The Peri-Urban Interface:

a Tale of Two Cities

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Contents

7 GIS and the peri-urban interface

Introduction

Cartography is as old as civilization, essentially unchanged over millennia until the last 10 or 15 years. The advent of readily available computers facilitated the evolution of Geographic Information Systems (GIS), which essentially was born as a way of digitising cartography (Miranda, 2000). It enabled the development of thematic overlays of conventional maps (e.g. population densities, land use types), which are descriptive uses, and spatial analysis allowing area, perimeter and volume calculations. Theoretically, GIS also allows qualitative spatial analysis such as diversity, proper or improper land use, simulation of alternative land uses, interactions between different land uses, probable impact of new agricultural practices on the environment, etc. In the peri-urban context, for example, this could encompass quantification of the expansion of built-up areas and new roads and their effects upon use made of land for agriculture or forestry. These possibilities spawned a series of GIS-based projects in the Kumasi city region, and these are described in this chapter.

Use of land can be described at several levels, or hierarchies: plot, field, farm, village, valley, watershed or district, each operating at a different scale. The type of technology employed to describe each level varies according to scale. For example, in Kumasi a satellite (SPOT) image taken in 1994 was superimposed as a layer over a 1974 paper map to determine the extent of urbanisation over that period. However, satellite imagery does not have the resolution to describe features at the lower end of the hierarchy. Here, aerial photography is a more appropriate technology, and this chapter describes how this has been utilised around Kumasi. GIS can also be used to generate thematic overlays from relational database management systems. Such a system (KUMINFO) has been developed for Kumasi, and was developed to assist planners.

This chapter will describe the situation in Hubli-Dharwad first, as this is the simpler of the two cases. In Kumasi there has been considerable input into developing a GIS, spanning several projects. The objectives and outputs of each sub-project are described here.

GIS and maps for Hubli-Dharwad city region

Map and GIS resources available, Hubli-Dharwad

University of Birmingham *et al* (1998b, p.196 ff.) gives a summary of the map and GIS information available for Hubli-Dharwad: The current (1998) software and hardware facilities being used for GIS are summarised (Table 7.1).

Table 7.1. Summary of map and GIS information available for Hubli-Dharwad city region

Type	Scale	Availability / Utilisation / Remarks
Topographic	1:50,000	Maps published in 1978. Rarely used in planning, partly because difficult to obtain from SoI, Bangalore, partly because of lack of "map culture".
Soils	All 1:250,000	Availability and use not known. Probably poor.
Geology		
Forests		
Drainage		
Major Irrigation		
Groundwater		
Census	1:126,720	
Urban Planning	>= 1:7,800	
Revenue Maps	1:10,000 ?	Revenue Department originals only. Details not accurate
Remote sensing data (University of Birmingham *et al*, 1998b, p. 200)		Karnataka State Remote Sensing Technology Utilisation Centre (KSRSTUC), Bangalore has capability to use remote sensing to map and monitor land use & water resources. Development of capabilities to apply work to PU problems and integration with GIS work of the District Natural Resource Data Management Service (NRDMS) is needed (University of Birmingham *et al*, 1998b, p.202).
GIS (University of Birmingham *et al*, 1998b, p.196)		NRDMS produces GIS maps on district basis, but not specifically for the PU project. Software & peripherals inadequate. Problems with matching locations of villages. Topographical sheets have been scanned - raster data only.

A summary of present users of GIS in the area is given in table 7.2 (University of Birmingham *et al*, 1998b, p.206).

Table 7.2. Users of GIS in Hubli-Dharwad city region

Organisation	**Use**
NRDMS	GIS used for district administration
HUBLI-DHARWAD Urban Development Authority	GIS being used for land records
KSRSTUC/ RRSSC	Have produced hard copy maps of Hubli taluk showing land use, land cover, soils - all being used by Principal Agricultural Officer
Forest Department	Have hard copy outputs from NRSA showing forests
Geology Department	Used for planning in coastal and mining areas

The picture is one of growing capability in GIS and satellite imagery but its use for storage and retrieval of maps seems to be more widespread than for planning and analysis. These skills need to be developed further if the technologies are to be of value to PUI projects. More analysis of the information entered onto GIS systems need to be undertaken.

