Cranfield UNIVERSITY
Silsoe

Solving Socio-Economic and Natural Resources Issues with GIS and Remote Sensing

Development of methods of peri-urban natural resource information collection, storage, access and management

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G. Thomas, J. C. Taylor & D.C. Marshall
Cranfield University
United Kingdom

In collaboration with

Dr. James Quashie-Sam, Dr. Sam Oppong, Olivia Agbenyega,
Dr. B.E. Kwesi Prah and Kingsley Boateng,
University of Science and Technology
Ghana

Cranfield University
Silsoe
Bedfordshire
MK45 4DT

Tel: +44 (0)1525-863000
Fax: +44 (0)1525-863001

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1. Introduction

1.1 Background to the visit

A field visit was undertaken to Kumasi during the period 15 to 29 September 1999. The aim was to further develop methodology for collecting and using information on peri-urban production systems to benefit the poor, using GIS and remote sensing technology. Previously, a series of map products were developed using the aerial digital photographs and satellite imagery acquired for the project. Initial testing of the map products was undertaken during a previous visit to Ghana in the villages of Swedru and Pease.

In this visit a greater integration of the technical methods with the social and economic issues affecting the poor was sought, with the aim of identifying actions that would bring material benefits. This report details the progress made in accomplishing this aim. The procedures developed during the previous field visit in 1998 were used to develop large-scale image map products for use during field survey based upon the aerial digital photographs. It is important to note here that the image maps contained in this report are illustrative and are not reproduced at true scale, i.e. at the scale at which they were used during the surveys. An example image map at true scale is presented at the end of the report. Access to image data suitable for the rapid production of map products at scales of 1:2500 is unprecedented for use in studying the peri-urban environment.

1.2 Geographical overview of the south-east Kumasi study area

The study is geographically limited to an area where aerial digital photographs have been processed into a mosaic of the SE Kumasi urban fringe (Figure 1). The area includes the campus of the University of Science and Technology, small-scale industrial developments and several villages that are undergoing various transitions from natural resource-based to urban-based economic activity.

1.3 Identification of priority issues

A 1:10000 scale image-map of the study area was produced using a portable image processing system. 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 Cranfield University field 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 the subsequent discussions (Figure 2). The focus group identified the following issues with the aid of the ADP mosaic:

- land use and social change in areas evolving from natural resource based to urban based economies;
- pollution of water courses;
- land use and tenure conflict in valley bottoms.

Local knowledge and experience of focus group members was used to identify the geographical locations on the image map where examples of these issues were to be found for exploratory investigation.

1.4 Key Findings

It was apparent from the participatory 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.

