of the peri-urban area around Kumasi using digital cameras imaging in the red and near infrared wavebands and at pixel ground resolutions of 10 cm and 25 cm mounted on fixed-wing aircraft flown by the Ghana Air Force. Airborne surveys using digital camera equipment of this sort showed considerable potential, both in providing valuable direct and inferred information about the extent and quality of a number of natural resources, and in promoting interest and valuable discussions amongst those concerned with the development of the peri-urban interface area (Curr et al., 1996).

As part of this project, the Bath Geotechnologies group carried out a review and some trials to investigate whether platforms other than small fixed-wing aircraft could be used in areas where it was not possible to use small aircraft, and whether or not the operating costs would be significantly cheaper. The usefulness of tethered balloons and microlight aircraft was assessed (see Appendix 2 and 3).

For small-area remote sensing applications, the tethered balloon was found to be a simple, easily deployable, cost-effective solution requiring minimal maintenance. The system was easily transportable and responsive to image requirement demands. However, the major difficulty was in manoeuvring it especially in windy conditions or where there were many obstructions on the ground such as telephone lines and power cables.

Microlights were found to be a low cost, compact and transportable aircraft capable of performing the majority of manoeuvres of a light survey aircraft. Their power to weight ratio and efficient wing geometry gives them low stall and cruise speeds, and enables them to perform short take-offs and landings on most natural surfaces. The power units do not require aviation grade fuel (AVGAS) and need little maintenance. This enhances its range and area of operation. Their ability to perform in cloudy conditions, below any cloud base when appropriate wide-angle lenses are used is another advantage. Furthermore they have a relatively low capital, maintenance and flying cost. However, in field trials, shock and vibration were found to be limiting factors, and the design of special mounts would be required. Further details of the field trials conducted in the UK are provided in Appendix 3.

Whether balloon or microlight aircraft are used, the use of differential GPS is recommended. Although they were not needed in Ghana, the reported usefulness and cost-effectiveness of these alternative platforms was a useful contribution to the NRSP as they may have to be used in areas where the use of fixed wing or other aircraft is not possible technically or politically.

4.2. Overall assessment of urban change in peri-urban Kumasi , 1972 – 1994 using maps and digital satellite imagery

Several researchers, planners and other professionals in Kumasi had referred to the large growth that had taken place in and around Kumasi. However, very little was reported regarding the quantification of the direction and extent of where the growth had taken place. In our initial project proposal and plan, we aimed to make a broad overview map of the extent of the urban area, and to use this overview map as a stratification tool to identify areas where more detailed data collection and analysis should be undertaken. Our premise was that the rate and extent of urbanisation at a particular location as well as other geographical parameters (such as proximity to roads to Kumasi) would be indicative of the type of socio-economic and natural resource pressures taking place at that location.

The whole of the peri-urban area is mostly covered by two of the series of 1: 50,000 topographic maps. These maps represent the first edition published by the Survey of Ghana and are based on aerial photography collected in April 1972 and February 1973. The Ghana national mapping system is based on the Transverse Mercator projection, with a co-ordinate system in Imperial units (feet). The 1972/3 maps use the Accra datum. In 1977 a new datum, the Ghana mapping system was made metric and a different spheroid (Clarke 1880) and datum (Leigon) was adopted. The 1972/3 maps were digitised under the auspices of the GERM project, and were purchased and made available for our use by project R6799.These maps were used to represent the urban area in 1972/3.

A SPOT-3 HRV-2 panchromatic scene (56-336/7) was purchased for this project. It was acquired on 17 December 1994 at 10.51 am and covers most of the Kumasi peri-urban interface area. The principal benefits of the use of satellite systems for the collection of natural resources data is the large area coverage provided by the individual scenes, the low cost relative to conventional methods and the currency of data afforded by the repeated satellite coverage. The map was geometrically-corrected to the GNG 1:50000 map sheets using 26 ground control points (GCP), cubic convolution resampling, a 20 feet output pixel size, and a RMS error of about 60 feet (consistent with the digitising error). More details are provided in Appendix 4, and a pictorial representation of the geo-corrected SPOT image is shown in Figure 3. On this image the brighter parts represent the built-up areas, and the darker areas correspond to dense vegetation (forested areas). The density of the central area, with the pattern of satellite villages located along the roads radiating from Kumasi is evident. This image was found to be a useful product in itself for many of the Kumasi town and country planners were able to see, some for the first time, the actual magnitude and direction of the spread of the city in the last 20 years or so. In the image, Lake Bosumtwi can be seen in the South East corner.

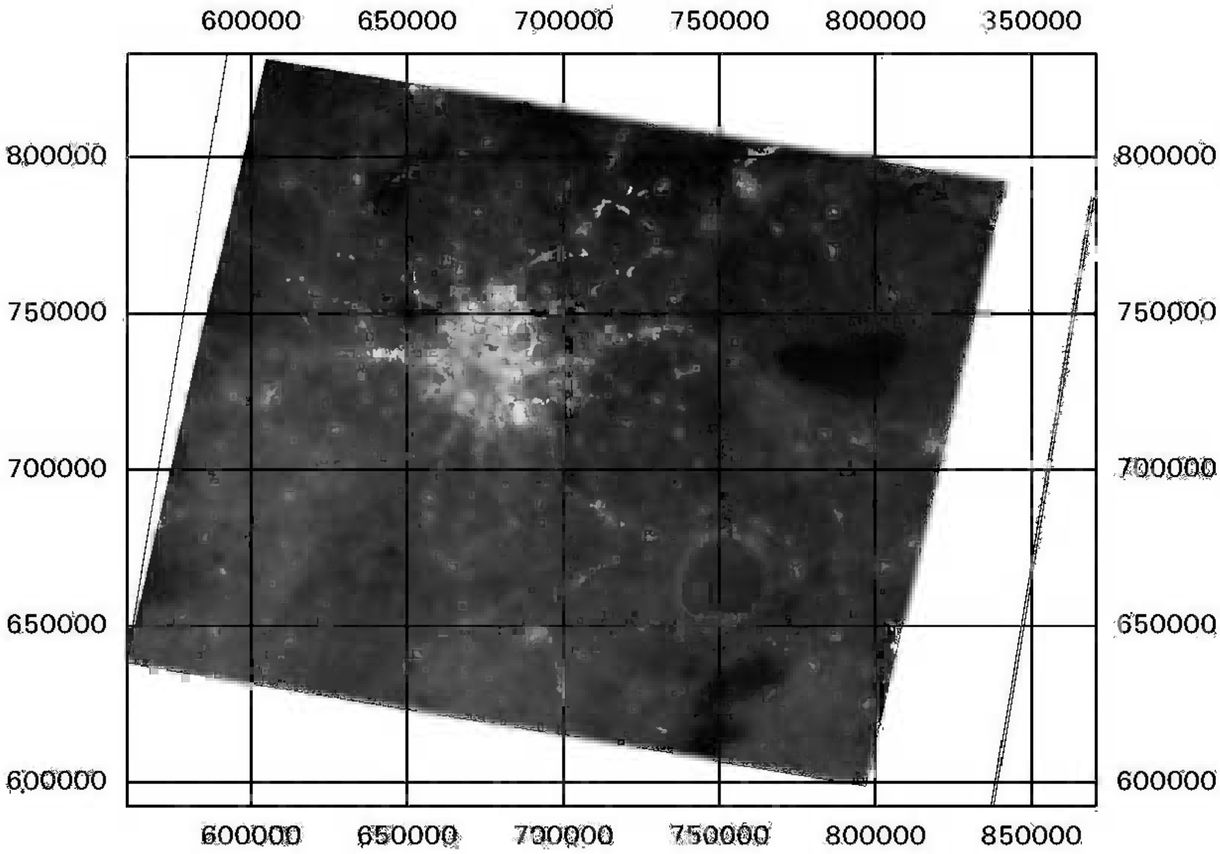


Figure 3. SPOT panchromatic image (1994) geometrically-corrected to the Ghana National Grid projection (feet)

Using the 1:50000 map sheets, a village database comprising 387 peri-urban villages was created. Where villages were made up of more than one polygon, a centroid point of all their merged polygons was used to represent the village location. Using the contours supplied with the 1:50000 map sheets, a digital elevation map was made, and the mean elevation for each village was calculated. Other geographical parameters such as distance to main roads and estimated travel distance to Kumasi via the road network were calculated.

In a parallel study, NRSP-PUI project R6799, known as the Kumasi Natural Resources Management Project (KNRMP) had conducted a questionnaire and key-informant survey of 66 villages in the peri-urban area (a Village Characterisation Survey, VCS), and a detailed PRA at five villages. The KNRMP had chosen the sample of villages based on a simple stratification of five concentric zones based on crow-flies distance from the centre of Kumasi and six sectors each of sixty degrees arc. A total of 66 villages were then chosen within these strata based on three criteria (a) on or within 2km of a main road; (b) off-road or more than 2km from a main road; and (c) within 5km of the city centre main market. An enormous amount of detail about each of the 66 VCS villages was collected and entered into KUMINFO by the KNRMP. However, because their method did not define the full number of the villages within each of their strata, their observations cannot be correctly weighted for scaling-up of the results. It is also not clear if all villages in each stratum had an equal chance of being selected, so the sample may not be considered random.

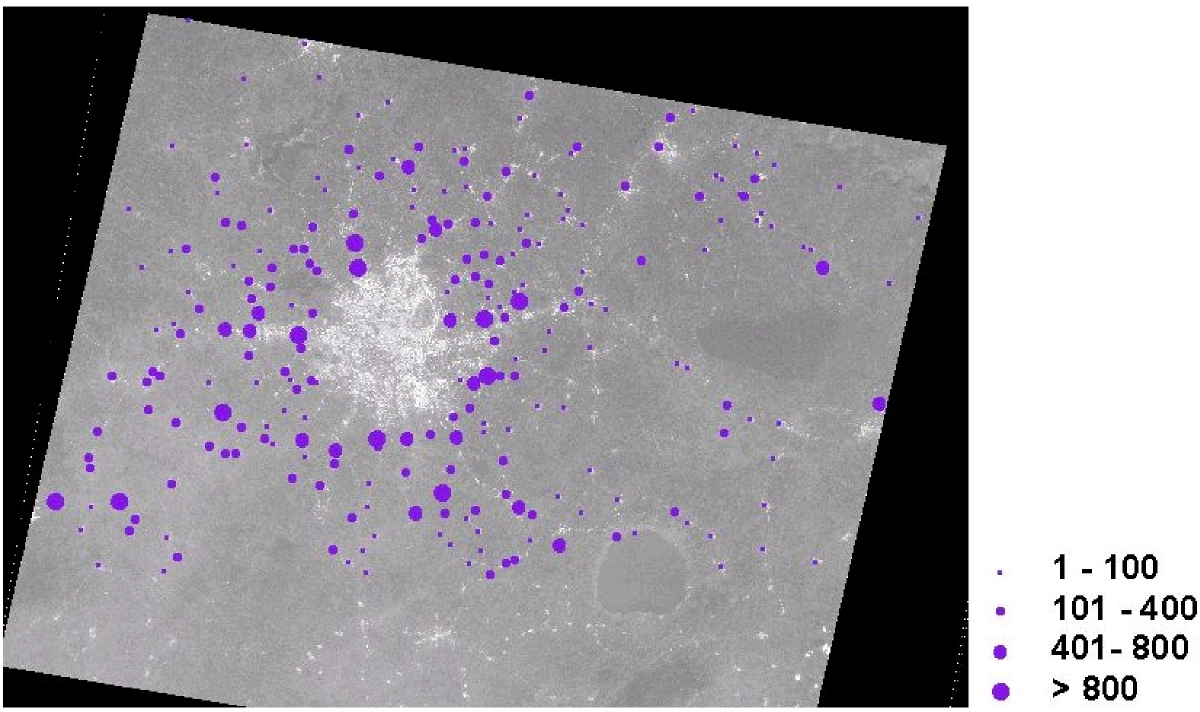


Figure 4. Estimated growth in extent 1972-1994 of 387 villages in peri-urban Kumasi region. The size of the circles are proportional to the percentage increases in village extent at that location.

In this project, we attempted to develop a stratification which could be scaled-up, based on village growth and size. Our underlying hypothesis was that villages of similar size, which had experienced a similar growth rate in the last 30 years would have similar development characteristics, at least in terms of dominant livelihoods, pressures on natural resources, etc. The SPOT image (1994) was classified into built/non-built classes, and the area measurements of urbanised area for each village was compared with that depicted on the topographic maps (1972/1973) (see Appendix 4 for more details). Using these two datasets it was possible to arrive at the areal size and estimated growth rate for each of the 387 villages in our prepared database. This procedure meant that measurement of village growth could be determined consistently and independently for all the villages in the study area. Figure 4 shows the spatial location and depiction of each of these villages in terms of areal growth in the 22 year period . It shows the generally expected pattern of radial growth outwards from the city centre with most growth taking place along or close to major roads. However, with more examination, some interesting anomalies can be found. For example, the examination of some villages very close to the city and on major roads which had displayed very little urban expansion, were found to be areas where disputes over land ownership had been present, thereby preventing any building or urbanisation as the land conflict was being pursued. Conversely, some villages at considerable distance had shown significant growth. In most cases this was due to rapid growth because of the development of some local industry, e.g. Fumisua. A couple of villages on the lake indicated large growth rate because of the new building taking place there.

Figure 5 shows the estimated growth rate as a function of distance of the villages to Kumasi, from which the anomalies may easily be detected.. In order to calculate the travel distance from each village to Kumasi, the road network had to be created and checked. Further analysis should involve the type of road and travel speeds along them. Given more time, there are clearly more details that can be drawn from this analysis.

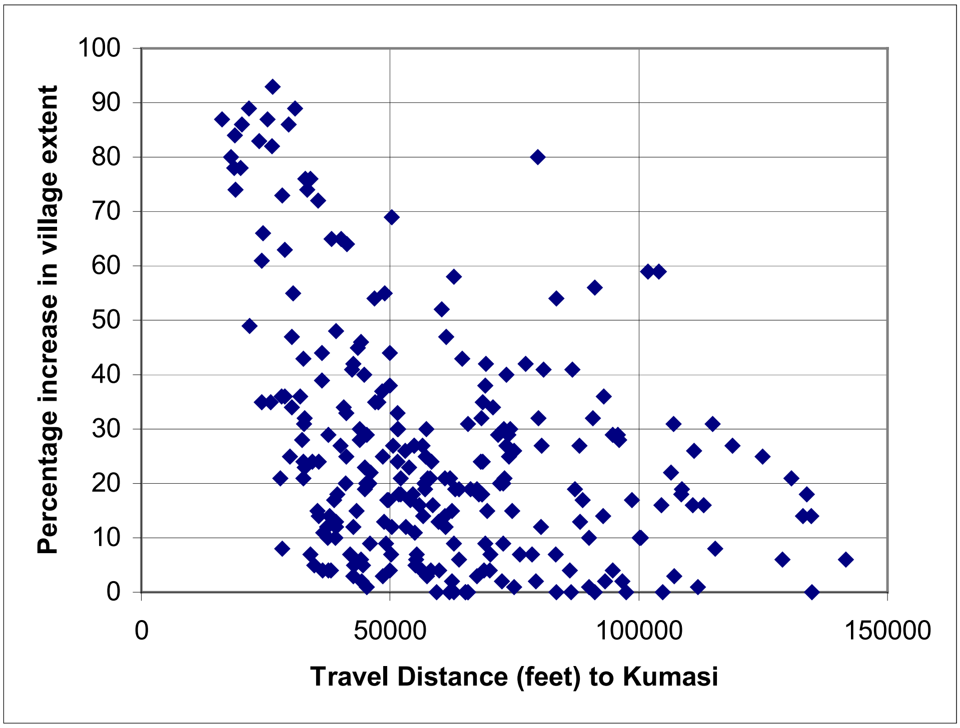


Figure 5. Percentage increase in village area versus travel distance to Kumasi

Although no formal evaluation was carried out, the display of the 1994 SPOT image with the 1972/3 village boundaries overlain proved very informative to a number of decision-makers in the Kumasi area, especially the town and country and district planners, and especially where contrasts in terms of areal growth were found close to each other.

Figures 6a and 6b show a summary of the estimates of absolute area in 1972/3 and the subsequent degree of growth up to 1994 for all the villages defined in the study area. The village growth variable was divided into four classes, and the village size variable was divided into five classes based on an approximately equal number of villages from the mid-point of each class. To illustrate the procedure of village selection, a single village from the mid-point of each category was selected for each of the 20 categories. Figure 7 shows the absolute size in 1972/3 and 1994 for two of the villages in the sample.

The KNRMP used clustering methods to divide their VCS villages into three classes of those with :primarily urban, primarily rural and primarily peri-urban characteristics. Their results compare very well with our depiction in Figure 4 , indicating that the methodology developed here could be used very efficiently to obtain a very quick and informative assessment of the level of change in an area. The relative growth characteristics of the 66 VCS villages are shown in Figure 8. Comparison with Figure 6b suggests that the village selection method applied by the KNRMP had resulted in a sample of villages which covers the range of growth and size classes, although there are clearly some categories of growth that are under represented. The availability in the % growth in area for the population of villages provides a sound basis in which an appropriate weighting can be applied to the results of the VCS. Also there may be interesting links which can be established between village size and growth and the access criteria used in the original survey. These are avenues for further research.

Although village growth alone can be used to stratify villages for selection, additional factors can also be derived from simple visual interpretation of the satellite images. There is scope for additional derived measurements such as the proximity of other villages, the presence of forest reserves, sacred groves, or riverine forest, and the amount of cultivated land and fallow/non-fallow proportions. However, detailed assessments of the associated village lands are not possible from the SPOT image because of its 10m spatial resolution and single panchromatic band. For this we resorted to ADP imagery (see next section).