The "Hubli-Dharwad Baseline Study" project (c.f. R6825) produced some thematic maps based on the 1981 and 1991 censuses, depicting changes in village populations (University of Birmingham *et al*, 1998a, p.19) and changes in number of landless people in 25 surveyed villages (ibid, p. 29). That is the entire extent to which projects based there have utilized GIS methodologies. Availability of maps for the area is limited (Table 7.1). One of the editors (RMB) attempted during the production of this book to procure 1:25,000 maps for the Hubli-Dharwad area from the Survey of India office in Delhi, but these maps were not in stock. The lack of maps and natural resource data to facilitate better planning has been remarked on by several authors (*e.g.* Fowler, 2000). The use of satellite imagery and aerial photographs to make up to date thematic maps is thus quite justified.

Application of GIS, GPS and ADPs in Kumasi

Introduction

As already mentioned, there has been considerable investment is establishing GIS in Kumasi. A list of resources is given in Holland *et al* (1996b). Unfortunately, the degree of integration between projects has not always been as great as it could be, although more recent projects have started to utilize and

expand the capabilities of the KUMINFO GIS. A range of software has been used for GIS in addition to the frequently used Arc-Info and Map-Info. Software had included Iconoclast (which apparently cannot export to any other software), Idrisi and Autocad. Clearly much better standardisation is needed, and KUMINFO has settled upon Arc-Info. Ways of integrating the utilisation and sharing of digitised information as well as making it more available is nevertheless still needed. Land evaluation maps at much larger scales than are available are also required if they are to be of use for local planning.

This section of the chapter is an appraisal of the knowledge generated by a series of technical GIS related projects, or GIS components within other projects. As these projects were principally determining the suitability of remote sensing for mapping purposes, they dealt with in this chapter in a document by document manner, unlike the format used in previous chapters. This approach was considered to be the most suitable for the following projects:

- R5149, "LARST CORE: Development of local satellite data reception" (duration 1989 to March 1996).
- R6347, "Integration of remotely sensed environmental data of different resolutions and spectral characteristics for natural resources management" (duration April 1995 to March 1996)
- R6799, "Kumasi natural resource management" (incorporating sub-project "Installation, support and maintenance of an integrated information system for peri-urban natural resources systems research") (duration January 1997 to March 1999).
- R6880, "Development of methods of peri-urban natural resource information collection, storage, access and management" (duration January 1997 to March 2000).

Further details of these projects are presented in Appendix 1.

R5149, "LARST CORE: Development of local satellite data reception" (duration 1989 to March 1996).

The overall objective of LARST activities was to improve renewable natural resource management by enabling local resource managers to obtain and use environmental information from satellites. This core component project concerns itself mainly with basic issues of satellite data reception and processing. Some development in this direction had already occurred as part of the construction of the NOAA Operational Manager (NOM) within the Africa Regional Project (T0480). This software combines NOAA data capture with downstream product generation. The NOM is also designed to be used in concert with third party software packages should such an application to be required. Success with the development of direct, real-time, in-country reception of NOAA data has stimulated the development of high resolution satellite reception capabilities.

The prototype tested core software: LARST satellite receiver systems for local reception and processing of data. The systems evolved throughout project and became more user-friendly and automated.

The need for very high resolution information was addressed by the airborne remote sensing research activities (AIS) involving low cost videography and digital camera systems. This work provides low cost accessibility to extremely high resolution information useful in its own right in urban locations and rural areas with small field plots but also offering another layer of detail for comparing and calibrating other data sources.

The use of GIS for data integration - focus on areal interpolation methodologies and their applicability to GIS in developing countries (provisional title) (Woodfine, 1994).

This components of the project consisted of a hort summary based on literature review of main methods used for areal interpolation in GIS. A key theme in GIS is the integration of different databases (which makes GIS more than computing mapping) and one of the key problems in data integration is the diversity of areal units (districts, provinces, post-code areas, etc.) in use for different purposes. This report also examined the literature on different methodologies to integrate different areal units (also know as areal interpolation).

The work consisted of a desk review of different areal interpolation methodologies. Review of the potential use of Ghana databases (maps, census, etc.) for GIS applications, and produced a very short summary of different aerial

interpolation methodologies. The report recommended the “intelligent aerial interpolation (IAI)” methodology (Woodfine, 1994, p.7) which may use satellite images, census enumeration areas and commercial GIS software. However, the report suggests that even using intelligent aerial interpolation, it is not possible to claim totally accurate results. Therefore, users should indicate how the data has been derived and hence the likely inaccuracies. The report also argued that the 1984 census of Ghana provides valuable data for peri-urban studies around Kumasi. Although, the census in now considerably out of date and indications are that although a new census is planned, the spatial categories will be very different from those used in 1984 (therefore, the areal interpolation will be difficult).

