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

Dr Graham Thomas, Director MSc Geographical Information Management, Cranfield Centre for Geographical Information Management, Cranfield University, Silsoe, Bedford MK45 4DT
Tel: +44 (0)1525 863061; Fax: +44 (0)1525 863099 ;
Email: g.thomas@cranfield.ac.uk
Web: http://www.silsoe.cranfield.ac.uk/GIM

Introduction

This report summarises some of the substantive results from the 3-year programme of research funded by the UK Department for International Development and based in the peri-urban environs of Kumasi, Ghana. The aim of the research was to develop methodology for collecting and using information on peri-urban production systems to benefit the poor, using GIS and remote sensing technology. As part of the work, an aerial digital photographic (ADP) survey was conducted to collect false colour images with ultra-high spatial resolution. The ADP data provided a basis for the development of large-scale image map products. A SPOT panchromatic satellite image was also acquired. A GIS system was established to facilitate integration and analysis of data collected during the research programme. The latter included data with both explicit and implicit spatial referencing, for example: spatially referenced socio-economic surveys; village land boundary identification undertaken with a global positioning system (GPS); transect walks referenced to image maps; participatory sketch maps; and land use and built environment maps derived from remote sensing images. These data were collected at different times, using different methods and with different spatial referencing and a GIS was established such that all the data sources could be made spatially coherent.

A specific focus of this project was to achieve a high level of integration of the technical methods with the social and economic issues affecting the poor in the peri-urban interface of Kumasi, with the aim of identifying actions that would bring material benefits. A series of field visits were undertaken and the image maps and GIS products were evaluated within several communities around Kumasi. As a result of these visits a number of key benefits were identified that can result from the

explicit integration of remote sensing and GIS approaches to resource survey and assessment into the current frameworks for establishing development initiatives. These benefits encompass: (1) technical issues relating to definition of the geographical frame of reference for ensuring compatability of spatial data sources; (2) the provision of macro level contextual information; (3) elements of the design and implementation of participatory inquiry methods;

Defining the geographical frame of reference

Relevance to development issues

It can be envisaged that an increasingly fundamental requirement of development projects will be that data are collected in a form suitable for incorporation into a Geographic Information System (GIS). This situation will evolve if existing assumptions relating to the technical feasibility and value of combining conventional data sources describing the socio-economic, environmental, and infrastructure conditions of communities with non-conventional behavioural and cognitive information within a GIS framework prove valid[1]. Examples of data with explicit or implicit spatial referencing may include: spatially referenced socio-economic surveys; village land boundary identification undertaken with a global positioning system (GPS); transect walks referenced to image maps; participatory sketch maps; and land use and built environment maps derived from remote sensing images. These data may be collected at different times, using different methods and with different spatial referencing and a GIS provides a system by which all the data sources can be made spatially coherent.

In this context it is apparent that defining the geographical frame of reference for a study region becomes one of the most important pre-requisites to establishing a GIS with the capability to manage these diverse data sources. The absence of a defined framework for spatial referencing will reduce the value of any GIS established for a specific project by removing the inherent capability for integrating data, with an

[1] Daniel Weiner, Trevor M. Harris, and Philip K. Burkhart, 1996. Local Knowledge, Multiple Realities, and the Production of Geographic Information: South Africa and West Virginia Case Studies. http://www.geo.wvu.edu/i19/papers/weiner3.html

associated reduction in the analytical capability of the system. This will impact the quality, type and potential uses of GIS products available from the system.

In countries with developed economies definition of the geographical frame of reference does not normally lead to any difficulties, and can normally be taken to be the national mapping system of the target country. For countries with developing economies, however, the situation can be more problematic since the national mapping systems in use may not be explicitly defined in either available GIS or GPS software. Although GIS software incorporates capabilities to establish any local system as a user defined mapping system, this requires access to geodetic transformation parameters. In many countries these parameters are not made available for security reasons. In this instance any data collected using GPS for spatial referencing will not be made easily compatible in the GIS with data geo-referenced using alternative systems.