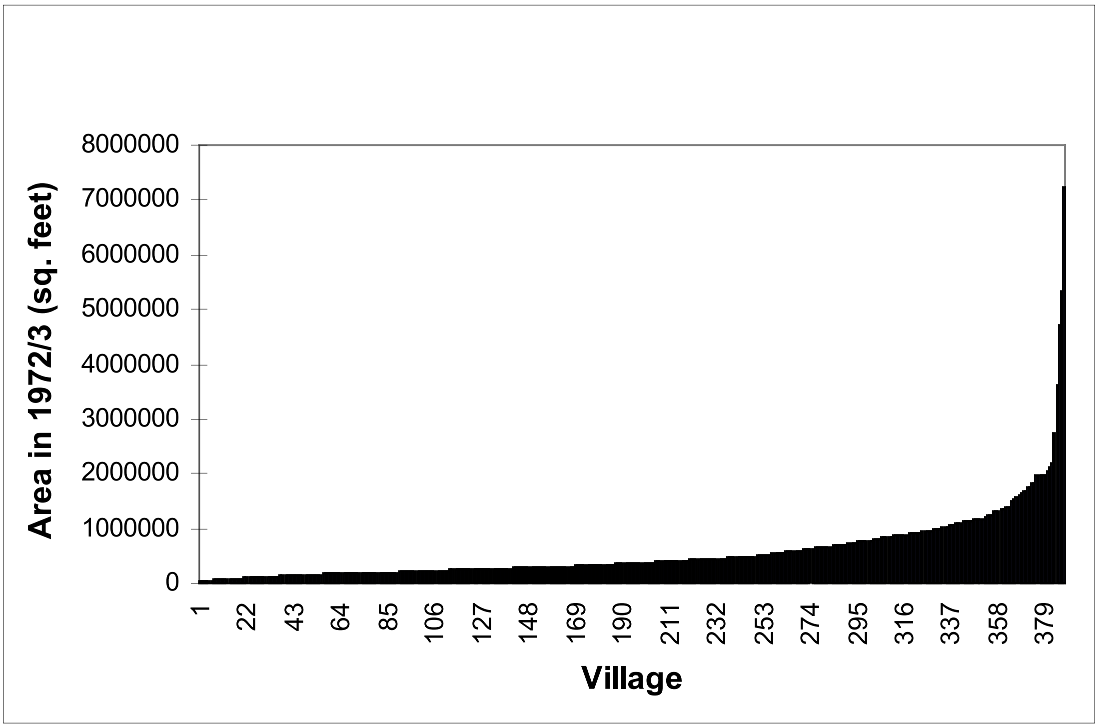


Figure 6a. Absolute area estimates for the 387 villages, ranked in ascending order

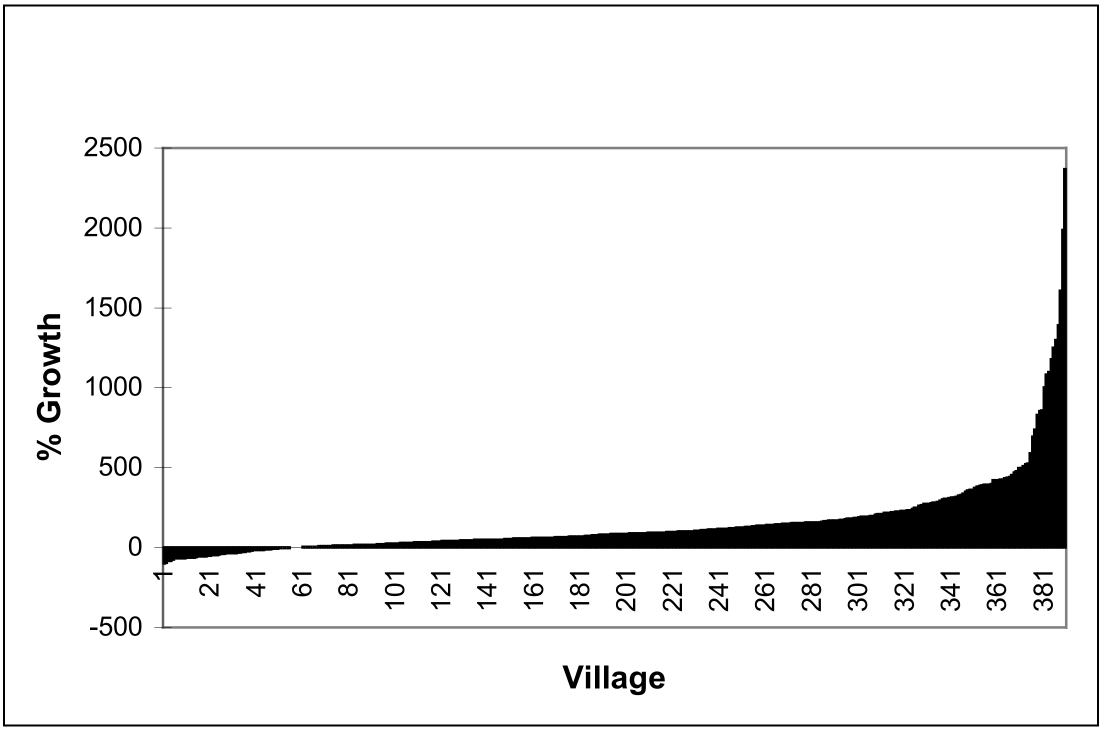
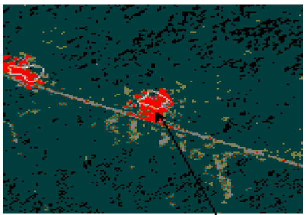
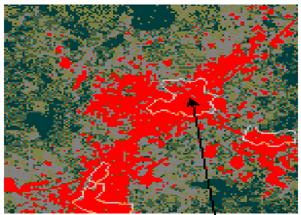


Figure 6b. Relative area growth estimates for the 387 villages





	Growth Criteria			
Village Size	Negligible (~0%)	Moderate (100%)	Medium (200%)	Large (400%)
Very Small	SISKURO	KANAGIO	KAPRO	SWEDRU
Small	FREBOYE No 1	ASEMPANEYE	ABONU	AHWIAA
Medium	DOTOM	YABI	KWASI-PANIN	YAASE
Large	SAWIA	TRABUOM	DWAASI	FUMISUA
Very Large	ADWUMAKA-SEKESE	OYOKO	KOFORIDUA	NKAWIE-KUMA

Figure 7. Procedure for selecting representative sample villages from change analysis

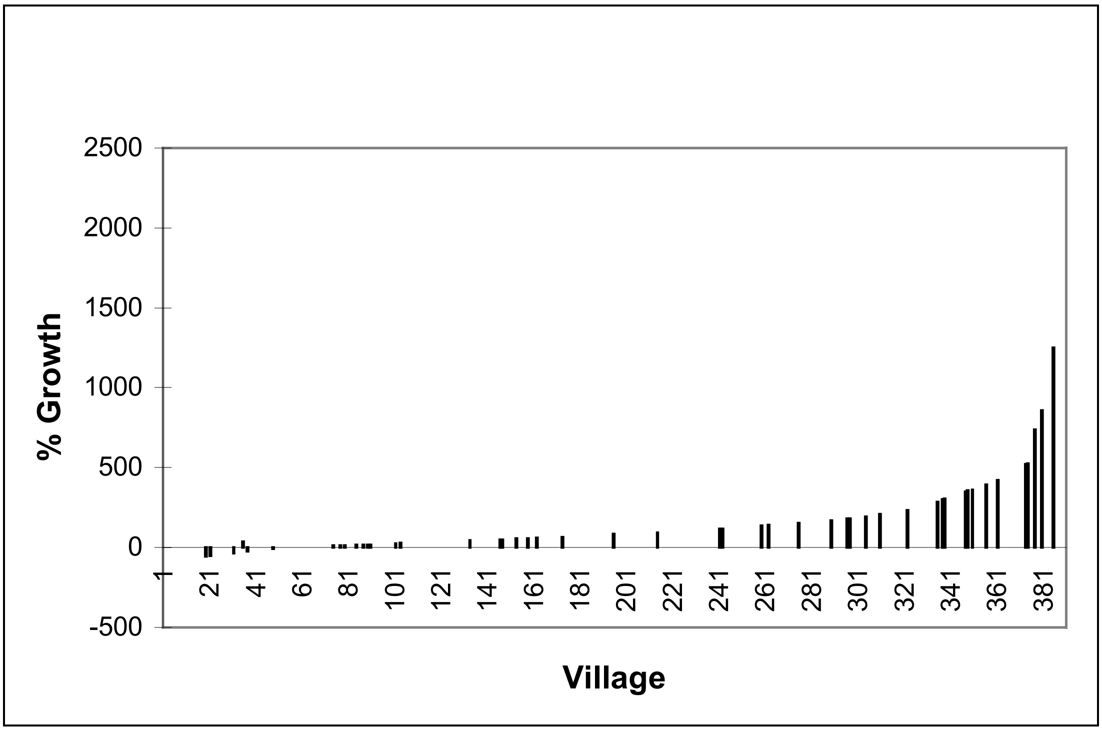


Figure 8. Relative village growth estimates for the 66 VCS villages.

In summary, the methodology developed demonstrated a novel and repeatable approach to the issue of selecting locations for more detailed data collection, based upon the degree of village growth. In addition it was demonstrated that a range of additional contextual information could be derived from a single satellite image source that can also be used within this context. The derived information covered the complete study area, was current, and was made readily accessible from the GIS.

Even simple visual interpretation of the image provided useful information to those concerned with particular areas. To assist the researchers of this and other projects, a set of village profiles was developed and circulated. Examples of some of these village profiles are shown in Appendix 5. A number of cursory interpretations of important identified issues were also made. These include an overall visual interpretation of large sand and stone-winning sites (Figure 9) and proportions of crops and fallow/non-fallow lands (Figure 10). These products do require validation and are not presented as definitive maps, but serve to illustrate the range and type of products that could be generated from further interpretation of the imagery if resources permitted. These sort of products, however, were more useful to the higher-level decision makers (regional and town and country planners). For more detailed investigation and involvement at the local level, where much better image details was required, the ADP imagery and GPS systems were used (see next section).

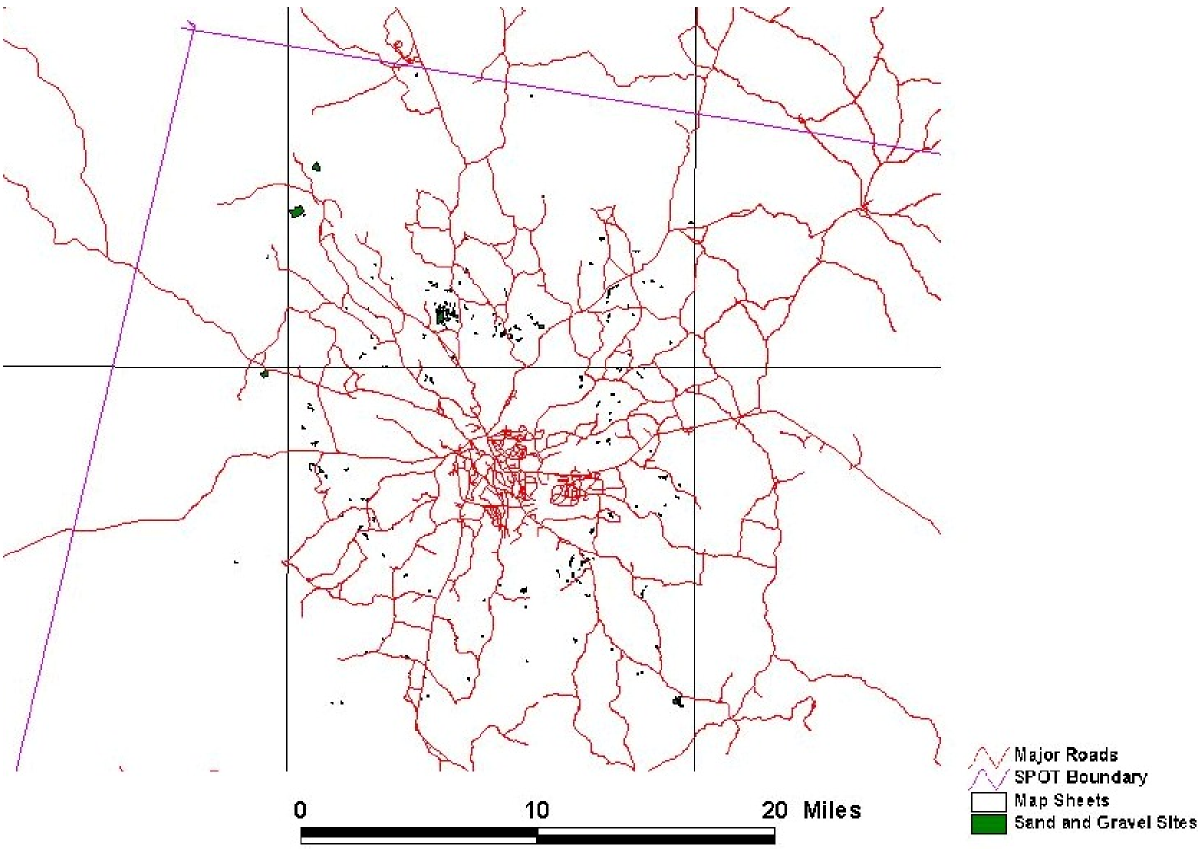

0
10
20 Miles
Major Roads
SPOT Boundary
Map Sheets
Sand and Gravel Sites

Figure 9. Visual interpretation of sand and stone-winning sites from SPOT image

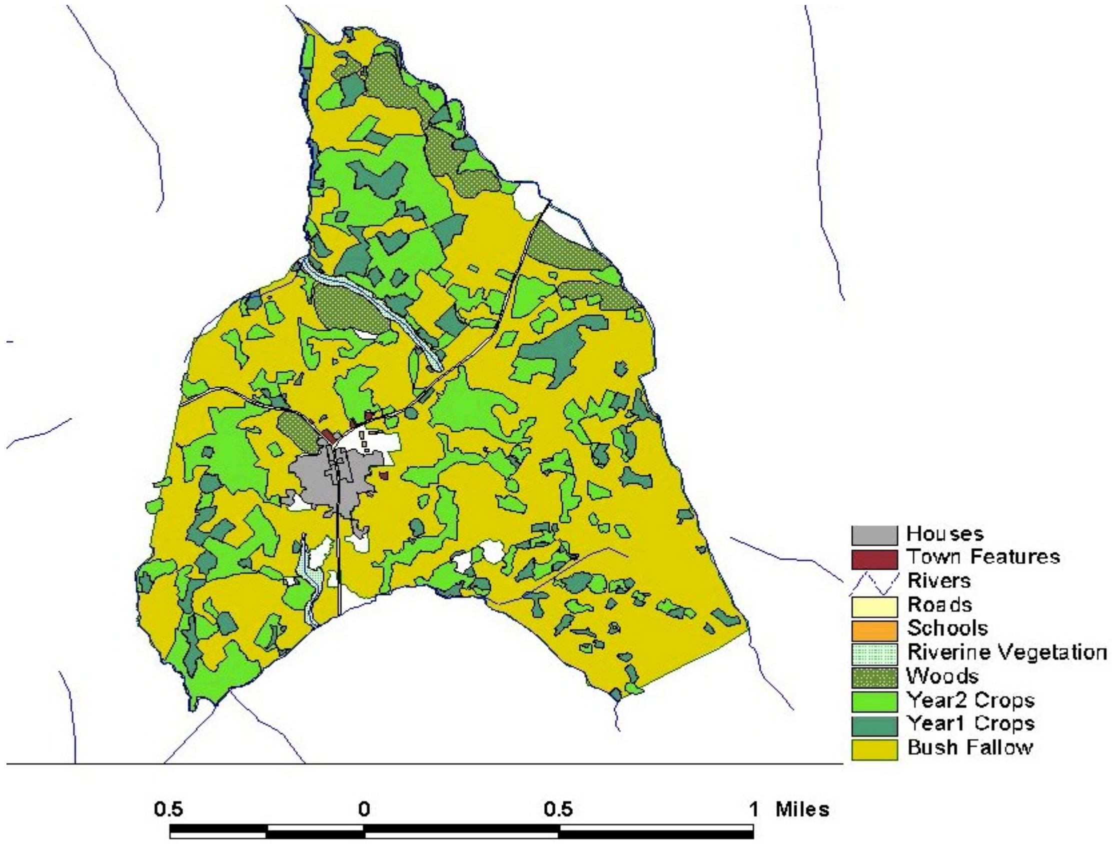


Figure 10. Fallow/non-fallow and other agricultural activity interpreted from SPOT image (for Swedru area).

Another use of the geo-corrected SPOT image was to develop a methodology and coefficients of transformation to allow conversion of GNG to standard (lat/lon or common UTM co-ordinate systems) and vice versa. The GNG projection is not standard in most GIS or GPS systems, and this had led to duplicate systems being used in Kumifo and other systems. However, Thomas et al (2000), developed a generic and transferable approach to establishing the GNG mapping system within GIS software based upon the geo-referenced image and precise location co-ordinates for a single control point. Details are provided in Appendix 6, and conversion routines that allowed the conversion of datasets from UTM to GNG and vice versa were provided to the Kuminfo systems installed in Ghana and UK.

4.3. Aerial Digital Photography survey

Our original intention had been to acquire ADP for a large area of about 40km x 40km around Kumasi, with a nominal spatial resolution of about 1m. The ADP survey was planned for December 1997 between the end of the harmattan and the start of the rains. The overall objective was to capture as much data as possible, with primary target areas of Pease, Swedru, the area around the university Campus, and parts of the inner city of Kumasi (in support of the home gardens survey work being proposed by KNRMP, project R6799). The objectives were to obtain stereo imagery with 20% forward and 15% side overlap imaging at 1: 25000 scale at the focal plane, at a spatial reolution of about 1m pixels.

However, there was persistent cloud cover during the period allocated for flying, and so the objectives and target area of the ADP survey had to be adapted in the field. The survey was therefore conducted at a much lower height below the cloud base. This led to a much more detailed nominal spatial resolution (23cm), but a reduced coverage area. The extent of the area covered is shown in Figure 11. The total area of coverage was about 290 square kilometres, consisting of 1360 individual ADP colour infrared images at a nominal spatial resolution of 23cm. The resultant data comprise an image database of 7 Gigabytes contained on 21 CD-ROMs, which consisted of a data volume of an order of magnitude larger than that first envisaged. Further details are provided in Appendix 7.