Review of spatial data integration methodologies: Report on remote sensing in peri-urban areas in developing countries (Mather and Williams, 1996)

The production of accurate data using remote sensing presents several problems. These problems may be more exacerbated in peri-urban areas where a mixture of land uses, small plot sizes, and rapid change makes more complex the process of classification and data integration procedures.

The sub-project consisted of a desk review of main aspects of satellite images, a literature review on current application of remote sensing to peri-urban areas, an annotated bibliography containing 47 abstracts of material related to applications of remote sensing to peri-urban areas in developing countries (mainly on urbanisation and land use changes), and presented a list of telephone and e-mail contacts with institutions and professionals in developing countries which are working with GIS in peri-urban areas.

The short review presented details of different sources of satellite images; applications of satellite images for urban morphology; population estimation; change detection; technical problems with remote sensing including atmospheric distortions, sensor calibration, surface reflectance; a comparison between hard and soft classifications; and a review of classification methods. The report concluded that in the case of peri-urban environments, which consist of complex mixtures of a number of land cover types, the soft classifier methodologies are more appropriated. Also, the Grey Level Co-occurrence Matrix (GLCM) method of texture description is suggested as a mean of incorporating information concerning the spatial neighbourhood of a given pixel (Mather and Williams, p.19-20). The report suggested than even when appropriate studies do exist, insufficient technical details have generally been included on the procedures adopted to overcome the potential problems of remote sensing applications in peri-urban areas.

Institutions and professionals in 24 developing countries that are dealing with remote sensing and peri-urban issues were surveyed, and results of the survey conducted to these institutions was presented. However, the response rate to their survey was disappointing. Possible reasons were that remote sensing institutions are difficult to contact and most of them are reluctant to disclose information which would be commercially-useful for potential rivals.

The report concluded that GIS and remote sensing have potential applications in peri-urban research in Ghana. The major limitation is the high cost of data capture for the base maps and specific layers or coverages (e.g. soil maps, population density,) from existing hard copies of maps (maps in paper format as opposed to digital maps) scattered around in different government offices in Ghana[1].

Spatial data integration with special reference to peri-urban areas and high potential agricultural areas in developing countries (Barr et al., 1999)

This component was a review of GIS and remote sensing applications for peri-urban research, similar to Mather and Williams (1996), but with a focus on research conducted in United Kingdom in GIS and remote sensing applications to urban, peri-urban and agricultural studies. It consisted of a desk review on the relationship between GIS and Remote Sensing, a short evaluation of different types of sensors (aircraft borne, satellites) and its potential for peri-urban research, a literature review on current applications of remote sensing to peri-urban areas in UK and a survey of methodologies for the integration of data on peri-urban and high potential agricultural areas in developing countries (95 UK institutions were contacted).

In its introduction to GIS and remote sensing including definitions and applications, it concluded that satellite based remote sensing is more useful for determining land-use but is inadequate for cultural features such buildings and roads. The level of detail required to identify such features and activities in the urban fringe implies large scale mapping such as those produced by aerial photography (Mather and Williams, 1996, p.7). Better mapping is the key to peri-urban analysis, however, its success will not lie in the nature of the sensor or the choice been aerial photography or satellite imagery. It will lie in the quality of the base map, and the attribute information that can be collected for areas identified on that map (ibid p.8). The report also contains around 120 bibliographic references on GIS and remote sensing applications, around 215 abstracts on GIS and remote sensing applications (very general).

The survey of 94 UK institutions currently using GIS and remote sensing (not necessarily for peri-urban research) realised a response rate of only 12% (11 questionnaires submitted). Reasons for lack of response include the concern that NRI (Natural Resources Institute), which is seen as a commercial competitor, was seeking to obtain commercial valuable information from competitors. A lack of GIS and remote sensing applications for peri-urban research was postulated as another reason. The result of the 11 replies received indicated that the field (GIS and remote sensing) is, as yet mainly theoretical. The responses also indicated that peri-urban land use involves a mixture of built structures and natural vegetation. This complex mixture of land cover types, each of which has a markedly different spectral signature, makes conventional single pixel techniques inappropriate when using relatively low-resolution sources such as Landsat or SPOT (Mather and Williams, 1996, p.41). A two stage classification method is recommended as appropriate to deal with this problem. In UK, respondents were using UK mapping sources at scales of 1:10,000 - 1:25,000. This scale is seldom available in developing countries, thus information cannot be very precise.

R6347 "Integration of remotely sensed environmental data of different resolutions and spectral characteristics for natural resources management" (duration April 1995 to March 1996)

Modern remote sensing technologies give access to a very wide variety of natural resource data at different scales of resolution. Most natural resource managers require access to these data at more than one scale in order to provide useful information but there are important technological and methodological obstacles to be overcome to achieve this satisfactorily. This is especially true for the peri-urban interface where urban and rural resource managers traditionally deal with different classes of information collected at different scales.