Figure 1 ADP image mosaic of the south-east Kumasi study area

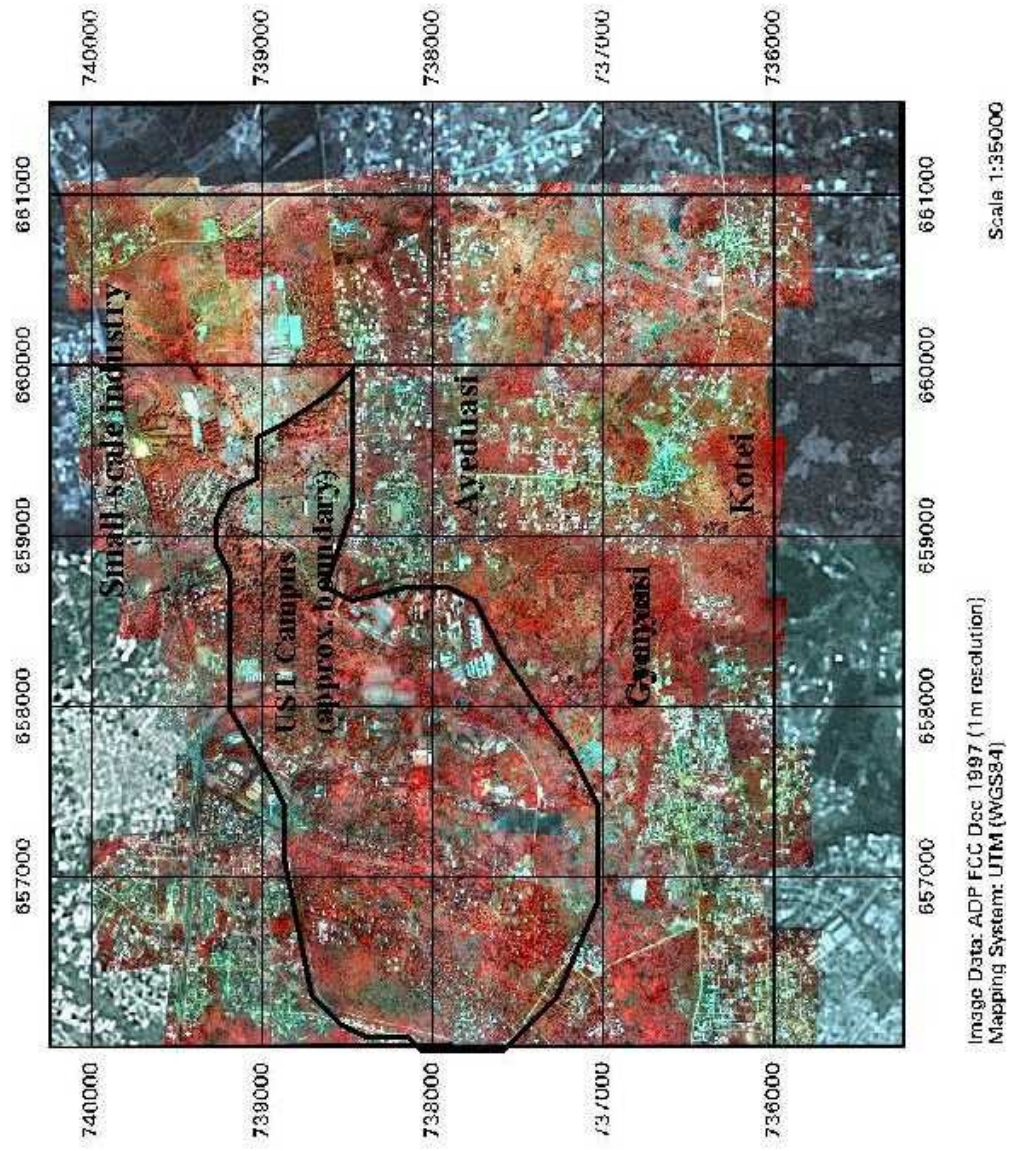
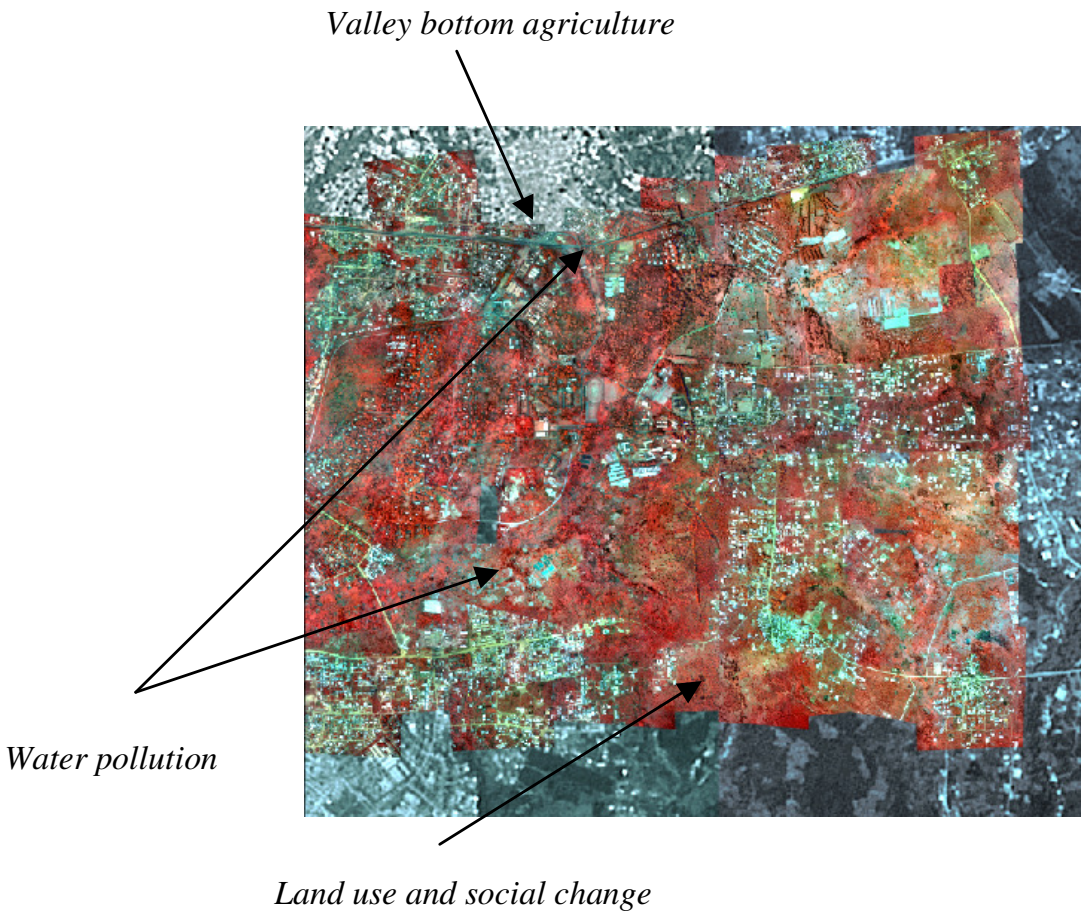