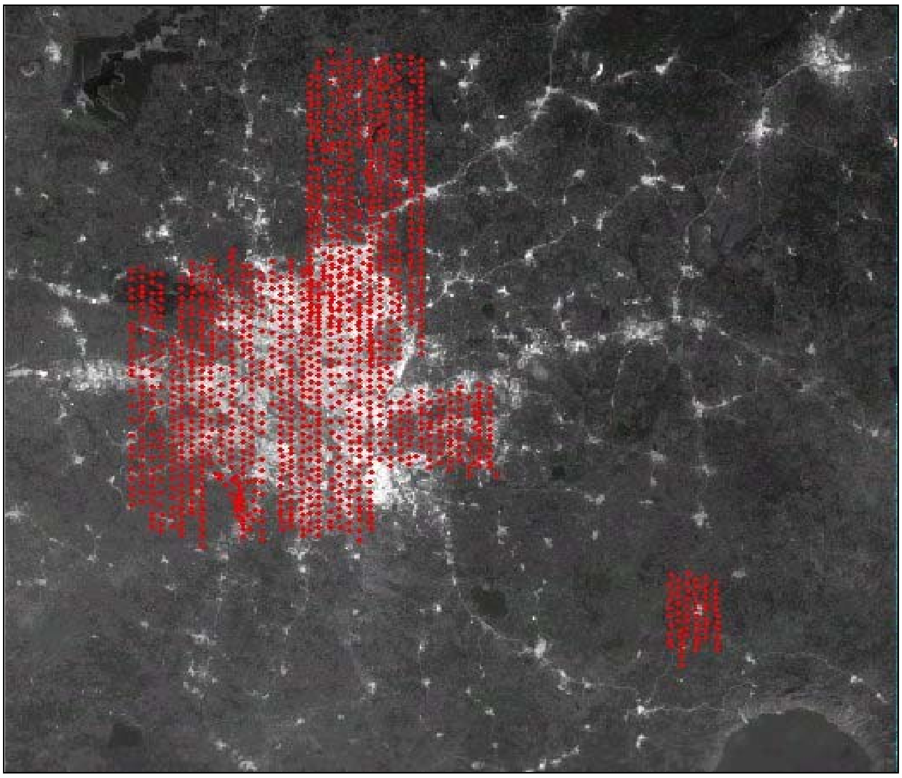


Figure 11. ADP coverage in relation to SPOT image and Kumasi

The survey team used a differential GPS onboard the fixed wing aeroplane to track the fifty-six flight lines flown. The data were stored directly onto PCMCIA removable hard disks and the image data in their native TIF-EP format were written overnight to a recordable CD. Image location was obtained by synchronising the camera clock with the GPS and logging the track of the flight lines during the survey. In theory, the image location was obtained by examining the time of image capture and locating the corresponding position data. Unfortunately because the GPS recordings were not in good synchronisation with the image acquisitions, the image location was more difficult than first envisaged, and a certain amount of manual location was necessary in the post-processing stage. Newer versions of the digital cameras have built-in GPS systems with them, so this problem should not occur in the future.

Copies of the 21 CD-ROMs containing each digital image, and software to view them was installed in the Kuminfo Laboratory at the local target institution (the Institute of Renewable Natural Resources, at the University of Science and Technology). A full set of copies was also provided to KNRMP.

A simple user-friendly image index system was developed to assist researchers to access the relevant image for an area of interest. The image index system was developed in ArcView so that it could be used within the Kuminfo system being developed by the KNRMP (project R6799). Details of the image index and a copy of the user manual are included in Appendix 8. The image index allows the users to pick a village, or define an area of interest in the Kumasi region, and the system informs the user which images on which CD are the ones required. Where they have been prepared previously, thumbnail prints of the images are available for the user to view before loading the full images from the CD. The image index and the full-resolution ADP images have proven to be a valuable resource for a number of researchers and visitors at the Kuminfo lab.

For some areas, Pease, Daku, Swedru, Ahenema and Bakwankye image mosaics were produced by joining the relevant individual images. The mosaics were produced at a nominal spatial resolution of 1m. The quality of the 23cm imagery is excellent, even very small features such as small chicken sheds, individual trees and other features can be identified easily. The trade-off is that data at the higher spatial resolutions are much more difficult to manage due to the much larger data volumes.

Shape	X-coord	Y-coord	Blockrun	Image	VillName	Geocorrect
Point	681414	786998	Block3,Run5	300		y
Point	681252	785321	Block3,Run5	290		y
Point	682816	787287	Block3,Run6	370		y
Point	683188	785765	Block3,Run6	380		y
Point	683060	784046	Block3,Run6	390		y
Point	683974	785869	Block3,Run7	10		y

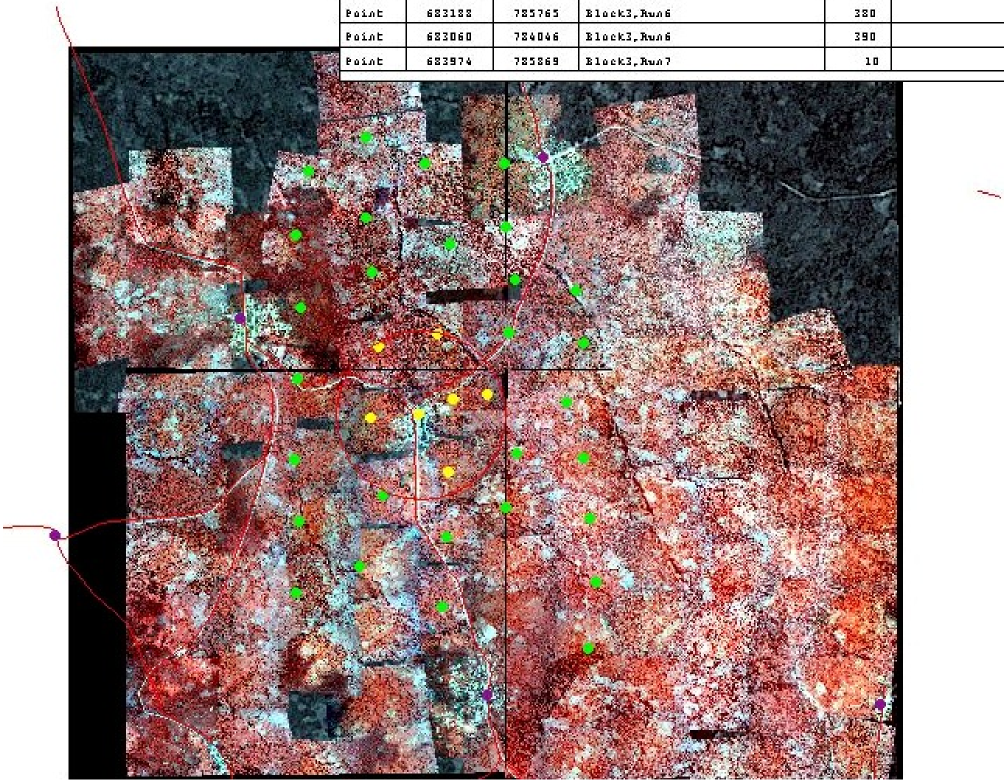


Figure 12. Image Index retrieval example. The user requested all the ADP images within a 100ft radius of a village. The green dots are the centres of ADP images, the yellow ones indicate the selected ones. Details of those selected are provided in the

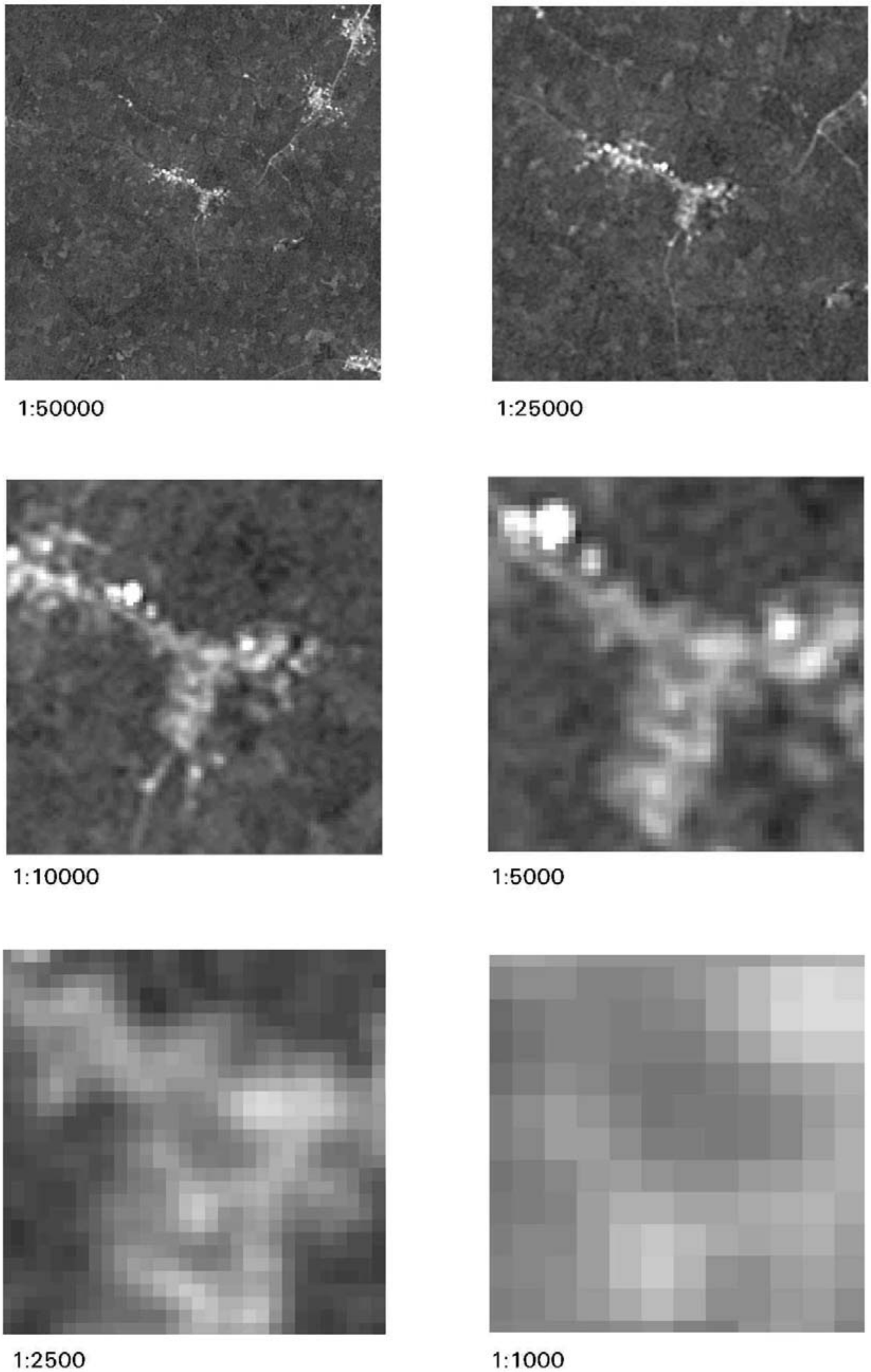


Figure 13a. SPOT image of peri-urban village at six different mapping scales

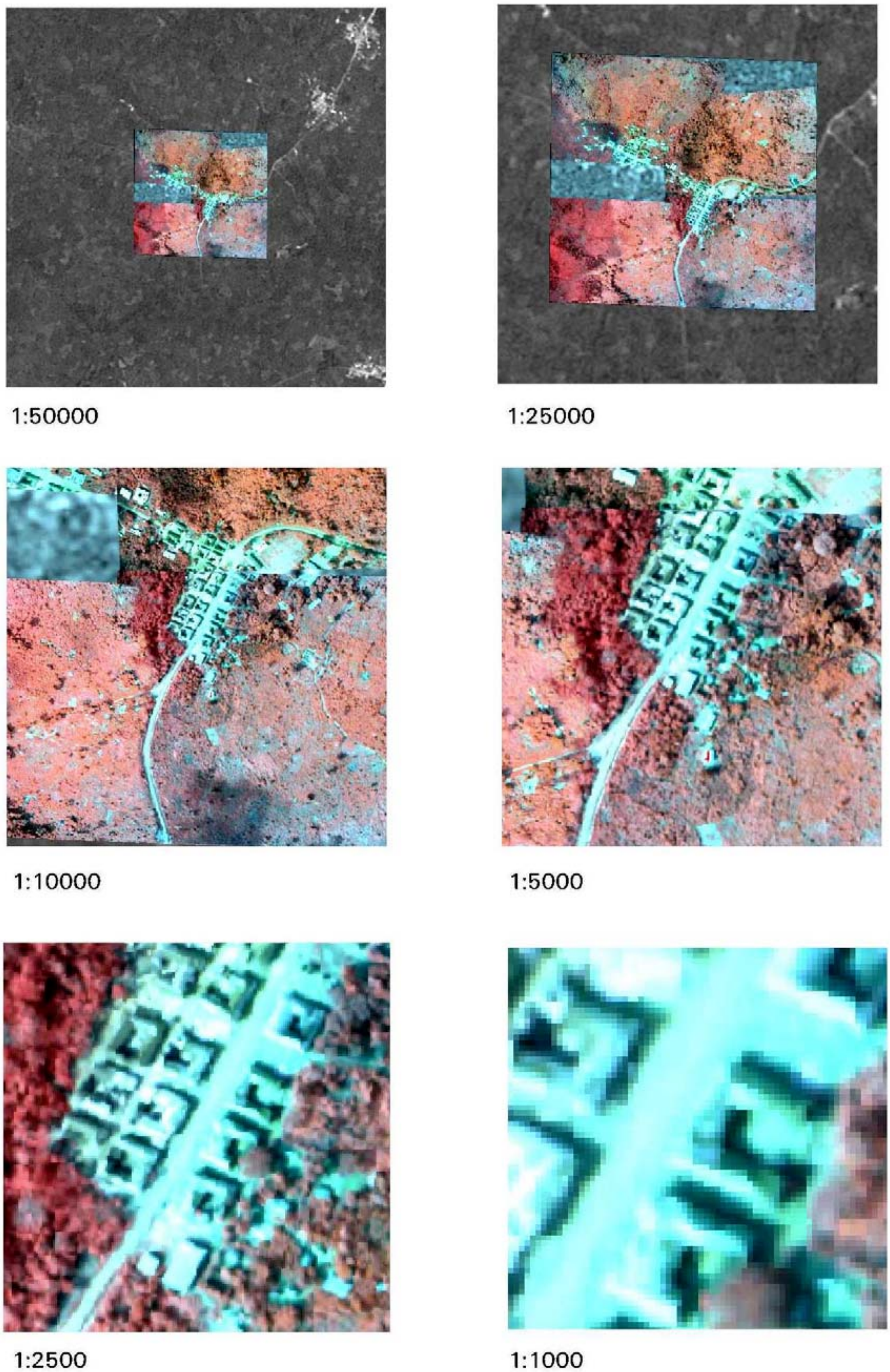


Figure 13b. ADP 1m resolution mosaic image of peri-urban village at six different mapping scales

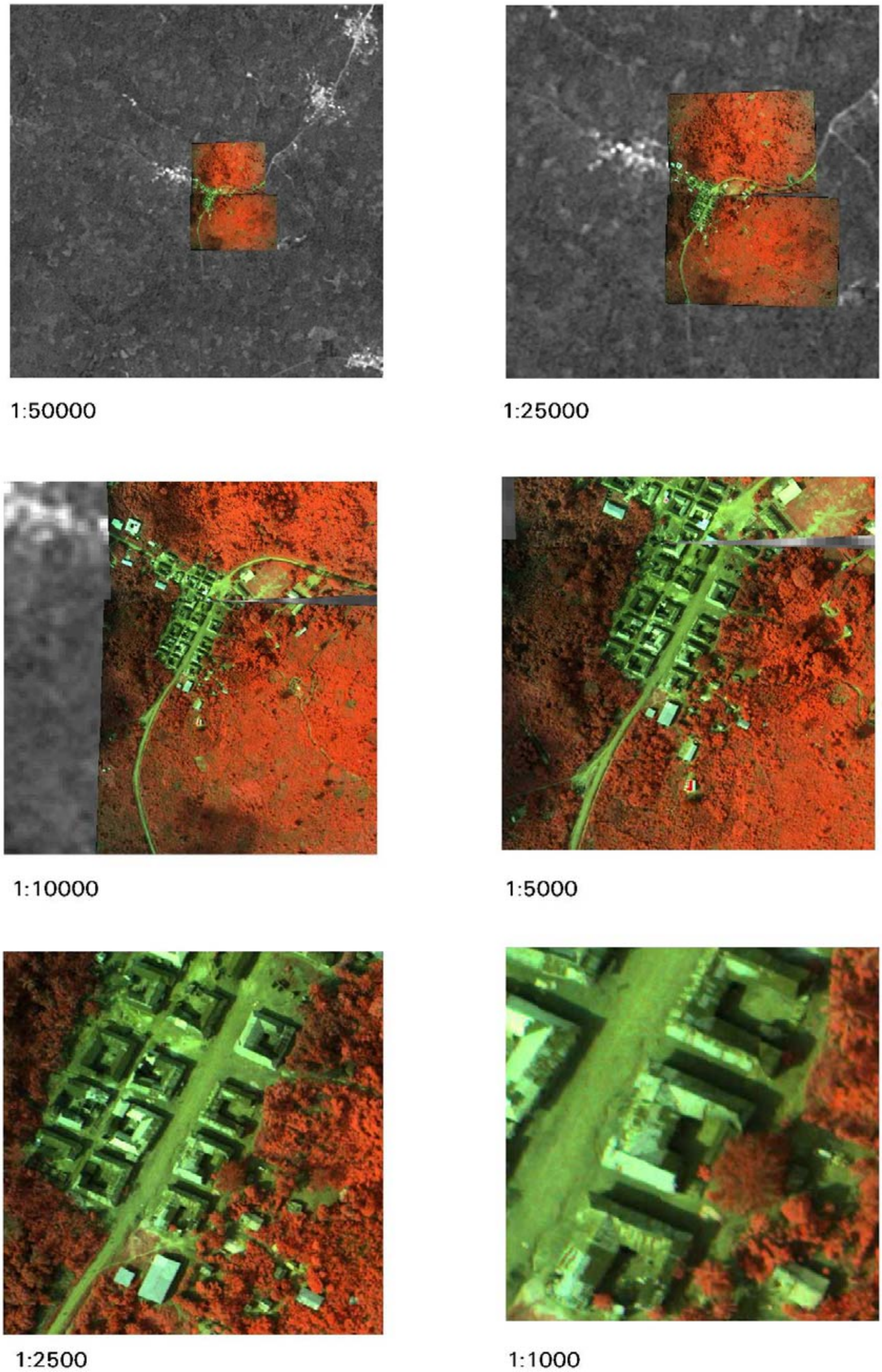


Figure 13c. ADP 23cm resolution mosaic image of peri-urban village at six different mapping scales

4.4. Rapid rural mapping: use of ADP in local level assessments

The objective of this part of the research was to try to improve methods for local level data collection (of natural resources and socio-economic conditions) and to develop methods and products which may provide information and stimulate local participation in natural resource issues. Individual researchers are rarely familiar with both GIS and participatory research, and projects have seldom combined these skills successfully. Therefore in this part of the work, an important aspect was to involve a multi-disciplinary team that included physical scientists and natural resource surveyors as well as those of a more socio-economic orientation. This section reports on the use of ADP in local level field survey and the development of a new methodology, termed rapid rural mapping, to allow the rapid collection and assessment both of natural resource and socio-economic indicators.