The objective of this short project was to generate generic adaptive tools that would provide linkages to translate information between hierarchical levels (scales of resolution), to integrate information sets from each resolution level with data from sources (maps, GIS etc.) and to facilitate delivery of the above tools.

This is a range of diverse data sets relevant to Kumasi which have been installed in a well organised directory structure. The project produced an Access database which stores all the metadata relating to the spatial data sets, a GIS user interface, based on ArcView2, for displaying , querying and analysing the spatial and non-spatial data sets. The intention was that this would lead to a better understanding of what potential users may like to see incorporated into such a system. A technical manual was produced.

The availability of a GIS user-interface for examining a sample of data sets for Kumasi which allows users to examine various data sets and explore the spatial inter-relationships between different data sets, will allow a much better evaluation and understanding of how peri-urban production systems may be developing or changing and the subsequent environmental impact of such development or change. The better evaluation and understanding of the type, rate and extent of peri-urban change may lead to the better management of peri-urban resources, and to better control of environmental degradation and energy efficiency.

Airborne videography and ADP for high resolution mapping and monitoring

Curr and Curr (1996) describes a project to investigate the application of high resolution videography (HRV) and ADP to urban mapping, particularly the differentiation of vegetated / cropped areas, buildings and infrastructure. The work was done in connection with the Kumasi Geographic Information System - KUPGIS. This was developed by Bath Spa University College to look at the imagery from the aerial digital photography.

ADP was carried out in a light aircraft with very little specialist equipment apart from a small format control unit that managed to cameras. It was considered that ADP was superior to HRV. The location was identified using GPS and SPOT images and a published topographical map (dating from 1965). The ground resolution was 10 cm. The project successfully classified buildings (5 classes) and infrastructure (4 classes - 3 classes of road plus "rivers"). Vegetation was classified by type and activity as follows:

Type	**Activity**
Oil palm (mature)	Commercial
Oil palm (immature)	Domestic
Row crops	Unknown
Plantain	
Uncultivated	
Grassland	
Mixed (non-riparian)	
Mixed (riparian)	

It was thought that it would be advisable to extend the survey coverage from the sample area, develop the technology further and include a training component

in a follow-up project but this seems not to have happened. The GIS system used MAPINFO software for data storage and presentation. Though not as powerful as ARC-INFO later used for KUMINFO, the software was more user-friendly and less expensive.

The design and development of a prototype peri-urban demonstrator for spatial data integration (PUDSI) (Geographic Data Support Ltd., 1996).

This component of the project consisted of generation of a GIS user interface - called Prototype for Peri-Urban Demonstrator for Spatial Data Integration 'PUDSI' -, based on ArcView2, for displaying, querying and analysing the spatial and non-spatial data sets for Kumasi, Ghana[2]. However, the lack of the actual GIS application PUDSI made it difficult for the reviewer to consolidate information on this project. Integrated maps extracted from PUDSI displaying data were available

The objective was that the GIS user interface tool would allow local decision-makers and planners to examine a wide range of data in a sensible and integrated manner which would not only lead to a better understanding of the information content of the data and the spatial relations between them, but also enable better decisions and plans to be made regarding the environment. PUDSI allows for sophisticated spatial and quantitative analysis (if good data is available for it).

PUDSI, GIS application which incorporate maps and database in ArcView2, was installed at NRI in April 1996. PUDSI incorporates the following data:

- Map of the World at 1:2,500,0000 (country boundaries)
- Digital Chart of the World for an area of 50km radius surrounding Kumasi City at 1:1,000,000. Data include contour lines, elevation levels, villages, urban areas, railways, roads, rivers and water bodies.
- Topographic data of an area around Kumasi City at 1:50,000 including rivers, roads, railways, village and large settlements/urban areas (based on maps from 1972 digitised by NRI).
- Map of Soils at 1:250,000 (from maps digitised by NRI) and related database.
- Districts associated with demographic data.
- A georeferenced digital image from Bath College (Swedru?)
- Theoretical application (with hypothetical data) on: river pollution, demographic data.

The report mentioned that the lack of clearly pre-defined user-needs and requirements, and the lack of available data for Kumasi limited the development of PUDSI. GDS argued that the Kumasi Baseline Study (R6448), which commenced after PUDSI projects, could have been an important source of information. As a result only a limited range of data was available to be placed on the system, thus, hypothetical databases were used to demonstrate the potentials of PUDSI. As a consequence of this, a limited range of possible functions were included in PUDSI.