Figure 2 Stimulation of participatory discussion for identifying and localising priority issues



2. Land Use and Social Change near Kotei/Tweneduasi

2.1 Introduction

The theme of land use and social change was identified during the focus group as being an important issue affecting the villages of Kotei and Tweneduasi. The pattern and scale of land use change between the 1960s and 1997 is evident from comparison of available 1960s, 1:10000 scale, panchromatic aerial photography (Figure 3) and the 1997 ADP derived 1:10000 scale image map (Figure 4). The built environment of the two villages has merged, such that the smaller village of Tweneduasi is located adjacent to the east of Kotei.

During the initial focus group, the geographic bounds of the study area were agreed and provided the basis for subsequent development of additional image maps. The aerial photographs were scanned and geometrically corrected in the Kuminfo Laboratory to allow map products to be derived. A procedure was developed during the visit to allow geometric correction to be undertaken using the IDRISI software. This was necessary because the GIS software in use in the lab did not at that time have the capability to implement this process.

The use of the map products as an aid to the process of collecting socio-economic information was then tested and refined by visits made to Kotei/Tweneduasi.

2.2 Deriving contextual information from image maps

The image maps were initially visually interpreted to extract contextual information about the study area that might have relevance in structuring subsequent surveys. In particular information was sought regarding:

- 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
- the structure of the village built environment

Interpretation of the image maps revealed that 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 (Figures 3 and 4). The main village built environment area exhibits a smaller degree of change, with recent developments taking place mainly on the eastern side. Little development has taken place in the lands to the south of the village.