4.4.1. Image map production and usage

The Kumasi peri-urban environment is dominated by scattered and poorly defined agricultural features. The precise determination and recording of the position of field survey sites is very difficult in this type of environment to the extent that the same survey sites may not be capable of being located for subsequent field visits, even when aided by GPS. The combined use of non-differential GPS with appropriate image-maps, however, makes accurate detailed survey possible, so a principal objective of the field work was to convert the ADP photographs into map products that would assist collection of field data. More details are provided in Appendix 9

Although it would have been preferable to use the full spatial resolution ADP, some logistical problems were encountered (power shortages and cuts at the time of the field visit to Ghana), so the image mosaics at 1m resolution were used instead. Even so, a considerable degree of processing was required to produce the image-map products and subsequent field documents. This processing could not be undertaken in the Kuminfo laboratory due to lack of power. Virtually all the processing was undertaken in the hotel which possessed its own generator providing electricity from 6pm to 2am on most days. The processing was carried out using portable equipment brought by the team. One of the aims of the field visit was to test portable equipment, including PC and printer and image processing software, for processing ADP data into digital and hard copy map products. The equipment taken to the field proved successful in meeting this aim.

Although some logistical problems were encountered during the field visit a capability to derive map products at large scale based on false colour airborne digital mosaics supplied by Bath Spa University College and using a portable processing system was successfully demonstrated. These products were developed and subsequently tested as an aid to the development of both a village characterisation survey and natural resources field survey as described in the next two sub-sections.

4.4.2. Uses of Image-maps for Village Characterisation Surveys

The aim of this part of the work was to test in the field the application of large-scale ADP derived image-maps for collecting natural resource and socio-economic data in the context of a village characterisation survey (VCS). In addition we intended to identify potential uses of the image-maps by villagers and also any limitations to their use. Since ADP imagery was readily available in mosaic form for the village of Swedru, located 14 kilometres north of Kumasi, it was chosen as the case study village. Additional information was also available, as the village had been used as one of the PRA villages undertaken by the KNRMP team.

The time available to the team in the field was limited and consequently the visit focused on the development and testing of different approaches to the use of image-maps for a village characterisation survey.

The two principal objectives of this part of the work were:

1. To assess the capabilities of members of the village to interpret the false colour ADP derived image-maps; and
2. To make direct use of the ADP derived image-maps for the construction of:
   - A land ownership profile;
   - A family profile linking socio-economic data to relevant geographical features, for example family land ownership, number of family members (to assess the work load of the family), and constraints to production and natural resource use.
   - A village profile of resources in the village and the constraints to their use.
   - A mobility profile to assess the flows of resources within, outside and into the village.

<u>General Interpretability of Image-Maps by Villagers</u>
An assessment of the capabilities of members of the village to interpret the false colour ADP derived image-maps was undertaken based on recognition of notable features and landmarks whilst sitting in the village. These included houses, boreholes, the school and farm land. The image-maps were shown to three different groups in the village: the village chief, Mr Mawere Poku and the village development committee, the women and the young men. Although the village development committee has not been active for some time many members of the committee were present at the discussions with the chief.

<u>Discussions with Chief Mawere Poku</u>
The initial focus of the discussions was on interpreting the extent of the village lands using a 1:15000 scale image-map. The main roads to the village and the extent of the built environment are clearly discernible at this scale. The location of streams can be readily inferred in some parts of the map from the associated tree growth. Upon initial viewing the chief asserted that he felt able to trace the boundary of the village and an attempt was made to identify the 'stool' land. In reality this proved a difficult exercise. This was thought to be principally because the scale of the initial map product at 1:15 000 was too small to allow clear identification of physical features

that the Chief would know. The laptop computer was not at that time available to allow the ADP images to be magnified to facilitate such identification and which may have aided the process.

A subsequent visit was undertaken with a 1:10000 scale image-map of the village and its environs (see Figure 16). With this larger scale map the Chief was able to indicate the boundaries of the village a little easier. However, there remained considerable uncertainty regarding the actual extent of the village lands.

Discussions with the chief concluded with him enthusiastically identifying that the information describing his village provided in this form, even at the scale of 1:10000, would be of help in the:-

- control of the allocation of land to immigrants;
- planning of the resource use of the village land

The Chief saw these image-maps as extremely valuable documents worth many millions of Cedis to him.

<u>Discussions with the women</u>
During these discussions a family profile overlay was attempted. The aim was to collect socio-economic data from the image-map by identifying:

- the house in the village,
- the farm lands belonging to the family,
- the distances travelled to water, school, farm lands
- other activities engaged in by the selected family.

Identifying the house was a difficult exercise. As expected one or two women were able to locate their houses after a great deal of prompting and discussions. Overall the images were not easily interpreted. An attempt was made to relate distance and area in the mind of the villagers to the image-maps that possess a true representation of scale. This attempt was unsuccessful despite trying to convert distances to time travelled to a fixed identifiable point and relating it to distance to farm land which did not have clearly identifiable landmarks. This process also failed with this group of women and was abandoned.

An attempt was made to develop a mobility overlay by asking individuals to describe a normal day. This was expected to provide details on movements to and from the field, to and from shops etc. Additionally information was sought on the goods sold outside of the village and cash/materials brought in. Time limitations resulted in inconclusive results from this element. However, it was felt that the image maps would clearly provide a basis for estimating the distances involved in day-to-day activities.

<u>Discussions with the young men of the village</u>
These focused on identifying village landmarks and farm plots. The young men also indicated, as expected, a variation in their ability to interpret the images.

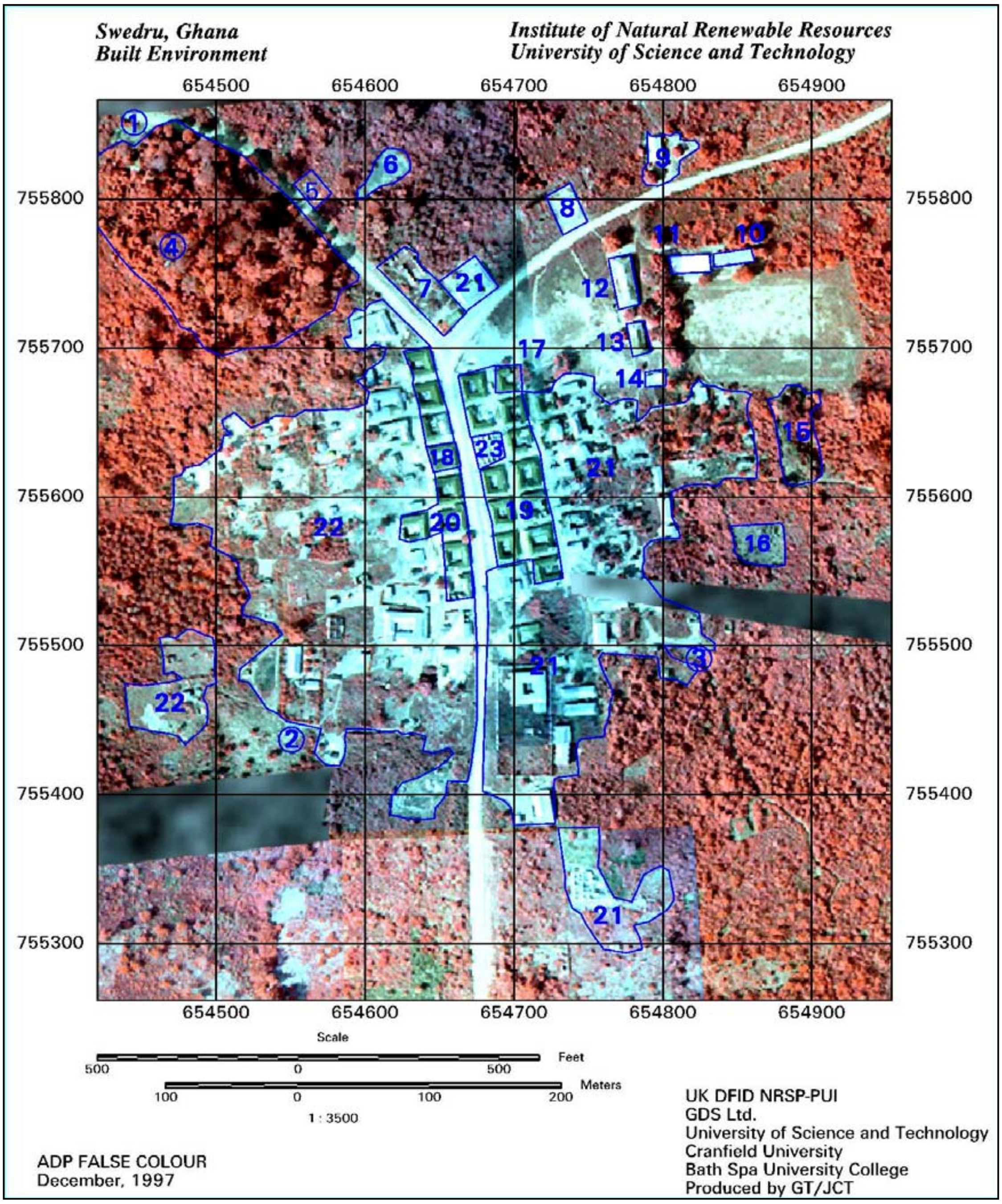


Figure 14. Interpreted ADP image map of Swedru built environment

Features are: 1,2,3 boreholes;4. Forest used for non-Christianburial site; 5. Christian cemetery; 6. Refuse site; 7.Methodist church; 8.Toilets; 9.True Faith Church; 10.Middle level school; 11. New middle level school- under construction; 12. Upper primary school; 13.Lower primary school; 14. Kindergarten school; 15. Sacred grove; 16. Originally cleared as playing field; 17. Chief Mawere Poku's house; 18. Oldest house (1920); 19. Houses built between1920 and 1963; 20. Houses built between 1920 and 1942; 21. Houses built in last five years (east)- includes backyard gardens; 22. Houses built in last five years (west)- includes backyard gardens; 23. Houses being built.

Village Profile

Prior to visiting Swedru a photo-interpretation of the built environment of Swedru was undertaken in the Kuminfo laboratory using a 1:3500 scale image-map. This provided a basic template for use during discussions with the villagers. The villagers' local knowledge of the area was then used to label specific features such as the bore-holes, churches, schools, cemeteries, sacred groves, and houses. These features were quite accurately identified. The positions were confirmed later in the day during a walk around the village. The villagers indicating the age of the houses added additional socio-economic information to the image-map during this time. Some assessment could then be made regarding the time periods and extent of the expansion of the village. An interpretative overlay was subsequently developed and is presented as Figure 14. Figure 15 presents the mental sketch developed during the PRA exercise undertaken in Swedru.

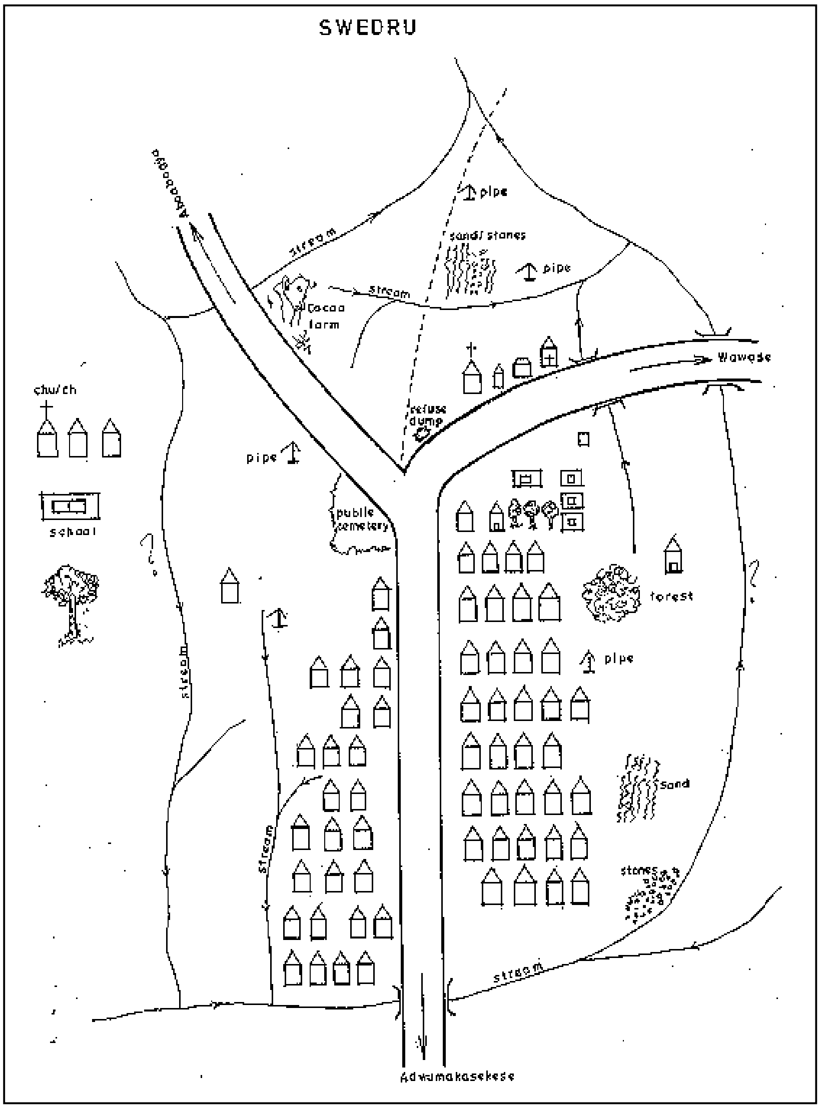


Figure 15. Participatory sketch map for Swedru village.

The inaccuracies and ambiguities inherent in such sketches when considered in mapping terms are readily apparent. For example, many of the identified features (e.g. the refuse dump) would be difficult to locate using the sketch alone. The symbols on the left side of the sketch are an interpretation key, although the tree is not labelled as such. The relative density of housing on the west and east side of the main road do not accurately reflect the real situation when compared with the ADP image. Although it is recognised that PRA maps should only be regarded as aides to the PRA process, not products, had the image maps been used initially as a basis for the development of the mental map, the geographical proportions and clear depiction of natural and man-made resources would have assisted the PRA process.

Because of the detail in the ADP images, it will be possible to use them as a basis for determining estimates of population (by determination of each type of house times the average number of people per particular type of dwelling).

<u>Family Profile</u>
Another purpose of the visit was to attempt to develop a family profile by overlaying information onto the image-maps. The materials taken were:

- 1:10000 image-map of the village;
- 1:2000 image-map of the buildings (Figure 15);
- digital camera;
- Garmin GPS system.

The Chief selected Mr. Mensah's family to base the family profile on. Figure 16 shows a composite of the information collected. The ADP 1m resolution image provides a plan view of Mr Mensah's house as well as indicating the local environment. A digital photograph provides a ground view of the dwelling. Also included is a photograph of Mr Mensah. In March 1998 the occupants of Mr. Mensah's house totalled 23 persons, which consisted of 7 females, 6 males and 9 children. A simple plan of the house was also recorded.

<u>Land Ownership and Farm Management</u>
Land is one of the most important and contentious issues in the peri-urban area. Land allocation and ownership is poorly defined, and has often led to a number of conflicts (Kassanga, 2000), thus the ability of villagers to map or identify their land boundaries (with or without ADP images), could become very important.

It was clear in discussion with Mr. Mensah that his family owns a large piece of land which is individually farmed by various members of the family. It did not prove possible to clearly identify the boundary of this land whilst in Mr. Mensah's house by interpretation of the 1:10000 scale image-map. A similar attempt was made using a 1:2000 scale image-map produced in both false colour and black and white. Mr. Mensah and members of his family were still unable to clearly demarcate the family lands. It became necessary to physically visit the lands in order to determine more precisely the extent of the family owned lands. An interpretative overlay was produced (Figure 17) together with an analysis of the ratio of cultivated to fallow

land. The latter was estimated to be 1:5.5
During the visit to the family lands, additional information was collected in regard to management of the area. Mr. Mensah took the team to a field newly prepared for planting. At the time of the ADP survey the area was quite heavy bush. For the land preparation Mr. Mensah employed 2 people who each spent 15 hours clearing the land at a rate of 12,000 Cedis per person. The ADP with its clear definition of physical features such as rivers, will prove to be a useful tool for historical analyses of land use and ownership.