R6799, Kumasi natural resource management (incorporating sub-project "Installation, support and maintenance of an integrated information system for peri-urban natural resources systems research") (duration January 1997 to March 2000) (Adam, 2000a).

The objective of this broad-based project was the sustained improvement in productivity of priority NR in the Kumasi city-region. Within this project, there was a GIS component., and specifically related to this, the project planned to analyse the impact of urban growth on land use patterns and access to NR resources (Adam, 2000a, p. 217).

A major output from this project is the KUMINFO GIS, which is based on the pre-project prototype, PUDSI. Users have specifically programmed interfaces that allow easy access to research topics. Development is continuing with specific water modelling routines as part of the "Kumasi Natural Resource Management Project at the Watershed Level" (c.f. R7330). The system is run in Kumasi, within the Institute of Renewable Natural Resources (IRNR), a constituent unit within the University of Science and Technology (UST), Kumasi. A parallel system runs at NRI and at Royal Holloway College, University of London.

- KUMINFO uses the following hardware and software for which commercial licences are required:
- Windows NT or Windows 95 platforms with 64 Mb RAM and at least a 4 Gb hard disk and a CD-ROM reader
- MS Office 97 Professional
- Arcview 3.1
- Arcview Spatial Analyst Extension

A large number of datasets is available for the KUMINFO system. Information about the datasets is held in a metadatabase that also governs the display and accessibility of data within the GIS. The KUMINFO managers in Kumasi, NRI and Royal Holloway College manage the metadatabase.

Data in KUMINFO consist of geographically references data, related text, numeric datasets and databases of project research results. A catalogue of data is automatically generated from the metadatabase.

At this stage it appears that KUMINFO is a potentially useful system in search of people to use it. To increase access to outputs from the GIS, CDs which can be viewed with Arc Explorer have been produced. District planners from the four districts adjacent to Kumasi collected a lot of data from the villages in their districts. The Arc Explorer software is extremely limited, but it does enable some map outputs to be available to the planners. Arc Explorer can present the data in different ways but cannot manipulate the data. The potential use of such software in the area needs careful evaluation. It was also intended that it would encourage them to use the more extensive datasets and GIS capabilities available at IRNR, UST.

Although the Arc Explorer version of the Kwabre district database contains an immense amount of data though it is of little help for examining land and water management issues. For example. there are no data on soil type, land slope, water quality details (other than good/fair/poor) or the existence of irrigated plots. Output of the area using the full Arc View software is considerably more useful, and it seems to be a useful tool for general planning. However, at this stage little analysis of the data collected and entered onto the GIS systems appears to have been undertaken.

R6880, "Development of methods of peri-urban natural resource information collection, storage, access and management" (duration January 1997 to March 2000) (D'Souza, 2000a).

The objectives of this project were to:

- Determine and test the most appropriate scales and types of remotely-sensed imagery from which to derive PUI information.
- Determine how best the remotely sensing data may be used to involve local participants in the assessment of natural resource importance ranking and mapping,
- Development of a user friendly information system for natural resource assessment and management of a wide range of potential users.

Development of methods of peri-urban natural resource information, collection, storage, access and management: various document. (D'Souza, 2000b)

This report is a collection of several short documents which aim at reviewing literature on GIS applications, models for socio-economic appraisal and its integration on GIS and also a proposals for further research including the fieldwork in Kumasi in March 1998. The short documents include:

- A short desk review on methods for social appraisal including the Cochrane's Social Analytical Model (SAM) - an approach for national inventories of cultural resources - to collect social indicators for further integration in GIS.
- Desk review and evaluation of: the use of aerial digital photographic system for surveys in Kumasi, the use of microlight aircrafts, and the use of balloons for digital photography collection.
- Literature review of recent research in design and development of GIS user interface and review of specific GIS application for natural resource management in different countries.
- Literature review of some of the RRA/PRA literature related with the use of GIS, remote sensing, aerial photography, and participatory planning.

It was conclude from the review and evaluation of aerial digital photography system survey and aerial platforms that:

- Colour infrared aerial digital photographic system survey (ADPS) eliminate the difficulties associated with satellite remote sensing of cloud cover, ultimately coverage, slow data delivery and low resolution. The high resolution imagery from ADPS enables fine-quality mapping and high-definition classification of the peri-urban environment.

- The micro light platform - a low cost and compact aircraft - is suitable for small aerial digital photographic surveys due to its low-capital and low-operational cost. Page 6 shows the technical details (i.e. aircraft speed and altitude, camera settings) for the collection of digital photographs.
- The balloons platform - it is only suitable for very specific monitoring purposes where very high pixel resolutions are required

Finally the project opted for aircraft platforms.