Figure 1 1960s 1:10000 scale aerial photograph of Kotei/Tweneduasi

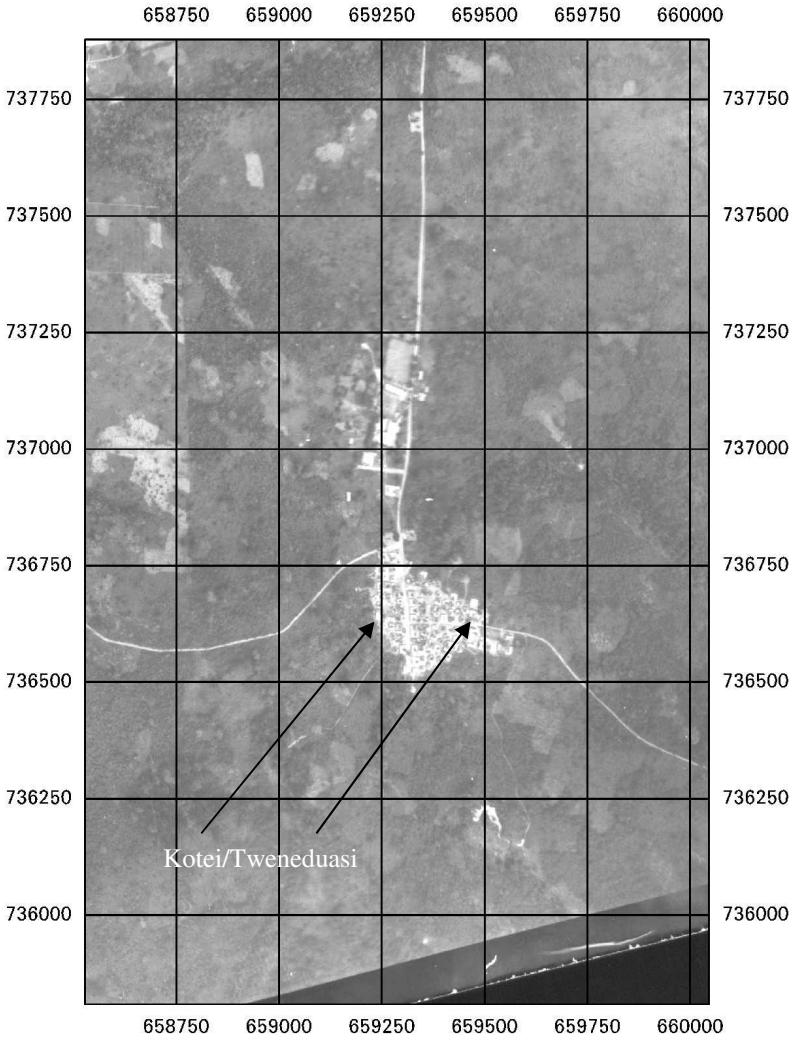
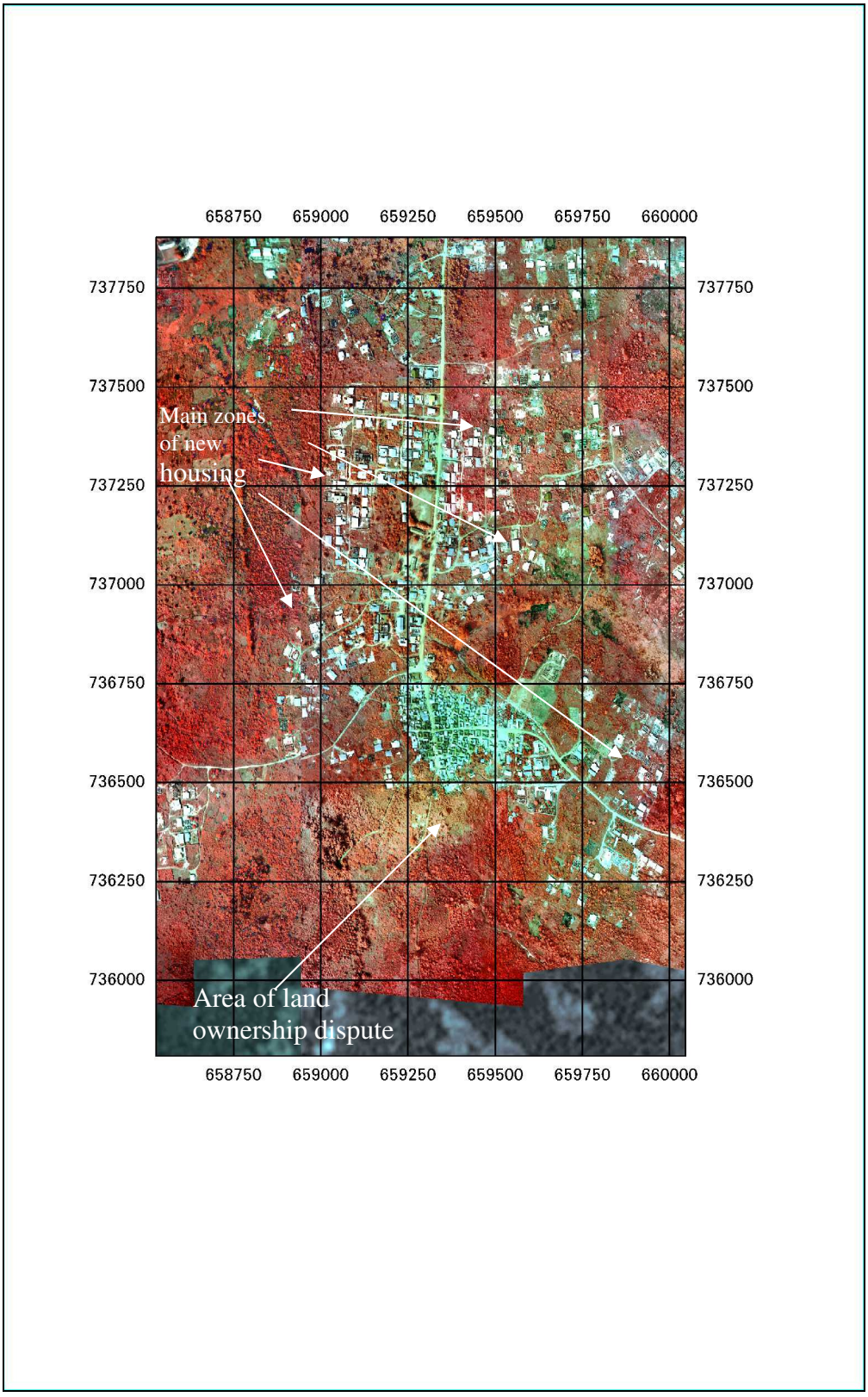


Figure 2 1997 ADP image of Kotei/Tweneduasi



2.3 Reconnaissance surveys

Reconnaissance 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 were held with members of the village. The selection of persons interviewed was ad-hoc and included the following:

- Detailed discussion with Mr Kwarteng who has lived in the village all his life;
- Discussions with Mr Kwame, a member of the Unit Committee, who has lived in the village for the last 5 years;
- Discussions with Mr Azamoah an elderly member of the community;
- Discussions with women selling produce in the market;
- Members of a small soap-making co-operative;
- Various people, using the maps as a stimulus for discussion of the issue of urbanization of the area.