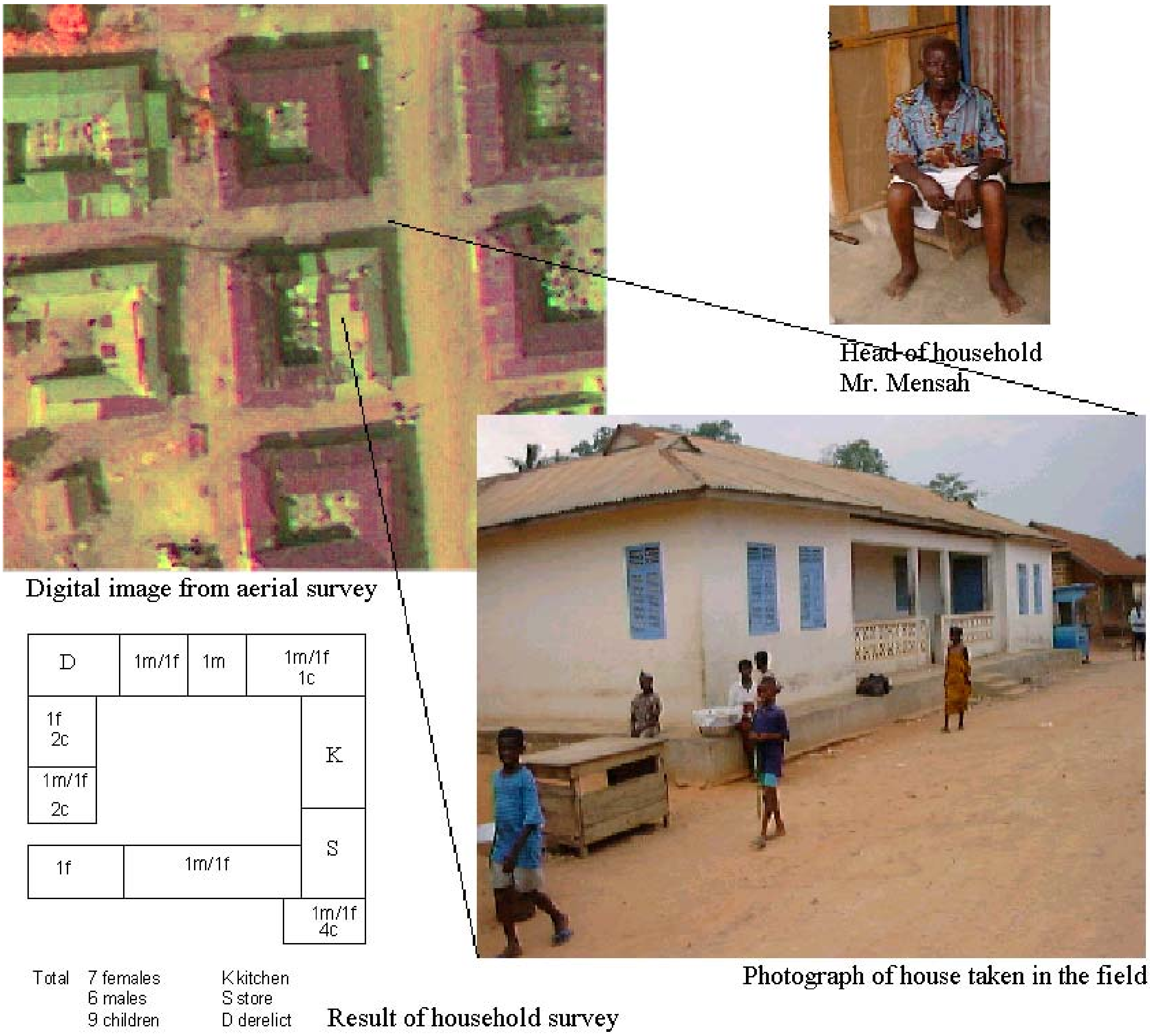
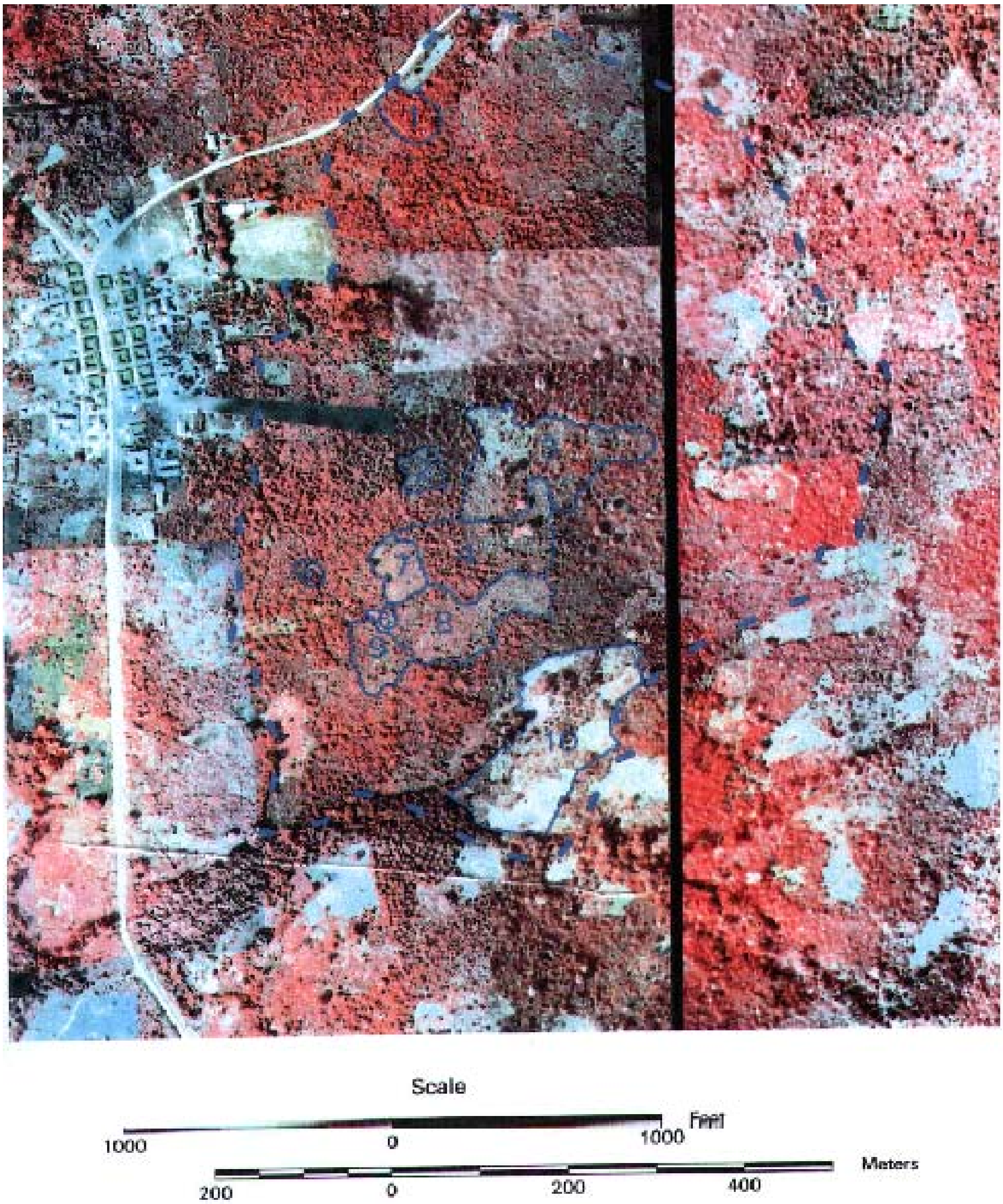


Figure 16. Composite of information collected at the house of Mr Mensh



<u>Figure 17. Family Lands survey- Mr. Mensah of Swedru, near Kumasi, Ghana</u>

Key :

1. Plot cleared for 1998/9 season- cassace and okra to be planted
2. Land in cultivation in 1997/8
3. Land in cultivation in 1997/8
4. Plot cleared for 1988/9 season
5. Site of new church
6. Land in cultivation 1997/8- cassava
7. Land in cultivation 1997/8- Mr. Mensah's nephew
8. Land in cultivation 1997/8- wife of nephes
9. Plot fo 1997/8 season- Mr. Mensah's wife
10. Valley bottom farming o sandy soil- tomatoes in 1997/9

Summary of uses at village level

The 1:10000 image-map of Swedru was seen by the chief to be a valuable tool to control the allocation of his land and to defend his boundaries. However, there was no opportunity to sit with the Village Development Committee to assess how they would use the image-maps. It became clear during meetings with various sections of the village that interpretation of false colour image-maps was variable. Some villagers demonstrated good levels of interpretation, despite having no formal training. Other villagers appeared unable to interpret anything from the images. The majority of those encountered would require further training and assistance before being capable of navigating around the village and farmlands. It should be noted that the image data are in the form of false-colour composites rather than natural colour and similar difficulties would be expected in the village context in developed countries.

There does not seem to be any strong requirement at the present time for any villager, other than the Village Development Committee and one or two other skilled interpreters of image-maps, to use the products developed. This may be due in part to the local people's unfamiliarity with the information being presented. It may also be due in part, to the fact that the project researchers were not in a position to offer any solutions to any development problems or conflicts that may have arisen in discussion (being primarily a research project).. This was one of the most difficult parts of the project: researchers had to assess the value of information to villagers but in a very careful way so as not to raise expectations that major aid was to follow.

It is clear that a period of time working with a 1:2000 or 1:5000 image-map would yield an accurate land tenure map of the village. This would consist of stool land, family land, family land being share-cropped, land used for sand-winning and other development activities. This data collection activity could be verified, if necessary, with the use of an outside technician, using image-maps and/or a laptop, GPS and compass. In particular in the peri-urban environment it will be necessary to monitor the use of the various lands for urban development activities.

In summary the field visit confirmed that if the need to develop a village level management plan were identified as a priority by the villagers of Swedru, then the process of developing the plan could be enhanced by use of ADP derived image-maps, though they would probably require some outside assistance (from an NGO, agency or government body perhaps) to prepare the image maps for them.

4.4.3. Application of Image-maps for Field Surveys

There are a variety of methods by which assessment of the natural resource base of a region can be carried out. Perhaps the simplest method is by direct observation of, for example, land cover/use or the quality of the soil, undertaken as part of a field or ground survey. The logistical resources required to undertake such surveys are such that it is impractical to determine by direct observation the complete resources of a region of any substantive size. An alternative and more cost effective method to cover larger areas is to interpret either directly or indirectly natural resources information from photographic or digital images. Typically the latter requires that some ground data be collected by direct observation during a field survey to be used for both calibration of the interpretation method and verification of the quality of the results.

Whether field survey data are the sole method of resource assessment or as part of an image interpretation approach, it is normally required that both the locations for the observations and the amount of data collected be determined as part of a statistical sample design. This ensures that the data that are collected can be assumed to be free of bias due to location and are representative of the area being surveyed. The use of a structured sample design also ensures that the extrapolation (or aggregation over larger survey units) of the results of the individual measurements can be undertaken using standard statistical methods with known levels of precision or uncertainty. This type of quantification can aid decision making.

The principal aim of this part of the work was to develop a methodology for field survey based upon interpretation of large-scale ADP image-maps, combined with use of non-differential GPS. Subsequently the method was tested in the field and recommendations made for an operational procedure. During the fieldwork in Ghana many of the operations had to be developed independently and out of sequence in comparison to an operational procedure due to the constraints encountered as indicated previously. However, this did not influence the validity of the conclusions drawn from the work.

The principal objectives of this part of the fieldwork were to:

- Design and test field sampling methods
- Develop large-scale image-map products for use in natural resources field survey
- Test combined use of image-maps and GPS
- Identify an operational methodology

Design and testing of field sampling methods

Area frame sampling is a well-known method for the collection of field survey data that incorporates image-maps. The method has been applied operationally by the European Commission within the Monitoring Agriculture by Remote Sensing (MARS) Project and by the US Department for Agriculture. In this method an area in the study region of defined size (e.g. most often between 700 m x 700 m or 1 km x 1 km) is mapped at large scale using an image source such as a high resolution satellite image or potentially an ADP image. The locations of the field survey sites (often known as sample segments) are pre-determined during the sample design. The sample segments are visited in the field and a map of the required resource data is produced with the aid of the image-map. In this way the complete segment is effectively mapped and field parcel boundaries delineated to scale. The latter allows for accurate area measurement. The application of such a method ensures consistency of the collected data with the rigours of national statistical services and world funding agencies.

An alternative method for determining locations within the ground segment where field data can be collected is by use of point sampling. The French Ministry of Agriculture statistics office, for example, make use of a point sampling method known as TER-UTI. A typical strategy would still systematically distribute segments of a given area across the study region. However, rather than map the segments as previously noted, a series of points would be defined in a grid pattern. Each point would be visited and the resource data collected, until all the grid points in a segment were surveyed.

Field documents were developed for both area frame and point sampling and each method was attempted in the field. However, it soon became apparent that the predominance of bush fallow with various degrees of density of shrubs and trees present in the area made point sampling impractical. The identification of point locations could not be achieved accurately in the field by interpretation of the image-maps due to the diversity of the bush fallow. Accurate location would require the use of differential GPS operating in real time mode rather than post-processing mode. The latter type of differential GPS system is currently available in the KUMINFO laboratory. The nature of the environment also made it impractical to efficiently traverse the area in a grid pattern. Consequently the best method to map the ground segments was determined to be an area frame method.

Production of field documents

Field survey interpretation documents were produced using large scale ADP mosaics for use in the field. Two sets of field documents were produced for testing in the field: navigation documents and ground survey documents. All map products were false colour. The basic navigation documents were produced at a scale of 1:15000. These were intended to provide a single map product covering a study site and for use in the location of individual survey sites by combination of GPS and recognition of ground features. As a result of the field visit to Swedru and Pease it was concluded that such documents should be produced at a scale of 1:10000. Field survey documents were tested at a number of scales ranging from 1:500 to 1:5000. Eventually a scale of 1:2000 was selected with a 100m UTM grid.

Field Testing

The field survey documents were tested and refined during two visits to Swedru and one visit to Pease. Upon arrival at a village the co-ordinates of the centre of the selected ground segment was entered into the GPS. The GPS was used to navigate to the site, using the ADP image-maps to help determine precise locations by visual comparison with the surroundings. Once the field team had located the boundary of the ground segment it was mapped into distinct parcels based on visual interpretation of the ground survey document and the required information noted. The land cover/use of each parcel is noted on a field recording sheet, as well as any other notable features. A digital camera was used to record specific features and parcels during the ground survey and to aid subsequent preparation of the interpreted map product.

Accuracy assessment with GPS

The effective use in the field of large-scale image-maps for the collection of natural resources information requires the integrated use of GPS for navigation to selected field sites. The Cranfield University team carried with them a Trimble Scoutmaster GPS. This is a simple, non-differential hand-held system containing a built-in antenna. The UST group possess a Garmin GPS system capable of operation in differential mode. For the field investigations this system was operated in non-differential mode.

During the ground survey investigations GPS data were collected in the field using the Trimble and Garmin systems. Locations were derived by reference to a 1:2000 scale image-map. Neither GPS unit was capable of being programmed to work using the Ghana National Grid (GNG) co-ordinate system. Instead the Universal Transverse Mercator (Zone 30) grid was selected with the WGS 84 datum. It is critical that the GPS unit is correctly set-up prior to field survey, since an erroneously selected map datum can result in location errors of the order of between 10s and 100s of metres. The selected GPS mapping system was consistent with the mapping system used for the preparation of the ADP derived field maps. Field maps were available at a scale of 1:2000 with a 100m grid.

During the procedure it soon became apparent that the Garmin system was not operating correctly and only 4 measurements could be obtained. For the data collected using the Trimble GPS the overall RMS error was 80.5m. This level of error is not unexpected given the limited precision capable with a non-differential GPS (usually 50-100m) combined with the error in the geometric correction of the ADP data (approximately 20m).

The efficient navigation to a field survey site using non-differential GPS requires that the scales of the navigation and field survey image-maps are consistent with the expected level of error in the GPS measured co-ordinates. The navigation documents were designed for navigation to several sites in the same general area, to allow an approximate route to be determined to a specific site and to display the relation between individual sites. Field-testing determined a scale of 1:10 000 to be most useful based on ADP image mosaics. Once in the general vicinity of the field site the GPS is used in navigation mode to direct the field team towards the field site. The field survey documents were produced at a scale of 1:2000 which corresponded to an area coverage of 300m x 300m. The field survey site was 100m x 100m located in the centre of the mapped area. This selection ensured that despite the lack of precision in the recorded GPS co-ordinates it was always possible to navigate by sole use of GPS to a point that was within the grid co-ordinates of the field survey document. Once the field team are located within the field survey document area, it always proved possible to confirm the precise location by reference to the detail visible in the image-map. However, even with the use of GPS it is advisable to have a standard compass to allow the image-maps to be quickly oriented in the field. Correct orientation of the image-map with respect to the field location substantially aids recognition of individual features within the images.

Conclusions
The field visit was successful in achieving the stated aim and objectives. An area frame method was selected for use in the area around Swedru. Field navigation and survey documents were developed using portable image processing equipment. These products were developed and field tested in Swedru and Pease by combined use of GPS equipment.

4.4.4. Operational procedure for Integrated Resources Survey

Design of area frame sample
A combined ADP and ground survey design can be based upon the technique of area frame sampling. In such a design a study region of say 10km x 10km (or 50km x 50km) is subdivided into grid cells. A sampling fraction in area terms (between 0.25 and 1.5%) is chosen which determines how many grid cells are required to be surveyed on the ground. The survey sites are then systematically distributed across the study region. Within each grid cell a ground segment of area 100m x 100m, for example, is located. The position of the first segment is determined on a random basis and the others systematically aligned. The previous step provides the geographical co-ordinates of the ground segments for which ADP images are to be collected. Using GPS and the satellite image-maps to navigate the aircraft, the segments can then be surveyed by ADP. Following the collection of the ADP data, the images of each segment are geographically referenced to the satellite image-map. The availability of the SPOT derived image-map allows for efficient geo-referencing of the individual ADP images. Finally the ground segment is mapped by field survey.

The actual survey essentially covers the complete study area allowing map products to be developed for any required site. This type of survey when applied to any significantly sized region leads to data volumes that are typically difficult to manage and store efficiently. Much of the data collected cannot be effectively interpreted within the resources of the projects for which the survey was commissioned. Consequently, complete coverage surveys are operationally only likely to be undertaken for small areas within any given country where complete mapping coverage at large-scale is essential to the project aims. Achieving national coverage at large scale must remain a responsibility of the national mapping agency. The area frame method represents an efficient method of sampling large regions of a country to obtain representative statistics that can be aggregated within statistical reporting regions. The method leads to manageable data volumes and efficient processing procedures that ensure rapid availability of map products. When properly designed the method will meet international standards for statistical reporting.

An integrated survey method
The method described above can be developed into a combined natural resources and

socio-economic survey method. In section 2 the degree of village growth in the peri-urban environment of Kumasi was determined by analysis of topographic maps and satellite remote sensing data. A method of selecting sample villages to cover the complete range of growth characteristics was illustrated. The identified villages could be surveyed using an ADP system and integrated into a village characterisation survey as indicated below. An area frame survey for natural resources data collection could be designed and integrated with the village ADP survey.

An analysis of the Village Characterisation Survey undertaken by the KNRMP identified 65 variables that appeared most useful for differentiating between urban, peri-urban, and rural villages. The report indicates that the interpretation of the data is made difficult due to reliance in the collection methodology upon the perceptions of key informants rather than independent objective assessment. In addition constraints on time, and the large number of variables being observed restricted the number of informants that could be interviewed in each village. Thus the information provided may be relatively inaccurate and biased. One of the key benefits of the proposed method here is the possibility of accurate and unbiased observations, particularly in regard to the provision of information aggregated to the district and regional levels (discussed in more detail in the following section). The use of image-maps provides a basis for accurate and objective measurement. Of the 65 variables for which observations were made it is possible to identify a number where accurate measurement could be obtained with the assistance of interpreted image maps. In particular:

- the proportion of the village that was residential
- the proportion of the village that was farmland
- the proportion of land that was stool-owned;
- the proportion of land that was family-owned;
- the number of new houses built or under construction;
- the number of corn mills in the village;

Accurate information on the proportion of the village area under different uses requires that the village area is known precisely. This information is not generally available in the Kumasi area but can be derived from the image maps once the boundary has been successfully identified. As demonstrated earlier in this report determination of the proportion of the built and non-built environment can be efficiently determined using the image-maps. Information on the proportion of households growing certain crops could be derived by application of area frame sampling. The perceptions of villagers regarding problems of pollution can also be objectively assessed by use of the image maps to determine the geographical extent of the problem. The image-maps have considerable utility in regard to any planned development of the village facilities, for example, the provision of piped water, electricity and sanitation. These developments can be examined in terms of the expected resource implications since realistic estimates of the expected requirements can be determined from analysis of the image-maps.

The above suggests a wide range of possible applications of the image-maps for combined natural resources and socio-economic surveys.