The report concludes that GIS applications have been 'top-down', cadastral information is vital in any peri-urban GIS, institutional aspects of GIS are frequently of secondary importance or totally neglected. GIS should be a service provision. A comparison between RRA/PRA (in reference to participatory mapping and modelling) versus aerial photographs and other 'high-tech' mapping methods concluded that both methods have their benefits and limitations and an integration should be sought.

D' Souza (2000a) reviews international literature reporting the use of PRAs in conjunction with aerial photography. The use of aerial photographs in PRAs is proposed for Kumasi to allow villagers to assist in the interpretation of the photographs. Information about natural resources and socio-economic data collected during PRAs could be integrated into the computer-based information system used to manipulate and analyse the aerial photographs. There seems to be an assumption that the main (if not only) purpose of PRAs is to collect data from villagers for the purpose of planners and researchers. The empowering aspect of PRA work is ignored by virtually all the studies in both cities.

Estimating the datum transformation parameters associated with the Ghana National Mapping System. (Sannier et al., 2000)

Most spatial data in Ghana are not suitable for incorporation in GIS due to problems with incompatible geo-referencing systems. The project sought to find a mathematical formulae for the conversion of map co-ordinates between the different projection systems currently (and potentially) in use in Ghana,.thus improving the use of GIS for the handling, integration and management of spatial information related to land use and natural resources from topographic maps, aerial photography and satellite images.

The project conducted a review of mapping systems used in Ghana, generated and an estimation of datum transformation parameters for the Accra datum using the Molodensky method. This was tested out Application of estimated parameters to a road survey data undertaken along the main ring road in Kumasi.

The project did produce an estimation of a parameters for datum transformation (Sannier *et al,* p.7). The datum helps to convert maps co-ordinates to an homogeneous geo-referential system for their further integration in GIS applications for land use planning and NR management. However, the precision required by the Molodensky method (5-10m) was not achieved due to several sources of error in topographic maps and the SPOT image used.

Application of aerial digital photography to rapid rural mapping. (Thomas et al., 2000)

This component of the project sought to produce map products (in a short period of time) by processing of airborne digital photographs (ADP) and to demonstrate the capability of these maps for village rapid rural appraisals. This was done by:

- Conducting an ADP survey conducted during four days in December 1997.
- Testing the capabilities of portable equipment (PC, printers, software, etc.) in fieldwork
- Application of large-scale ADP derived image-maps for a village characterisation survey in Swedru (14 km north of Kumasi).

This report does not present the actual data on production systems in Swedru village, but just indicates the methodology undertook for the production of image-maps of Swedru.

Outputs from this project components were:

- 290 km^2 of Kumasi covered by ADP (1360 images at a nominal resolution of 0.23m)
- A database (21 CD-ROM's) of ADP images from December 1997
- One CD-ROM with mosaics of Swedru, Pease, Daku, Ahenema and Dakwankye villages
- Image-maps (derived from ADP) of Swedru village at 1:2,500 (Thomas *et al,* 2000, fig 2.)
- Characterisation of Swedru village using image-maps:
    - Identification of village boundaries: effective method and may help in boundaries disputes
    - Field, family land and farms survey: boundaries, total area, ownership, crops.
    - Built environment classification (Thomas *et al,* 2000, fig. 4a)
    - Household survey: number of family members, work load of the family (Thomas *et al,* 2000, fig. 6)
    - Mobility profile to assess the flow of resources within, outside and into the village: data on accessibility (time and distance) using image-maps and people's perceptions.
- Assessment of villager's capability to interpret ADP images: unequal capabilities to interpret maps.
- Production of family profiles for Swedru village. Information was overlaid onto image-maps at 1:10:000, based on fieldwork in March 1998.

It was recommended that thee should be further assessment of whether or not the availability of ADP derived image-maps could actually speed up the process of collecting socio-economic and natural resource data. The project argued that there appears to be considerable potential for reducing the amount of direct field observation through use of map products, although some level of field survey is normally required (Thomas *et al,* 2000, p.23). there should also be further investigation of technical procedures for production of image-maps from raw digital maps.