The people were able to identify clearly the change that has taken place during the last 30 years in terms of loss of natural resources. The following opinions and ideas were elicited during the discussions:

- urban forces in the form of the establishment of new settlements have resulted in considerable reduction of natural resources in the form of: land for cropping; the wildlife habitat; loss of medicinal plants and scarcity of fuelwood;
- natural resource-based production systems are no longer a principal source of livelihood for particular groups of poor people because:
    1. There have been shifts in occupation from farming and hunting to buying from commercial centres in the city for sale in the community. This has made some people worse off;
    2. Raw and cooked foods sold in the market are not from local farms;
    3. There is more reliance on urban production systems such as soap making and providing skilled and unskilled labour for the construction of houses in new settlements;

- existing urban production systems obtain natural resource-based raw materials from outside the community and not from the natural resource systems in the community;
- opportunities exist for using natural resource systems to feed these urban production systems;
- there is more reliance on charcoal instead of fuelwood which used to be obtained from sources near to the village.

Various other opinions were expressed:

- loss of natural resource systems has had a negative effect on livelihoods, some people are worse off;
- loss of natural resource systems has had some positive effects as it resulted in the provision of amenities, electricity and pipe borne water (too expensive to provide the amenities to a small village on its own);
- a few individuals, if given the opportunity, would do things differently after having seen the maps;
- those questioned were able to relate to the ADP image-maps and felt they would be a useful tool for the chiefs, elders and planners of the community;
- access to the ADP would assist the community to be in a better position to plan for change and the integration of natural resource and urban production systems;
- the natural resources 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.

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 image maps provided a powerful catalyst for stimulating the participatory inquiry process. The use during the surveys of the large-scale image maps was a direct stimulus to the exchange of information on the social implications of the rapid urban development taking place in Kotei/Twneduasi. It became apparent during the surveys that information relevant to the livelihoods of the village community could be obtained by appropriate use of the image maps in a very

short time frame and without undue raising of expectations within the village community as a whole.

2.4 Developing a programme of action research

The considerable erosion of the natural resources base around the villages of Kotei and Tweneduasi has produced a number of negative as well as positive impacts on the village inhabitants. This points to a need for an in-depth review of the current situation with all the stakeholders. The principal aim would be to discuss the requirement for development of a land-use plan to promote a balanced development of the village lands to manage the transition an urban economy with appropriate preservation of the natural resources based economy. Emphasis should be given to identifying means whereby the poorest occupants of the village may be given priority access to the remaining natural resources base within the village. The image maps provide a basis for developing such an approach.

The issue of land tenure is highlighted within the village by the on-going dispute over access to the lands located to the south of the village. It would appear beneficial if the land tenure could be established and future use of these lands demarcated to the benefit of all the villagers.

2.5 Key Findings

The availability of the large-scale image 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 during a short time period and without undue raising of expectations of the village community

The information gathered was directly focused on locally perceived priority issues and provided a sufficient basis for developing an appropriate action research programme

3. Pollution, Valley-Bottom Agriculture and Land Tenure in the Wewe Watercourse

3.1 Pollution and 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 bounds of the study areas determined.

3.2 The University of Science and Technology Sewage Treatment Works

The ADP image index was used (as described in section 5.2) to locate the ADP image covering the study site. This was extracted from the CD archive and printed for use during the survey (Figure 5). 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 6-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 6-photo 2) and this discharges untreated effluent into a nearby stream (Figure 6-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 to plantain and cassava. Crops grown in the wetter areas were sugar cane and taro.