Scaling-up of resource data

The terms scaling-up and scaling-down (alternatively up-scaling and down-scaling) appear in increasingly common usage in both the physical and social sciences. In spatial terms it implies making generalisations at one level of aggregation (e.g. the district) based on observations or understanding derived at a different level (e.g. the village). Normally the spatial units over which the generalisations are made are administrative units rather than geographical units. Scaling-up is an important concept since the aim is provision of information or understanding at the level at which management and planning decisions are often initiated.

Scaling-up can simply involve the calculation of averages of some measurement made at a number of locations within the total study area. The property can relate to the physical (e.g. proportion of land that is fallow), social (e.g. the proportion of income generated from external sources) or economic (e.g. total population) environment. Under the assumption that the sample design is statistically-sound statistical methods can be applied to derive information at the study, region or district levels together with an estimate of uncertainty. The latter is normally provided as a range within which the estimate most probably occurs. When comparing various physical, economic and social indicators the measure of uncertainty allows different weightings to be applied to individual estimates thereby reducing the influence of data which are known to be less reliable.

As noted in the previous section, a number of important variables observed as part of the Village Characterisation Survey undertaken for the Kumasi peri-urban project can be derived by analysis of the ADP image-maps. By following the survey design procedure suggested by this work, observations of relevant natural resources, social and economic factors derived through analysis of the image-maps can be scaled-up to appropriate administrative levels to aid planning and monitoring decisions. A current application of up-scaling within the natural resources area is the determination of national level statistics on crop areas within the European Community. A procedure was developed as part of the Monitoring Agriculture with Remote Sensing (MARS) project. The information on crop areas is required for management of the Common Agricultural Policy of the EC. The individual observations on crop areas are collected using area-frame sampling. Statistical methods are used to aggregate the sample crop area data into regional estimates suitable for EC level planning purposes. The methodology we describe is an adaptation of these techniques for application in the developing world.

4.4.5. Summary

We were able to define a rural resource mapping methodology which could be applied rapidly (typically within a time frame of a month or two) allowing it to be integrated within the typical life cycle of most development initiatives. The joint inter-disciplinary work of natural resource and socio-economic scientists was important from an early stage of this part of the project.

The ADP was a valuable source of up-to-date scaled imagery which would be invaluable for the preparation and presentation of village layout maps, which are often the first stage of a proposed development or intervention programme. Further, ADP appeared to offer a new and informative perspective on local knowledge and was an effective tool in the participatory process. However, it was not possible to determine in the time scale permitted whether any of the groups were disenfranchised or limited by its use. Most people were able to interpret and draw information from the imagery after an initial description.

The use of ADP and GIS proved to be very useful in developing such informative products as extents of village boundaries, extens of family lands and patterns of crop rotation used.

Most of the work done was in an extractive way, rather than in a participatory way. This was due largely to the fact that, working with a research project, we did not want to raise any expectations about being able to implement any remedial or intervention strategies. In a development project with a budget for implementing remedial actions such as improving production or making livelihoods more secure, the work may have been done in a more participatory way. The general lack of planning (or at least community participation) at the community level was apparent.

Land is an important issue in peri-urban Kumasi, and the combined use of ADP and GIS was found to be an important tool in defining land ownership parcels. The annotation of the imagery with indigenous names for places and features such as rivers would be of considerable help in this application.

There is scope for using the ADP and SPOT imagery for developing a population survey methodology, and this will be pursued with various funding agencies.

Results from this part of the project were presented at a number of local workshops and were generally well received.

4.5. Prototype Geographical Information System

A key component of the project was to develop a user-friendly geographical information system for natural resource assessment and management for a wide range of potential users. The system was designed to complement the Kuminfo system being developed by project R6799, and to have additional functionality and methods to support the work done in this project where necessary. Any appropriate developments and applications were integrated into the Kuminfo system. The information system developed within this project has been a key component in data management and collection, and has underpinned many of the activities reported in these sections.

The information system for both projects was designed to handle a wide range of both quantitative and qualitative data, including raw and classified SPOT satellite imagery, digital 1:50000 topographic maps, scanned historical aerial photographs, ADP image locations, GPS locations of field positions and transects, digital photographs from various field sites and locations, and PRA-type village maps and layouts. The system used in the project was designed to work in several different map projection systems: Ghana National Grid, Universal Transverse Mercator and simple latitude/longitude and routines for conversion from one system to another were developed. All data collected was "tagged" geographically. Where these were quantifiable geographically, i.e. they had known projection parameters and defined geographical extents, the data were entered in the appropriate projection at the defined location. Where the data were of a more qualitative nature (for example PRA-type sketch maps, documents or photographs), these were accessed as "hotlinks", attached to some geographical feature such as a digitised point, line or polygon. For example, usres clicking on a point location would bring up the corresponding scanned photograph or document for that location. In this way, users browsing the system for a particular village, would have access to all the data collected and input for that area (both qualitative or quantitative). Where data were of a general nature (for example overall planning guidelines for the Kumasi area), these were made available within a specific application, as shown below. Developments made in the UK and Ghana, were all eventually transferred to the system at the IRNR-UST. Detailed training and documentation was provided for all installed modules.

The major developments of the geographical information system included:

- the development of the database of 387 villages (described briefly in section 4.2. and more fully in appendix 5) including village profile samples.
- the development of the ADP image index system (described briefly in section 4.3 and more fully in Appendix 8) which allowed users to define an area of interest, either by a selected village name, or geographically by points or digitised areas. The corresponding ADP images for the defined area would then be listed, along with a reference to show the user which CD the images were on, whether or not someone else had geo-corrected them and/or made products from them, and other details such as whether they required to be rotated or not.

- The development of a facility to allow users to create scaled image of map output at a specified scale. Previous software scaled output automatically, which was a big limitation when controlled scaled output was required as in the case of producing documents for field survey. Within this project we developed special routines which allowed users to create "panel-maps". This allows the user to specify an area, a scale of output, and a paper size. The routines we developed would then calculate how many sheets of paper would be required to generate the desired output at that scale, and print the sheets with an index which would allow the user to tape the individual paper sheets together, thereby creating a composite output at the desired scale. This was found to be a very useful routine in the Kuminfo lab where they previously only had A4 printers.

Although the information system proved an invaluable support for the data collection, storage, access and management, it was felt that the key worth of natural resource and socio-economic information would only really be appreciated when integrated into a system which would allow users to evaluate and rank the likely impact of development on these resources by running "what-if" scenarios and assessments. We therefore developed of a prototype GIS application that showed how natural resource and other information may be used to evaluate possible development alternatives, where possible at a local level. One of the major application areas where such analysis can have a major impact is in planning. The KNRMP has developed applications at the regional planning level. We were keen to demonstrate how the type of information collected within this project could be used to evaluate different development options at a local level. Therefore a local planning application was designed after discussion and consultation with other projects within the RNRRS Programme, in particular the KNRMP which included a large component of planning (led by Keith Williams, Nottingham University), and with a range of planning-related researchers at UST. Although a specific user requirement study was not carried out with village and town and country planners in Kumasi, several researchers contributed their knowledge and experience of the planning processes to help design the prototype system. The system and a user manual is provided in Appendix 10.

The village-level planning application takes the user through a number of steps:

1. It shows all the "development constraints", i.e., the areas where development is not permitted (according to the planning guidelines). For example, it can show areas within a certain distance to a river, or areas exceeding a certain slope. The user can select the limits (e.g. can enter the slope limits, or distances to a river), and can then add other features that should be "buffered" e.g. sacred groves (Figure 18)
2. The application then allows the user to digitise on a map, areas of proposed housing development.
3. The application then analyses each proposed site in terms of the total area digitised; the composition of current land use within the proposed polygon; the average elevation; the distance to nearest features such as rivers and roads; and the maximum and minimum distances to the nearest water supply, toilet facility and various categories of school. For each proposed development site, it produces a summary report with the overall assessment of the planned development polygon.

Where a proposed site does not conform to the general planning guidelines, the user is warned. Where the user has digitised two or more proposed areas, various aspects may be compared visually, e.g. the current land use within each of the digitised polygons.

The application was installed in Kumasi, and tested with a number of users and presented at a couple of workshops. Because the data requirements for such an application were so considerable, it was only possible to run the scenarios for Swedru where a lot of the data had been collected and interpreted already. It was felt that the data requirement for such an application are considerable, but the illustrative and educational potential of the application were recognised.

It was also generally felt that more detailed socio-economic information, such as the current land occupation and economic productivity of the area would be needed before the system could be fully utilised to illustrate or examine the effects of land use changes on the local dwellers and the local economy. Validation by taking the computer maps and modelling outputs back to the village and local planners for feedback and comment also still remains to be done.

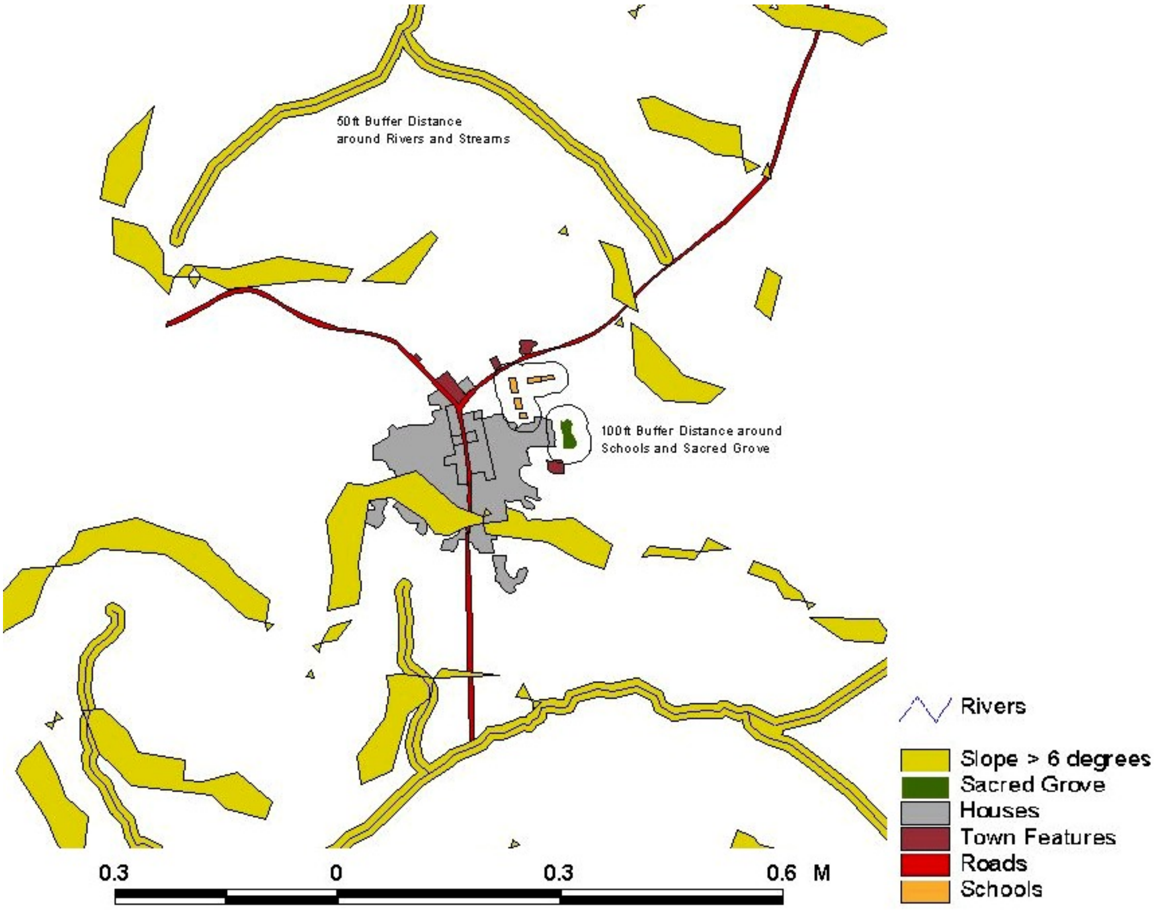


Figure 18. Illustration of constraints to building developments in Swedru

4.6. Further In-field testing and use of developed RS/GIS techniques

The original project plan was to have generated the following outputs:
- Report on the transferability of the prototype system
- Report on the image acquisition system transfer to local area
- Report on new and appropriate technological developments.

However, these aspects of work were suspended in favour of more effort on investigation and application of how the type of image information being generated by the project could be better utilised in the generation of poverty alleviation action research.

Because of the new DfID focus and the findings to date on this project, it was decided that another field visit should be undertaken to Kumasi during the period 15 – 29 September 1999. The aim if this visit was to further develop the methodology for collecting and using information on peri-urban production systems to benefit the poor, using GIS and remote sensing technology. In keeping with other areas of DfID strategy, the use of RS/GIS techniques for stimulating and developing action research themes was also developed. Previously, a series of map products using ADP and satellite imagery was tested in the villages of Swedru and Pease. In this part of the research we aimed at a greater integration of the technical methods with the social and economic issues affecting the poor, and sought to use these to identify actions that would materially benefit them enhanced by using the power of the technical methods. A full description of the work and list of Action Research ideas is presented in Appendix 11. A summary is provided here.

In this part of the research, the study area included the campus of the University of Science and Technology, small-scale industrial developments and several villages, which are undergoing various transitions from primarily natural resource-based to primarily urban-based economic activity.

Geo-coded versions of all the ADP mosaics were prepared in both UTM and GNG projections. The UTM versions were required if maps were to be used in conjunction with currently available GPS systems. The GNG versions are useful for relating all other data registered to that projection.

A 1: 10000 scale image map of the study area was produced and proved very useful to identify case study areas in a focus group. In addition, UST staff provided historical 1: 10000 scale panchromatic aerial photography covering the same study area. A multidisciplinary focus group comprising socio-economists and technologists from the UK team and collaborating UST staff met to identify priority issues. The image map and aerial photographs were employed as facilitating mechanisms to provide stimulus and focus in subsequent discussions (Figure 19). Three themes were identified: land use and social change in areas evolving from natural resource-based to urban-based economies; environmental pollution in water courses and land use and tenure conflict in valley bottoms. Local knowledge and experience was used to identify areas on the image-map for exploratory study. The focus group consisted of various local researchers including physical and social scientists, some of who had used maps and aerial photography before and some who had not. The ideas for detailed investigation came from the local group, without any prompting or suggestion from the visitors. It was apparent from the participatory research exercise that the image map and aerial photographs were a strong catalyst for the identification of socio-economic – natural resource linked issues within the area encompassed by the image sources. Identification of the bounds of the zones encompassing each main theme and the selection of potential sites for field visits was readily undertaken by use of the image data.

For the case study areas identified, a series of larger scale image-map products was produced. Also, parts of the original ADP imagery were extracted and printed at the full 23cm resolution. As part of this work, the image index system was improved (see previous section).

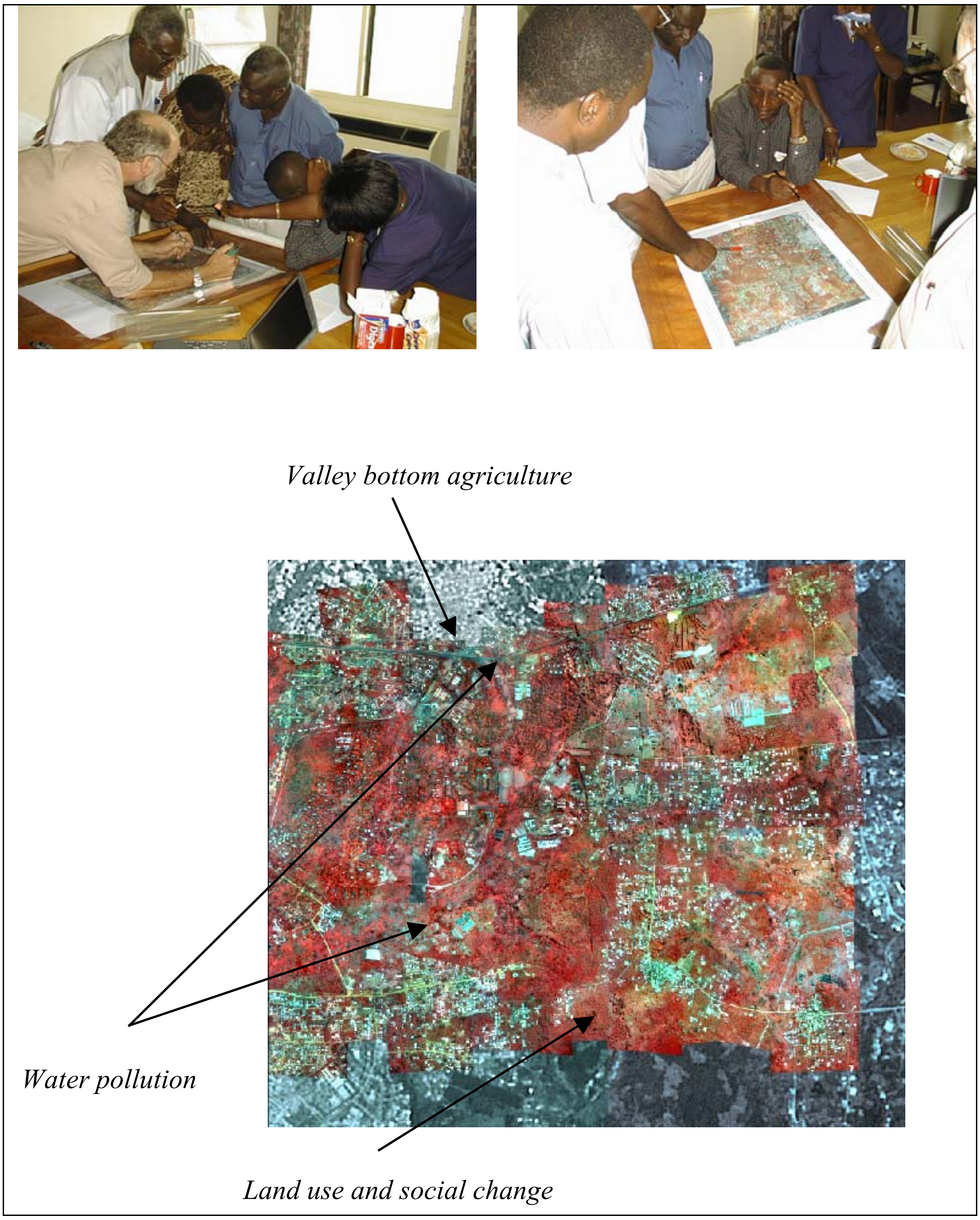


Figure 19. Stimulation of participatory discussion for identifying and localising priority issues.