The application of satellite image-mapping for stratification of the Kumasi peri-urban interface. (Taylor et al, 2000a)

This component focuses on the development of a methodology for stratification of village level surveys in the Kumasi Peri-urban interface. It consisted of satellite mapping of villages in Kumasi peri-urban interface, converting the satellite image to an image-map of practical applications, and statistical and spatial analysis of the area and growth of Kumasi peri-urban villages. "Characterisation" of aspects of a geographical area to provide information, upon which subsequent research or development must be based, is carried out either by collation (possibly with further processing) of existing data and/or by undertaking new studies or surveys. To facilitate the latter, prior to sampling, the area must be "stratified" by dividing the total area to be surveyed into sub-units which can be considered similar for the purposes of the study. In the studies so far undertaken (in both cities), stratification of the samples has rarely taken place.

Outputs from the study were:

- Production of a geo-corrected and visually enhanced SPOT panchromatic image[3]
- Interpretation of a SPOT satellite image acquired on 17 December 1994 which covered most of Kumasi peri-urban interface.
- Identification of 387 villages in the peri-urban interface of Kumasi
- Characterisation of 66 villages randomly selected using three criteria: on road (no more than 2 km from a main road); off-road (more than 2 km from main roads - based on 1:50,000 maps); within 5 km of the city centre main market.
- Stratification of villages according village size and growth 1974/94 (Taylor *et al*, 2000a, Table 3).

The study provided the methodology used to estimate villages' relative area growth from 1974 to 1994. The village growth data are then used to stratify villages on the basis of the current village size and growth rates of villages. It was noted that some villages had grown by as much as 2000% in area since 1972 (though most had grown by between 50 and 100%). The report on stratification suggests that a study on the relationship of growth rates and access to Kumasi is undertaken. Village size errors due to the occurrence of sand winning sites were noted.

The report concluded that satellite images provide a cost-effective method to collect natural resources data in large areas such as peri-urban interfaces. The report suggests the use of aerial (or "airborne") digital photography (ADP) to examine in a more detailed way, areas of the satellite images first identified by measuring differences in village areas. ADP is recommended for the collection of natural resource information for relatively small areas (e.g. small towns, individual agricultural fields). The application of satellite images for small areas could be limiting with respect to the spatial resolution (too large to see things in detail). For PUI areas of more than 1600 km^2, ADP images are not recommended due to the large amount of data that will need to be collected and storage. Satellite images could be used for the peri-urban interface and ADP for targeting specific locations. Visual assessment prior to digital classification is important. For example, digital methods tend to classify sand winning (quarrying) areas - which is a common activity in PU Kumasi - as built environment thus enlarging the area covered by a village. However, the report does not assess how "transportable" the ADP methodology actually is. Nor does it assess the efficiency and cost of the proposed stratification procedure compared with alternative approaches.

The application of satellite image-mapping for stratification of the Kumasi peri-urban interface - Kumasi field visit report (Taylor et al, 2000a)

A number of activities were undertaken, including workshops with potential users of GIS: Environmental protection agency, University of Ghana, Ghana Water & Sewage Corporation, Kumasi Metropolitan Assembly, University of Science & Technology, and the Department of Forestry. They also conducted an assessment of villagers' capability to analyse the maps produced from ADP.

The researchers found that ADP-map products allow for identifying village and parcel boundaries, land use and rapid measurements of areas at local farm level. They also facilitated a detailed mapping of the built environment as demonstrated in Swedru village. Research with villagers showed that image-maps are more accurate than mental sketch maps produced during previous RRA exercises, but some features like drinking water or wells cannot be recognised on image-maps due to its resolution (0.23m), thus, the report highlights the need for the combination of map production and data collection in the form of Rapid Rural Mapping or other type of fieldwork visits.

One issue is that power cuts and lack of adequate GIS equipment makes it difficult to work with digital information in Kumasi. Power generators and the implementation of adequate digital systems will facilitate the processing of ADP and satellite images. The authors of the report (Taylor *et al.*, 2000a) also described the technical difficulties of matching GPS and GIS/map data because of different datum. The possible problems with the methodology actually adopted for the VCS (based on distance from road and markets) were examined. Fieldwork indicated that each stakeholder group in Kumasi has different expectations of GIS images: University and Government bodies found image-maps useful for:

- Monitoring of illegal developments within the Kumasi Metropolitan area.
- Monitoring areas of potential pollution from stockpiles of sawdust.
- Monitoring illegal developments in the watersheds of the main reservoirs.
- Generation of an up-to-date city map.
- Services mapping and control of development on the UST campus.

The villagers of Swedru found the image-maps useful in establishing village and farm boundaries. Pressures on the land resources appear to be increasingly leading to land-ownership conflicts. Maps are also considered as a negotiation tool.