Within the vicinity a large area of intensive vegetable cropping was observed. The area is readily identifiable on the ADP image (Figure 5). The vegetables grown were lettuce (Figure 6-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 5. ADP false colour image of the Wewe watercourse and intensive lettuce cultivation (Numbers indicate site of photographs shown in Figure 6)

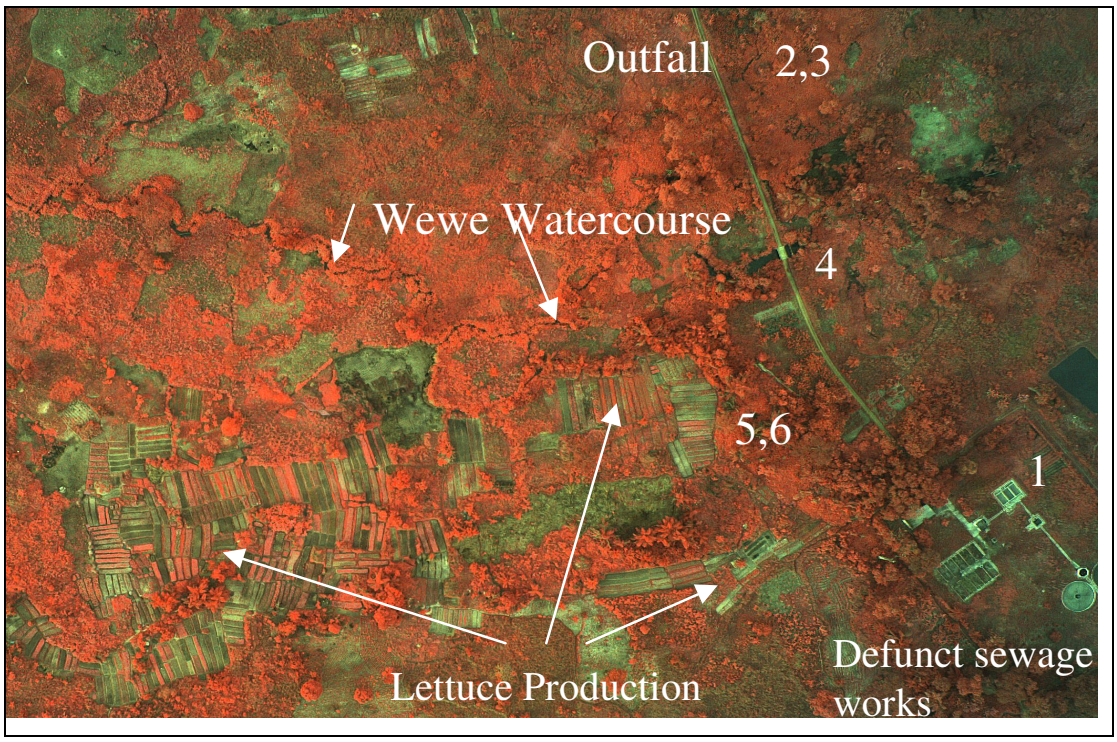


Figure 6. Photographs relating to numbers on Figure 5

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.

3.3 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.

3.4 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 exists 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 exists 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 type of economic information should be a valuable asset for use during discussions aimed at removing uncertainty over the tenure and future use of the land.

3.5 ADP and urban gaps / valley bottom agriculture

On-going research within the University of Science and Technology is aimed at 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. Once again the ADP images were used as a basis for stimulating discussion with respect to the type of agricultural activity.

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 C60000 and just C25000 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. 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.

3.6 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 derived 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

4. Awareness Raising Workshop

An awareness raising workshop was held at the University of Science and Technology to present the results of the field visit. There were 22 participants at the workshop representing a range of University and external agencies. A presentation was made by the Cranfield University 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.

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 claimed that this facility was working and denied it was polluting the 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.

4.1 Key Findings

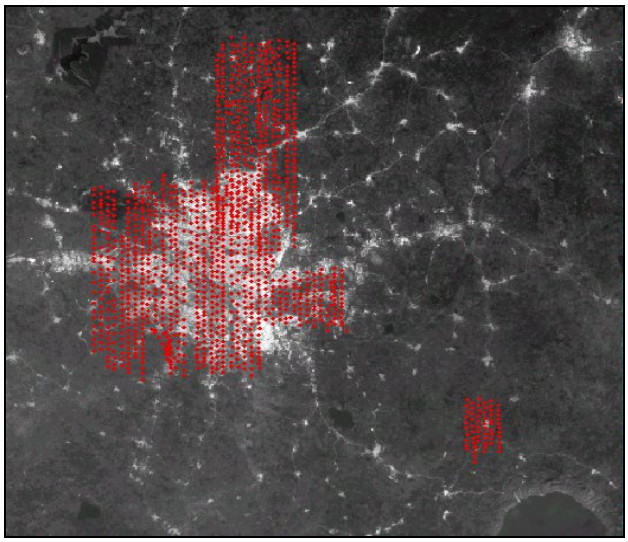
Information derived by use of the image maps has additional value because it is recognised as being objective and transparent

5. Review of Geographical Information Technologies

5.1 Aerial Digital Photography Coverage of Kumasi

Figure 7 shows the distribution of ADP image centres collected during December 1997. To date, seven digital mosaics have been processed from the available archive of ADP images for the project and their locations (SE Kumasi, Swedru, Pease, Bakwankye, Daku, New Ahenema and Ampetua) with respect to Kumasi City are shown in Figure 8. These mosaics were produced by Bath Spa University College and geographically referenced by Cranfield University.