Land Use and Social Change in Kotei/Tweneduasi

The theme of land use and social change was identified by the focus group as being an important one affecting the villages of Kotei and Tweneduasi. This reflected the findings of much other work which indicated that land issues were some of the most pressing in the peri-urban area. The pattern and scale of land use change between the 1960s and 1997 is evident from comparison of available 1960s 1:10000 scale, panchromatic serial photography and the 1997 ADP derived 1: 1000 scale image map

(Figure 20). The built environment of the two villages has merged, with the smaller village of Tweneduasi located to the east of Kotei.

The use of the map products as an aid to the process of collecting socio-economic information was tested and refined by visits made to Kotei/Tweneduasi. Initially these provided useful information related to: the magnitude and type of change in land use; the locations of the main zones of change; changes in the extent of the village built environment and the structure of the village built environment. A substantial degree of change had occurred in land use, with much of the natural resource base of the village lost to housing, particularly to the north and east of the village. The main village built area exhibits a smaller degree of change, with recent developments taking place mainly to the eastern side. Little development has taken place to the south of the village.

Reconnaisance surveys were undertaken in Kotei/Tweneduasi using the map products to assist in the exploration of any social impacts of the identified land-use changes. Interviews with several members and groups in the village were carried out. All interviewed people were able to identify clearly the change that had taken place during the last 30 years in terms of loss of natural resources. The following points were raised:

- new settlements have resulted in considerable reduction of land for cropping, wildlife habitat, loss of medicinal plants and scarcity of fuelwood; some people seemed surprised and shocked by the extent of land lost to development.
- natural-resource based production systems are no longer a principal source of livelihood for particular groups of poor people for a number of reasons
- loss of natural resource systems has had a negative effect on livelihoods, although some positive aspects such as the new amenities were also recognised
- the natural resource base to the immediate south of Kotei is still intact and the residents attribute this to an on-going dispute over allocation of land for development. Families in that area disagreed with the sale of land for building and had petitioned the previous Asantahene successfully to prevent it. The process will have to be repeated with the new Asantahene if the wish to preserve the status quo.

It appeared from these interviews that the heightened awareness of the actual degree of change resulting from the explicit representation of the available natural resources base of the area as represented by the image maps provided a powerful catalyst for stimulating the participatory inquiry process. The availability of the historical aerial photography, which allowed the degree of change over a finite time period to be assessed was important in this context.

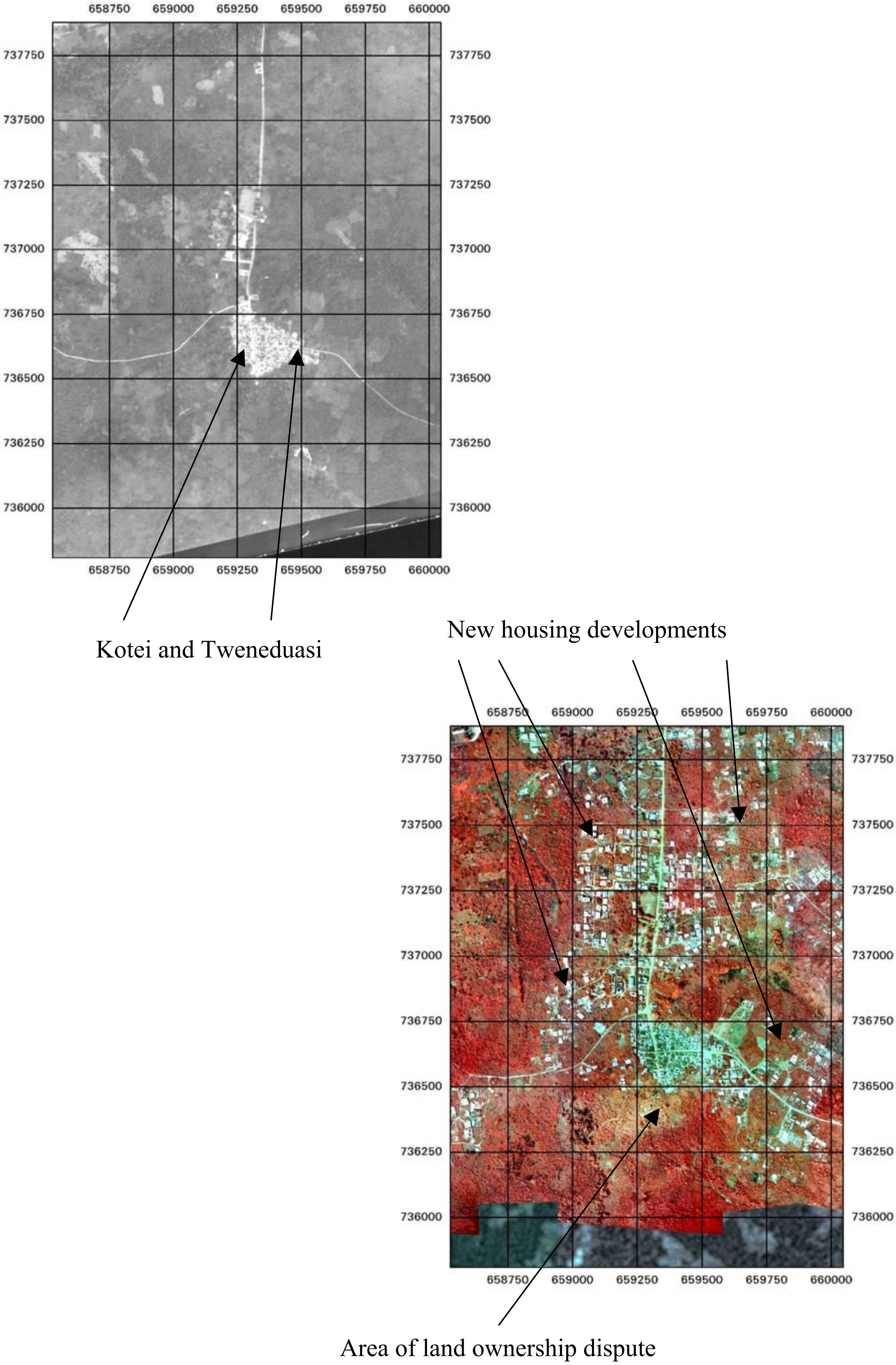


Figure 20 a and b. 1960s aerial photograph and ADP image maps of Kotei and Twenedasi

The availability of the large-scale maps was a direct stimulus to the exchange of information on the social implications of the rapid urban development taking place in Kotei/Tweneduasi. A substantive amount of information was obtained in a short-time period and without unduly raising of expectations of the village community. The information gathered was directly focussed on locally perceived priority issues and provided a sufficient basis for developing an appropriate action research programme (see Appendix 11).

Pollution, Valley-bottom agriculture and land tenure in the Wewe watercourse

During the focus group the occurrence of pollution in the Wewe watercourse was raised as an important issue that could have potentially harmful effects on the livelihoods of people in the vicinity of the pollution sources and within the wider peri-urban environment. Two pollution sources were identified from prior knowledge: the UST sewage treatment site and effluent from a vehicle washing bay adjacent to the Accra-Kumasi highway. The sites were identified on the ADP mosaic and the relevant full resolution ADP's were extracted and printed. The full resolution image was used rather than the reduced resolution mosaic since this would enable accurate location during the survey and because it was able to resolve the details of the agricultural activity, i.e. an intensive system of agriculture organised into regular beds that implied high value cropping.

During the field visit the team inspected the facilities at the sewage treatment site (Figure 22-photo 1) and noted that the existing treatment plant was defunct. Any rehabilitation of the facility is likely to be very expensive. The team observed that the emergency outlet for the sewerage was in full use (Figure 22-photo 2) and this discharges untreated effluent into a nearby stream (Figure 22-photo 3/4) which seemed polluted. Both people working at the university or living in the surrounding communities were intensively farming the valley bottom. Soils are sandy loam and well drained. The well-drained sites were cultivated with plantain and cassava, while in the wetter areas sugar cane and taro were grown.

Within the vicinity a large area of intensive vegetable cropping was observed. The area is readily identifiable on the ADP image (Figure 21), but many people working and living close to the site did not know of the intensive cropping area. The vegetables grown were lettuce (Figure 22-photo 5/6), cabbage, and onions.

Five operators were working at the site visited and two were interviewed. The operators grow mainly lettuce because it matures within six weeks. They have hired labour paid between C90000-C110000 per month, and employ at least 4 labourers.

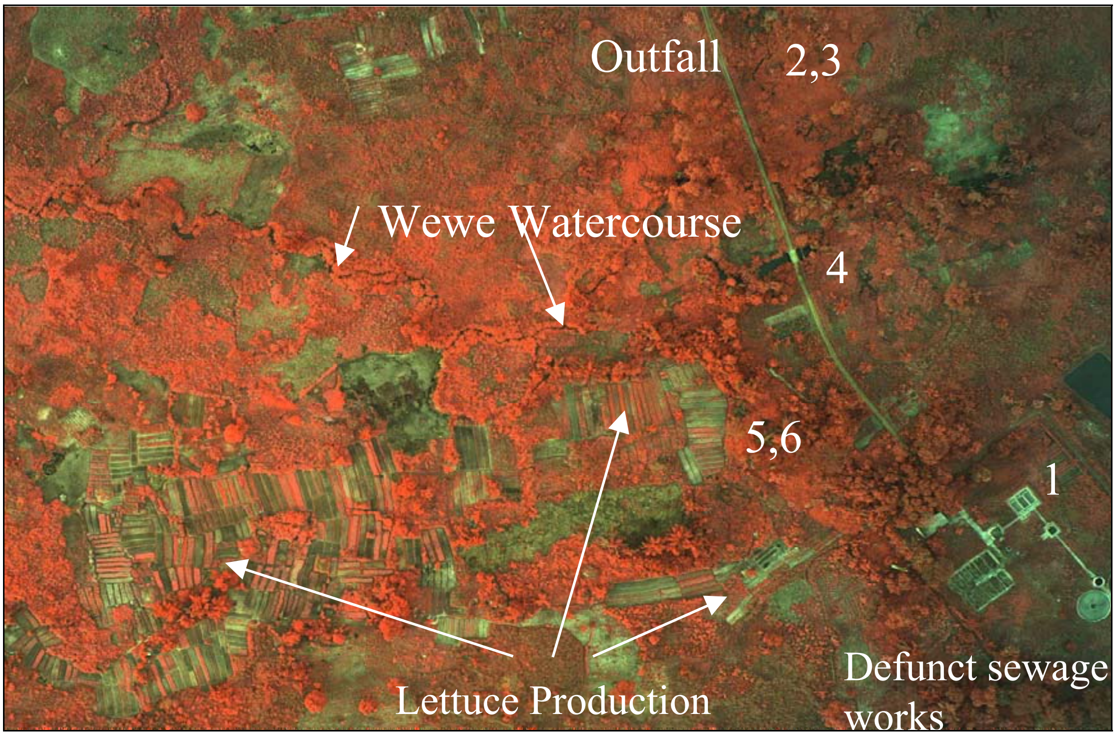


Figure 21. ADP false colour image of the Wewe watercourse and intensive lettuce cultivation (Numbers indicate site of photographs shown in Figure 22)

The crops were planted on transplant-beds and an operator owned between 30-40 beds. The cost of bed preparation was C5000. The transplant-beds were fertilised with poultry manure, which was obtained free, but payment was made for packing and transport to the site. The crops were watered using water from shallow hand-dug wells. The transplanted seedlings take within a week. Diseases and pests of lettuce were controlled with agrochemicals: leaf spot with diathane and larvae attack with thiodan. Drainage channels were constructed to offset flooding, as the area is liable to flood. Technical skill was developed through "learning by doing". The operators have basic education.

Each operator had a sale outlet, mostly managed by women. These customers sometimes pre-financed their activities. Operators incurred on average C1000000 costs over a production cycle of 6 weeks. They spent C22000 on lettuce and C80000 on cabbage seeds for 20 transplant beds. The income within the same period was C1500000, thus, a net income of C500000.

The operators stated categorically that they did not use water from the river, which appeared polluted. They also alluded to the poor quality of the water since they did not drink water from the wells.

1. Defunct sewage treatment works

ADP view of sewage treatment works

2. Raw sewage discharging

3. Taro crop below sewage outfall

4. The Wewe at main bridge

5. Lettuce beds downstream

6. Chicken manure on lettuce

ADP view of lettuce beds

Figure 22. Photographs relating to numbers on Figure 21

Wewe Bridge Enclave on Accra-Kumasi Highway

The pollution and degradation within this site was due to effluent from a vehicle washing bay adjacent to the riverbank. The area was visited and the principal types of agricultural activity determined with the aid of an ADP image. It was found that cassava was planted on the middle slope of the riverbank, while the riverbed was planted to sugar cane with the drier areas to vegetables. Some portion of the valley bottom was not cultivated during the wet season due to flooding.

Developing a programme of action research

The pollution of the Wewe watercourse raises a number of important issues that have the potential to affect both the farmers and the consumers of their produce. In addition there exists a considerable uncertainty regarding the rights of access to the lands under cultivation. There is a high probability that pollution is affecting the large-scale lettuce production and that the farmers are being exposed to biological hazards. In addition, there is the potential for exposure to biological and heavy-metal contamination for consumers of the produce.

A programme of action research can be envisaged to remove the uncertainty over exposure to pollution. The ADP image maps can be employed to define a rigorous sampling strategy to investigate pollution levels in both water and crops. In addition, the health profiles of the farmers should be compared to a representative sample of the local population that do not farm the area.

There could be considerable economic consequences if the University of Science and Technology were to exercise their right to develop the lands currently being farmed. The scale of the current activity can be assessed by use of the ADP images and a reasonably accurate estimate of the economic value of the enterprise can be determined by combining the ADP derived information with estimates of the value of the crops. This information could be used as the basis for removing uncertainty over the tenure and future use of the land.

On-going research within the University of Science and Technology is investigating the cropping activities of urban dwellers in low-lying valley bottoms. Even though these areas belong to government agencies, there are currently no attempts to restrict individuals who want to farm on these lands. Most people growing crops in these gaps are aware of the temporary nature of the tenure and know that when the need arises they could be asked to stop farming activities. However some farmers have been cropping in these areas for over 20 years without any interference from the agencies that own the land.

An area to the north of the Accra-Kumasi highway was visited. The valley bottom sites close to homes were farmed to spring onions although the drier areas were planted with plantain. The site was shared among the occupants of the nearby houses. Sometimes individuals from outside the community were permitted to use land on request. One operator interviewed had 30 transplant beds. The spring onions were grown by vegetative means. Reasons were that they are fast growing and yield better than seeds, and also the difficulty in getting viable seeds.

Operators could realise between just C25000 and C60000 from each bed depending upon the time of year and quality of crop. C10000 worth of onion seedling were planted on each bed. The transplant beds were fertilised with C600 worth of poultry manure during bed preparation. The beds cost C5000 to construct and watering per bed per day was C1000. Water from hand dug wells was used for watering crops. Due to pest problems (white snail attack on leaves) lettuce was grown only during the dry season.

Detailed information was obtained regarding the economic value of the crops grown under intensive cultivation in the area. By combining this information with an inventory of the vegetable crop production, accurate estimates of the economic value of the enterprise can be readily obtained. Once again this information was gathered rapidly using the ADP images as a stimulatory aid.

Key Findings

The image maps can be used as an important aid to stimulate exchange of information on the economic value of resources. Economic information can be combined with information derived from the image maps to allow accurate valuations to be made of agricultural enterprises. The image maps are invaluable as an aid to the development of action research programmes where direct observation and sampling are involved, for example water or soil pollution issues.

Workshop

A workshop was held at the University of Science and Technology to present the results of the field visit and discuss the findings in the context of poverty alleviation in the peri-urban region. There were 22 participants at the workshop representing a range of University and external agencies. A presentation was made by the UK researchers and UST field work team that reviewed the status of the processing of the ADP image archive and presented the results of the field visits.

An open discussion session was held after the presentation. Initial discussions focused on the coverage and availability of the image map products. There was a clear preference for access to image maps derived from the full resolution images rather than the reduced resolution mosaics. Subsequently discussion focused on the perceived value of the image map products. It was recognised that the image maps and derived products had value at both community and district level, as ways to obteain information about natural resources from any other source was extremely limited and time-consuming.

It became apparent during the workshop that the image maps have value as a source of information that is accepted as being both objective and transparent. Evidence of the value of these characteristics was obtained during discussions about the defunct sewage treatment works on the UST campus. The institutional representative from UST consistently denied that this facility was working or polluting a local catchment when questioned during a workshop. However, once digital photography was presented of the sewage treatment works and the potential area of pollution quantified, the true situation was accepted and the need for an urgent review agreed.

5. Outputs

Initially, the project aimed to achieve the following logframe outputs which were closely related to the logframe activities:

1. A literature review on various aspects related to the project.
2. Stratification map and report showing locations for stereo image acquisition and village PRRA sampling
3. Preliminary rapid rural appraisal results and report
4. Report on most appropriate image acquisition system
5. Photomosaic map and associated field data for Kumasi
6. A prototype GIS system with simple user interface and modelling demonstration capability
7. Reports on transferability of prototype image acquisition and GIS system and new and appropriate technological developments

Given the change in emphasis and findings in the earlier parts of the project, output 7 was revised to cover further use and testing of the imagery and supporting material in the development of local action research themes.

Output 1. Literature reviews.

“A literature review on various aspects related to the project.”

The literature was searched and reviewed and the full results are included in Appendix 1. The individual literature reviews proved useful on their own, and in formulating objectives and hypotheses to be tested in each of the research activities.

The literature review covered various aspects related to the project including reviews on:

- Recent developments in GIS software, hardware and applications of interest to the project objectives;
- Recent research and developments in design and development of user interfaces for the broadest range of users possible;
- Towards a synergistic use of RS/GIS technologies in participatory resource assessment;
- Recent developments and methods for incorporation of socio-economic data, including storage and manipulation of “fuzzy” data, incomplete data sets, scaling-up and scaling-down issues and spatial generalisation methodologies ;
- Methods of sampling with reference to stratifying the peri-urban area to help direct the preliminary RRA sample locations and higher resolution stereo image acquisition .

The reviews were provided as interim reports, and are included in Appendix 1. They were widely circulated amongst all the NRSP projects, and at collaborating institutes in Ghana.

Output 2: Stratification map.

"Stratification map and report showing locations for stereo image acquisition and village PRRA sampling. "

The development of the village database and the maps of areal change in built area of the villages was described under section 4.2. The areal change of villages showed to be a good proxy variable for the change of village characteristics (from more rural to more urban-based economies). The spatial distribution of the fastest growing villages was spatially uneven and could not be adequately represented by concentric circles around Kumasi. Instead, patterns of village growth were found to be related more closely to the road network and ease of access to the city and its markets is almost certainly a key factor in determining the rate and direction of development. However, some anomalies were found where low development rates had occurred at villages quite close to the city due to some resistance to urbanisation pressures, or where there had been land disputes. Conversely, some villages with poor access to the city had demonstrated faster growth, apparently where some locally specific industry, such as soap-making, had developed. The method for village stratification is one that can be applied quickly and independently and allows for scaling-up of the results.