Following on from these findings, the researchers recommended that there should be:

- Further villagers' awareness raising and training in map interpretation and GIS technology:
- Another field visit focusing on specific cases studies such as: mapping of the UST campus, monitoring sawdust pollution, monitoring illegal encroachment upon the watershed of the reservoir.

GIS-based village level planning system. D'Souza and D'Souza (2000).

One of the most important changes in the PUI is the allocation of land, in particular, the rapid conversion of agricultural land to housing. This report illustrates the impact of potential new housing developments on a village community (Swedru) using an prototype GIS application. The aim of this component of the project was the development of a prototype GIS application to land use planning scenarios.

A workshop was held in Kumasi to disseminate previous project material on the village characterisation surveys (VCS), to publicise the KUMINFO GIS, and to invite feedback from planners. The project also developed a planning application using GIS for Swedru (chosen because of the quantity of information available). This involved:

- Generation of database: planning laws.
- Production of maps using GIS (sources: ADP images, and VCS).
- Development of scenario planning maps.

Swedru has 1500 inhabitants, with the majority being engaged in farming or farm-related activities. More than 90% of the farmers have farms in the village. Major crops grown are food crops (cassava, tomatoes, okra and maize) which are becoming very popular due to the proximity of the Kumasi market and recent improvements in the road network.

Several maps of Swedru were produced however, the scale of the maps does not allow precise planning applications. One map showed the age of housing (houses built in 1920, 1920-42, 1920-63, in the last 5 years). The map demonstrated the expansion of the area of new housing, which has more than doubled the village extent over the last five years and encroached on lands suitable for food crops. Backyard gardens (mainly planted with plantain) are common around these new houses, often as areas 'staked out' by people planning to build on them.

The maps also depicted:

- Built environment (physical features: type of schools, houses, cemetery, church, toilets, playing field, boreholds).
- Land use (derived from ADP mosaic and not fully verified in the field). This map indicates location (and statistical data such as area, perimeter, etc.) of: bush fallow, year 1 crops, year 2 crops, woodland, riverine vegetation, village boundary, sacred grove, roads).
- Slopes (derived from a digital elevation model (DEM), a tri-dimentional image showing the topography of Swedru).
  This map was generated from a 1:50,000 map, for real planning applications a more detail scale is needed. This map shows areas not suitable for housing development due to steep slopes.
- Rivers and drainage (derived from 1:50,000 map).

A buffer zone maps was generating showing areas not suitable for housing development following planning guidelines.

These led to the production of composite scenario maps indicating new development options for housing. This map shows four areas suitable for new housing development based on planning guidelines (slopes no more than 6°, areas beyond 5ft of a river or stream, areas beyond 100 feet of a sacred grove, distance from basic infrastructure and services). The four areas proposed were mainly bush fallows.

The project developed the following recommendations:

- The use of more than three planning constrains in order to refine the search for suitable areas of housing development.
- The use of more detail data (including local knowledge) on land use, slopes, distances, crop production, economic value of farms.
- GIS in watershed management

In the "KNRM Project at the Watershed Level" (c.f. R7330), water sampling sites (including sites sampled by a previous project undertaken by WSIP-Gibbs consultants) and location of survey villages have been mapped using GIS techniques CEDAR (1999, p.20). The presentation of histograms of chemical analyses at each sample site on the maps are not clear and may have been clearer on separate tables. GIS will be used to identify water use and environmental problems such as cultivation of river banks.

It was proposed that the project will use ADP because the images are easily corrected, because ADP can be used to locate the sampling sites on the ground (though GPS systems could also be used), because it can be used to provide an overview (from the air) of the sampling sites and because it can be used easily to identify devegetated areas around villages.

Conclusion

The potential of GIS for land use studies in rapidly changing interfaces such as the peri-urban zone is clear. Computer generated maps can be revised almost instantaneously as new data become available, whereas paper based maps are inevitably out of date within a year or two. The power to analyse spatial effects and changes is also apparent. However, despite the expenditure upon setting up a GIS in Kumasi, so far its impact has been minimal. It should be borne in mind that this system was generated within the context of research, and not development, projects. Nevertheless, the opportunity to use the power of GIS to help understand processes of change driven by rapid urbanization appear to have been missed.

Notes

[1] Maps in paper format need to be digitised or scanned to be incorporated in GIS. This process can be tedious, time-consuming and expensive.

[2] Arc Info is a popular GIS software. It has several modules which make it a very versatile and powerful GIS, however, the language it uses is very technical and requires substantial expertise in GIS. Arc VIEW is one of Arc Info modules which cost around US$2000. It provides an inexpensive way to display and analyse (with some limitations) spatial data.

[3] SPOT: French company which produces different type of commercial satellite images.