Figure 7 Distribution of ADP Image Centres

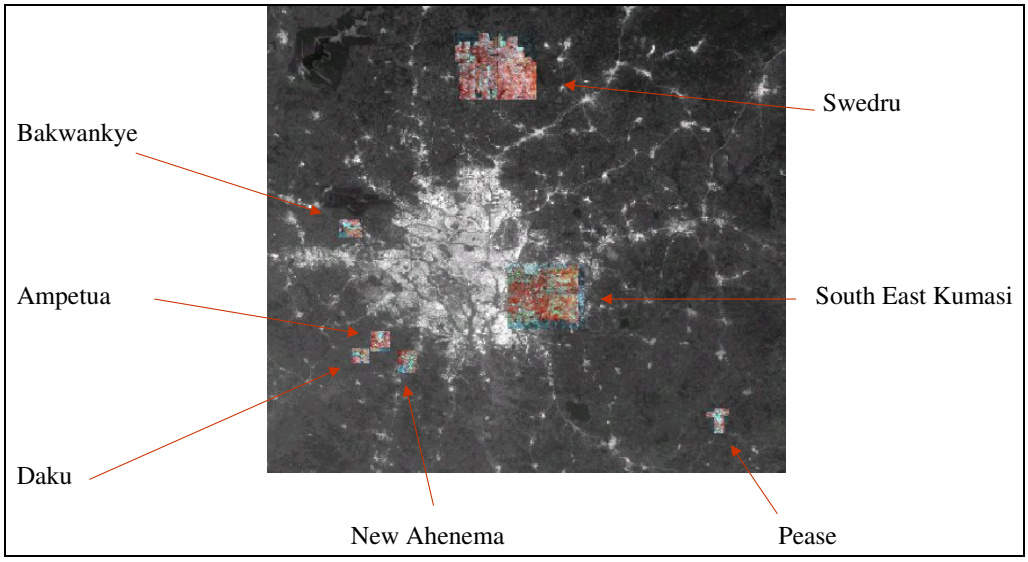


Prior to the field visit, geo-coded versions of all the digital mosaics were produced. This was because the KUMINFO Laboratory did not have the capability in house. The mosaics were geo-coded into both the UTM and Ghana National Grid mapping systems (this latter system appears to be sometimes referred to as 'Ghana UTM' in Kumasi, which is not correct). Both mapping systems are needed. The UTM version is required if maps are to be used in conjunction with currently available GPS systems. UTM versions of the mosaics have been left at the KUMINFO lab on CD.

There was a problem with the CD containing the Ghana National Grid versions and another has been sent.

Availability of geo-coded mosaics has in theory increased the capability of the KUMINFO system to produce map products for users from within the mosaic areas at different scales. However, there is a problem printing maps that are larger than the size of an A4 sheet, in sections so that they can be taped together for field use. This problem highlights a serious limitation of the current software and prejudices the uptake of the technology and use of the photographic data.