It was initially hoped that the stratification would have been done with the other researchers from the KNRMP, but because of timing and initial funding delays, they had already developed a stratification system for collection of their VCS data independently of our work. However, we did take into account their further needs and plans and incorporated areas of image sampling that were used for some of their projects (e.g. the urban gaps study). Although we had initially planned to target villages for more detailed PRA work, the work of the KNRMP and the provision of their results to us made this less necessary.

The stratification map and village database in the form of the village change figures and correlation with parameters such as travel distance to Kumasi have been used widely in this and other projects, and by researchers and planners in Kumasi.

Output 3. Preliminary Rapid Rural Assessment- Development of Rapid Rural Mapping Methodology.

"Preliminary Rapid Rural Appraisal (PRRA) and report".

By the time this project received its funding and was able to start, the KNRMP had already conducted a number of detailed PRA's. We therefore oriented our work more to the contribution of remote sensing and GIS in the participatory process. This work is detailed more fully in section 4.4 and Appendix 4. The salient points are:

- The joint inter-disciplinary work of natural resource and socio-economic scientists was extremely important in this part of the project.
- A method for rapid rural mapping of both natural resource and socio-economic data was developed which could be applied quickly with a minimal amount of expectation-raising within the community.
- ADP imagery provided a new, up-to-date and informative perspective of the local environment which could be used as the basis for development of layout maps and plans
- Most local dwellers could interpret the imagery with no difficulty after an initial introduction, but there was not sufficient time to fully investigate whether any of the groups were disenfranchised or limited by its use
- The imagery and maps were useful in stimulating discussion and debate
- Most of the work done was in an extractive, rather than in a participatory, way. This was due largely to the fact that we did not want to raise any expectations about being able to implement any remedial or intervention strategies. In a development project with a budget for implementing remedial actions, such as improving production or making livelihoods more secure, the work may have been more participatory in nature. The general lack of planning (or at least community participation) at the community level was apparent.
- The methodology and data proved very useful in deriving information such as land ownership, village extent and crop management maps. The imagery with detailed interviews and historical data may provide a useful means for assessing land use change.

Output 4. Appropriate Image Acquisition Systems.

"Report on most appropriate image acquisition system"

As part of this project, the Bath Geotechnologies group carried out a review and some trials to see if platforms other than small fixed-wing aircraft could be used in areas where it was not possible to use these, and whether or not the operating costs may be significantly cheaper. The usefulness of tethered balloons and microlight aircraft was assessed (see Appendix 2 and 3).

For small-area remote sensing applications, the tethered balloon was found to be a simple, easily deployable, cost-effective solution requiring little maintenance. The system was easily transportable and responsive to image requirement demands. However, the major difficulty was in manoeuvring it especially in windy conditions of where there were many obstructions on the ground such as telephone lines or power cables.

Microlights were found to be a low cost, compact and transportable aircraft capable of performing the majority of manoeuvres of a light survey aircraft. Their power to weight ratio and efficient wing geometry gives them low stall and cruise speeds, and enables them to perform short take-offs and landings on the majority of natural surfaces. The power units do not require aviation grade fuel (AVGAS) and need little maintenance. This enhances its range and area of operation. Their ability to perform in cloudy conditions, below any cloud base when appropriate wide-angle lenses are used is another advantage. Furthermore they have a relatively low capital, maintenance and flying cost. However, in field trials, shock and vibration were found to be limiting factors, and the design of special mounts would be required. Further details of the field trials conducted in the UK are provided in Appendix 3. Whether balloon or microlight aircraft are used, the use of differential GPS is recommended.

Although they were not needed in Ghana, the reported usefulness and cost-effectiveness of these alternative platforms was a useful contribution to the NRSP as they may have to be used in areas where the use of fixed wing or other aircraft is not possible technically or politically.

In Ghana, the project had developed a good collaborative understanding with the Ghana Air Force who had previously flown data for us, and were willing to do it again. There are also a number of very good survey companies that could provide the service. In this project we used a company called CTK who provided the cheapest quote or survey.

Output 5. Photomosaic ADP map of Kumasi.

"Compilation of photomosaic map for Kumasi, including ground data, interpretation and report"

Our original intention had been to acquire ADP for a large area of about 40km x 40km around Kumasi, with a nominal spatial resolution of about 1m. However, there was persistent cloud cover during the period allocated for flying, and so the objectives and target area of the ADP survey had to be adapted in the field. The result was that the survey was conducted at a much lower height below the cloud base. This led to a much more detailed nominal spatial resolution (23cm), but a reduced coverage area.. The total area of coverage was about 290 square kilometres, consisting of 1360 individual ADP colour infrared images at a nominal spatial resolution of 23cm. The resultant data comprise an image database of 7 Gigabytes contained on 21 CD-ROMs, which consisted of a data volume of an order of magnitude that first envisaged. Further details are provided in Appendix 7.

Copies of the 21 CD-ROMs containing each digital image, and software to view them was installed in the Kuminfo Laboratory at the local target institution (the Institute of Renewable Natural Resources, at the University of Science and Technology) and been provided to all the relevant collaborating projects.

A simple user-friendly image index system was developed to assist researchers to access the relevant image for an area of interest. The image index allows the users to pick a village, or define an area of interest in the Kumasi region, and the system informs the user which images on which CD are the ones required.

The data and the index have proved to be a very valuable resource in the laboratory. A number of researchers in the peri-urban projects and other projects have accessed imagery for assessment of a large number of natural resources and in developing proposals for development interventions in certain areas.

Output 6. Prototype Geographical Information System.

"Development of prototype information system including simple user interface and modelling demonstration capability"

This was a key component of the project The GIS was designed to enable the display and manipulation of a wide range of quantitative and qualitative data relevant to the Kumasi peri-urban environment. Datasets included raw and classified SPOT satellite imagery, digital 1:50000 topographic maps, scanned historical aerial photographs, ADP image locations, GPS locations of field positions and transects, digital photographs from various field sites and locations, and PRA-type village maps and layouts.

The major developments of the geographical information system included:

- the development of the village database (comprising 387 villages) with associated attribute data, and village profile samples.
- the development of the ADP image index system
- The development of a facility to allow users to create scaled image and map output at a specified scale.
- The development of a simple modelling demonstration tool based on the local level assessment of development of areas for new housing development.

All outputs detailed above are incorporated into the GIS system already installed and operating at the IRNR-UST. Detailed documentation and user manuals have been provided for all modules, and full user training has been provided. The village database, ADP image index and scaled output facilities are very widely used by a number of researchers at the Institute.

The modelling facilities developed within the project were found to be useful for illustrative purposes, but were only really applicable where the data had been collected and processed.

Output 7. Action Research Methodologies

"Use of RS/GIS in the development of action research developed"

The original project plan was to have generated the following reports:
- Report on the transferability of the prototype system
- Report on the image acquisition system transfer to local area
- Report on new and appropriate technological developments

For reasons already discussed in this report, these work packages were suspended in favour of more effort on investigation and application of how the type of image information being generated by the project could be better utilised in the generation of poverty alleviation action research.

More field work was carried out between 15 – 29 September 1999, with the aim of further developing the methodology for collecting and using information on peri-urban production systems to benefit the poor, using GIS and remote sensing technology. In keeping with other areas of DfID strategy, the use of RS/GIS techniques for stimulating and developing action research themes was also developed.

In this part of the research a greater integration of the technical methods with the social and economic issues affecting the poor was achieved. A full description of the work and list of Action Research ideas is presented in Appendix 11.

The overall findings were that:
- The image maps can be used as an important aid to stimulate exchange of information on the economic value of resources. Economic information can be combined with information derived from the image maps to allow accurate valuations to be made of agricultural enterprises.
- The image maps are invaluable as an aid to the development of action research programmes where direct observation and sampling are involved, for example water or soil pollution issues.
- The image maps have value as a source of information that is accepted as being both objective and transparent.

There is clearly substantial power in the RS/GIS methods developed by this project, especially in providing information which can be used to argue a case on behalf of the poor. The key point is to identify how this power can be harnessed in peri-urban environments in order to benefit the poor.

Clearly, in the context of peri-urban developing countries, we could not expect local communities to implement or use RS/GIS directly. Indeed, given that most local communities will not even be aware of RS/GIS techniques or their potential, they are unlikely even to request it. However, this does not mean that RS/GIS cannot be used in service of local communities, or that these communities should have no control over how it is used. An intermediary body- an NGO (ideally), or a government, university or surveying agency- could adopt the techniques and apply them in development projects or interventions that seek to implement poverty alleviation measures, as is done in the Indian watershed project (Lobo 1996, Honore 1997).

Many of the technological problems in implementing the techniques illustrated in this project have been solved during the research so the application of our methods will be much smoother if the recommendations made in this report are followed closely. The remaining problems are more institutional (in terms of equipment, training, sustainable operation and maintenance) rather than methodological or technological. Intermediary bodies could now have a range of techniques which would allow them to match more closely technology to the requirements of practical tasks. These techniques range from simple mapping using sketch maps, to technical maps, to digital images, to resource mapping using RS/GIS and to use of GIS itself as an analytical, modelling and planning tool (as discussed by Poole (1995)). They should also be able to control the accessibility of products to local communities. Indeed, it could be argued that local communities should not be de-linked entirely from GIS, or data analysis, mapping and modelling of planning and impact scenarios will remain totally in the hands of planners and experts, thereby undermining any original intentions of developing popular participation (Quan et al, 2000).

Our research has shown that recent imagery produced to a large-enough scale (for example, 1: 2000 to 1:5000) is very useful in stimulating participatory surveys and discussions, and for extracting important information about natural resources and socio-economics. The technology required to produce such products currently exists in Ghana, and can be developed fairly easily, relatively cheaply and in a sustainable manner in other locations. Given time and resources, research that could be applied to further develop the use of RS/GIS in participatory work includes the following topics:

- Is the imagery equally interpretable by all local dwellers, or are there some groups which would be disadvantaged or further marginalised by not being able to interpret the imagery? What are the best ways to introduce the imagery in participatory work, and what are the dangers to avoid in the introduction of essentially external information by outsiders? How best to feedback local knowledge and information to planning agencies to improve the effectiveness, accuracy and representativeness of the GIS?
- How do different social groups perceive their natural resource base, and how can the different perceptions be represented in GIS? How best to incorporate socially differentiated knowledge, for example by gender or by age?
- What is the currency of the data in a rapidly changing peri-urban environment?
- Who must have access to the RS/GIS products to apply them usefully? How can they be assured of access?
- What are the comparative advantages of adopting RS/GIS methods over conventional resource assessment/mapping methods? What are the cost/benefit/time implications of not using RS/GIS methods?

- Assuming that the data are provided to local communities, how far does provision of information go towards local empowerment, i.e. if they knew more about their environment what could they do about it? What are the possibilities of using GIS for more democratic spatial decision-making through greater community participation?

It is proposed that many of these issues would be better addressed in a technical co-operation as opposed to a research context where real resources for interventions were present. In such a context, more fuller community participation could be expected, and there would be no concern about unrealistically raising expectations during the participatory enquiry. Ideally, activities should focus on a relatively small geographical area where there are identifiable resource users and decision makers and impacts can be measured and replicated elsewhere in a relatively short time and at modest cost.

6. Contribution of Outputs

6.1. List of dissemination outputs

in chronological order

D'Souza,J.C. and Woodfine,A., 1998. A Review of GIS Applications of Interest to Development of Methods of peri-urban natural resource information colection, storage, access and management. Geographic Data Support Ltd. [unpublished report]

D'Souza,J.C. and Woodfine,A., 1998. A Review of GIS User Interfaces of Interest to Development of Methods of peri-urban natural resource information colection, storage, access and management. Geographic Data Support Ltd. [unpublished report]

Koh,A., 1998. The use of ballons and their suitability as imaging platforms for the color infrared aerial digital photographic system. *Geotechnologies Reports* , Bath Spa University College, 8pp

Koh,A., Curr., R.C., Curr,G. and Edwards,E., 1998. An evaluation of the use of microlights as an operational platform for the colour infrared aerial digital photographic (ADP) system. *Geotechnologies Reports,* Bath Spa University College. 15pp.

Koh, A. and Edwards, E., 1997. Color infrared aerial digital photographic system survey of Kumasi, Ghana, December 1997. *Geotechnologies Reports,* Bath Spa University College. 10pp plus disk. [unpublished report], plus 21CD set of data and quicklooks.

Marshall,D.C. and D'Souza,G.,1997. Two Analytical Tools: GIS and PRA. A review of PRA/GIS literature pertaining to Development of Methods of peri-urban natural resource information colection, storage, access and management. Cranfield University, Silsoe College [unpublished report]

Taylor, J.C., Thomas, G. and Marshall, D.C., 1998, Application of satellite image-mapping for Rapid Rural Mapping, Cranfield University, 15pp. [unpublished report]

Taylor, J.C., Thomas, G. and Marshall, D.C., 1998. Application of satellite image-mapping for stratification of the peri-urban interface around Kumasi, Cranfield University, 18pp, plus 10pp Appendix. [unpublished report]

D'Souza,J.C. and D'Souza,G., 1998. Database of 387 villages in and around the Kumasi peri-urban area, Report and manual for use.8pp. Geographic Data Support Ltd., [unpublished report]. Software installed at NRI for KNRMP and at IRNR-UST Kumasi

D'Souza,J.C and D'Souza,G., 1998. Village datasheet samples. Sample sheets of information about peri-urban villages in and around Kumasi. Geographic Data

Support Ltd., [unpublished report].

Thomas,G., Sannier,C., Taylor,J.C. and Koh, A., 1998. Estimating the Datum Transformation Parameters for use with the Ghana National Grid System, 12pp. [unpublished report]

D'Souza,G. and Thomas,G., 1998. Towards a toolbox of participatory enquiry tools. Summary of presentation at 4th Meeting of the NRSP Peri-Urban Mini PAC, Wed 21st October 1998

J.C. Taylor, G. Thomas, & D. C. Marshall, 1998 Development of Methods of Peri-Urban Natural Resource Information, Collection, Storage, Access and Management. Workshop Presentation, University of Science and Technology, Kumasi, Ghana. September, 1998.

G. Thomas, 1998. The Peri-Urban Interface of Kumasi, Ghana. Seminar, Cranfield University, July 1998.

G. Thomas, J.C. Taylor & D. C. Marshall, 1999. Exploring Socio-Economic and Natural Resources Interactions with GIS and Remote Sensing. Workshop Presentation, University of Science and Technology, Kumasi, Ghana. September, 1999.

D'Souza,J.C and D'Souza,G., 1999. GIS-based village level planning system. Report and User Manual 23pp, plus appendices. Geographic Data Support Ltd., Circulated to and software installed at KNRMP and IRNR.

D'Souza,J.C., 1999. ADP Image Index. Report, user manual and software installed at IRNR-UST, Kumasi. Interim Report.

D'Souza, G., 2000. A GIS for village level assessment and development planning. In Proceedings of Final KNRMP Workshop in Kumasi, Ghana, 9th – 11th February 2000.

G. Thomas, J.C. Taylor & D. C. Marshall, 1999. Participatory Inquiry in the Peri-Urban Interface Using Rapid Rural Mapping. Presentation at DfiD sponsored workshop on Geographical Information Systems and Participatory Methods. Commissioners House, Historic Dockyard, Chatham.

G. Thomas and J.C. Taylor, 2000. Supporting Rural Development: A Role for Geographical Information. Presentation at Graduate Symposium on Rural Development-lessons learnt, future prospects, Cranfield University, Silsoe, Beds.,UK.

G. Thomas and J.C. Taylor, 2000. Sustainable Livelihoods in the Peri-Urban Interface: A Role for Geographical Information. Poster presented at the International Conference on the Future of the Mediterranean Rural Environment: Prospects for Sustainable Land Use and Management, 8-11 May 2000, Menemen, Turkey.

G. Thomas, C.A.D. Sannier, J.C. Taylor, 2000. Mapping Systems and GIS: A Case Study using the Ghana National Grid. *Geographical Journal* (in press)

6.2. Other contributions to development goals

As well as the reports and publications listed above, the project contributed to several other research projects and proposals. Imagery and field information was provided to the KNRMP (some of which was used on their CD-ROM which was widely distributed), and also to project R7330 (the watershed development project). The software installed at IRNR has been used extensively by researchers from this programme and others.

A number of workshops and training seminars have also been held in Kumasi, involving a large number of participants.

The ADP have been used widely for a number of purposes, and a number of regional and town and country planners are now actively pressing the Regional Assemblies to commission the data collection and processing to update their knowledge on natural resources in their area.

The researchers involved in the project are continuing to develop publications from the work of the project. A web-site is also being designed to disseminate more widely the information derived during the course of the project.

6.3. Further stages needed to develop the Outputs

There are a number of stages that could usefully be carried out to develop the Outputs:

1. Workshops should be in both the UK and Ghana to describe the methodologies developed and their practical application. Further close collaboration between socio-economic and physical resource researchers should be sought.
2. This report and the underlying datasets should be condensed and made available as a CD-ROM for general dissemination, with a copy made available via Internet access. Although the Internet is not a feasible option in Ghana at the moment, most UK researchers rely on it, and its accessibility in Ghana should improve in the near future.
3. A further review of which target institutions would be able to use more fully the technology and methods developed should be carried out. An appropriate intermediary body, e.g. an NGO or agency, should be identified which has most need for the data and methodologies developed. Current ongoing

development projects that can make use of the data should be identified and supplied with copies if necessary.

4. The outputs of other research programmes, e.g. R6756, R6799, should be reviewed. If their dissemination methods of CD-ROM and video documentaries have been successful, similar dissemination outputs for the results of this project should be produced too.

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List of Appendices

1. Literature reviews on various aspects of the project
2. The use of balloons and their suitability as imaging platforms for the color infrared aerial digital photographic system
3. An evaluation of the use of microlights as an operational platform for the color infrared aerial digital photographic system
4. Application of satellite image-mapping for stratification of the peri-urban interface around Kumasi.
5. Database of 387 villages in and around the Kumasi peri-urban area
6. Estimating the Datum Transformation Parameters for use with the Ghana National Grid System
7. Color infrared aerial digital photographic system survey of Kumasi, Ghana, December 1997
8. Index to ADP imagery, report and user manual.
9. Application of satellite image-mapping for Rapid Rural Mapping
10. GIS-based village level planning system
11. Solving socio-economic and natural resource issues with GIS and Remote Sensing