Figure 8. Distribution of ADP Mosaics

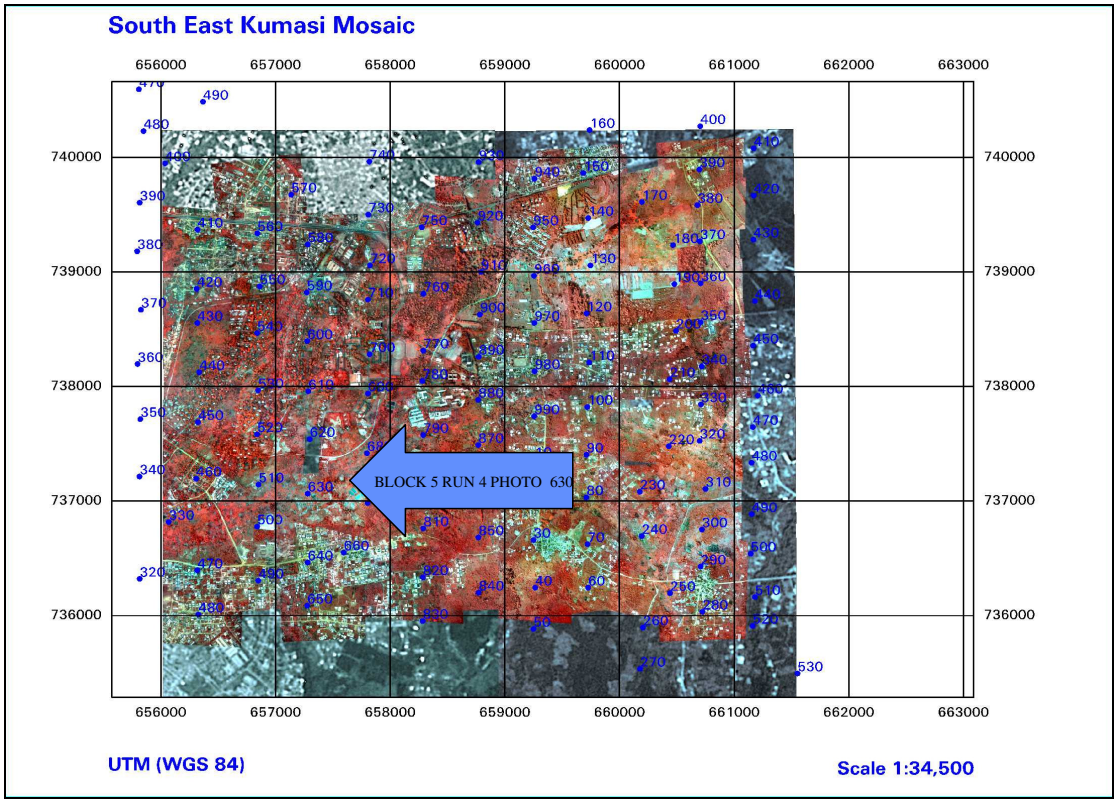


5.2 The ADP Image Index

It is often advantageous to extract and print copies of the original ADP images of parts of the case study areas because these images contain more detail than the products derived from the processed mosaics. The original images are contained on the CD archive in the lab. To facilitate rapid access of the raw photographs it is necessary to develop a geographical referencing system allowing indexing of individual images. During a survey, the positions of the image centres are recorded using GPS. Mosaics can be produced once the image positions are overlain on the satellite image using a

GIS. The image positions can be overlain on the satellite image or the ADP mosaics and thereby provides a system for locating individual images. The index available in the Kuminfo lab was not working properly. Considerable time was spent studying the index and the faults concerning the south east Kumasi study area were rectified. The problem lies with correctly matching the locations of the image centres with the block, flight-line and photo number in the CD archive. This work needs to be completed before users can access the photography of other areas on a routine basis. Figure 9 shows the index for the study area. The arrow shows some of the information that is retrieved from the GIS once an image centre has been selected. The full index parameters include the CD number, whether or not an image requires rotation prior to processing, as well as details of the block, row and image number required to locate an image once the correct CD has been selected. The production of the ADP mosaics and the ADP index rely upon access to a geographically referenced satellite image.

Figure 9. The ADP Image Index for the South East Kumasi Study Area



5.3 Key Findings

There exists widespread misunderstanding of the appropriate definition and use of mapping systems for defining the geographical frame of reference for a study region

A vital component of the design of any aerial digital photographic survey is the development of an accurate procedure for indexing the individual ADP images

The indexing procedure and the utility of the archive is enhanced by use of a satellite image to define the geographical frame of reference of the study area

6. Conclusions and Recommendations

The results of the field visit provide substantive evidence that the ability to define actions to materially benefit the poor can be enhanced by application of the geographical information technologies. This finding is based upon the following:

- Image maps and aerial photographs are 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 is readily undertaken by use of the image data
- The availability of large-scale image maps provides a direct stimulus to the exchange of information on the social and economic implications of changes in the natural resources base
- A substantive amount of information can be obtained during a short time period and without undue raising of expectations of the village community
- The information gathered is directly focused on locally perceived priority issues and provides a sound basis for developing an appropriate action research programme
- Economic information can be combined with information derived from the image maps to allow accurate valuations to be derived 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
- Information derived by use of the image maps has additional value because it is recognised as being objective and transparent
- A vital component of the design of any aerial digital photographic survey is the development of an accurate procedure for indexing the individual ADP images
- The indexing procedure and the utility of the archive is enhanced by use of a satellite image to define the geographical frame of reference of the study area

On the basis of these results it is recommended that the preliminary programmes of action research defined for the Kotei/Tweneduasi and Weve catchment studies are used as the framework for more detailed work in these areas.