These issues have been particularly relevant to those projects undertaken within Ghana that are making use of GIS. Ghana provides an example of a country where the national mapping system is not defined in common GIS software and GPS receivers. In the short term this has required a duplicate GIS system being established for use by organisations in Kumasi, using both geographic co-ordinates and Ghana National Grid co-ordinates in order to allow data collected using GPS to be made compatible with some historical data sources. In addition, a lack of understanding regarding the importance of establishing the spatial referencing system has lead some researchers to make fundamental errors with respect to what constitutes appropriate data collection procedures that ensure data can be readily incorporated into the GIS. This confusion was highlighted by the use of an uncontrolled aerial photograph mosaic rather than the geo-referenced ADP image mosaics for boundary delimitation. A digitised boundary from the aerial photograph mosaic would still require the spatial co-ordinates to be derived before the data could be used in the GIS. A second example involved the use of GPS for collecting spatial referencing information. The GPS data were logged using geographical co-ordinates and consequently were not directly compatible with the GIS data available that were encoded using the Ghana National Grid system. In addition the limited accuracy of non-differential GPS

(~100m on average) does not appear to be well recognised by some social and environmental scientists.

There exists a danger that these difficulties become ascribed as deficiencies characteristic of the technical methods rather than recognised as user misunderstanding of the requirement for defining a spatial referencing system suitable to meet the project purpose. For a given study, solving the problem of the geographical frame of reference need only be undertaken once at the start of the project, following the methods described in the next section.

Approach developed

It has been demonstrated within this project that these problems can be resolved by geo-referencing a satellite image covering the complete study area to the national mapping system of the target country. The approach developed is generic and transferable. Figure 3 shows the SPOT-3 HRV-2 panchromatic scene (56-336/7) available for the project. The image was acquired on 17 December 1994 at 10:51 am and covers the majority of the Kumasi peri-urban interface. The image was geo-referenced to the Ghana National Grid mapping system using available 1:50 000 topographic maps and therefore defines the geographical frame of reference for the entire study region.

A general solution to the problem of establishing the Ghana National Grid (GNG) mapping system within GIS software was developed based upon the geo-referenced image. This involved estimation of the required geodetic transformation parameters. In addition to the image map, the method used precise location co-ordinates for only a single (control) point. Location data were available from a previously undertaken differential GPS survey. Alternatively, the information can be obtained from a traditional triangulation survey.

Once the parameters have been derived, the mapping system can be established within the GIS, and any data collected using different spatial referencing systems can be made spatially coherent. An example of the significance of this issue is provided by Figure 5 of Appendix 6 that shows a section of the SPOT image map covering the north-east side of Kumasi including the airfield. The white line represents data

collected using a GPS with co-ordinates transformed into GNG. These data are spatially equivalent to the SPOT image map. The black line represents data collected using an alternative but equally valid mapping system and demonstrates the typical magnitude of difference (~ 40m in easting and 300m in northing in this instance) that can be encountered when the geographical frame of reference is incorrectly specified. It is important to note that the resultant error is readily apparent when use is made of the image map. However, the error might not be recognised if GPS alone were being used during the data collection.

Highlighting the Value of Macro Level Contextual Information

Relevance to development issues

The peri-urban interface exists as a mosaic of communities that possess substantial differences in social, economic, institutional and environmental characteristics. Development initiatives are often undertaken through pilot projects within which it is usually only feasible to define the objectives, scope and priorities for development by application of participatory inquiry and other methods of assessment within relatively few communities. However, an underlying rationale of the approach taken must be that the results can be applied more widely within the study region i.e. scaled-up. The concept of scaling-up is now being addressed from a wider perspective[2]. However, mechanisms of achieving large-scale replication on a sustainable basis of the approaches developed in pilot projects are less apparent[3]. It has been noted that although "scaling down or up between levels and across sites seems crucial, …this exercise is rarely carried out either in the planning stage or during project implementation" [4].

Recent work within water resources development confirms the importance of ensuring that any developed approach can encompass the wide range of social and physical

[2] Peter Uvin and David Miller, Scaling Up: Thinking Through the Issues. http://www.brown.edu/ Departments/ World_Hunger_Program/hungerweb/WHP/SCALINGU_ToC.html
[3] Cathryn Turton and Anthony Bottrall, 1997. Water resource development in the drought-prone uplands. Natural Resources Perspectives, 18, Overseas Development Institute.
[4] Rhoades, R.E., 1998. Particpatory watershed research and management: Where the shadow falls. Gatekeeper Series no. 81. International Institute for Environment and Development, London. 20pp.

environments that are usually found within a given study area[3,5]. Similar challenges face studies within the peri-urban interface where the importance of recognising within-community diversity of conditions is well recognised, but the importance of representing between-community differences appears less well developed. Reflecting this diversity of conditions within the analytical process may provide a basic framework by which approaches developed within pilot projects can be successfully scaled up and consequently have impact on larger numbers of the peri-urban poor.

One component of this framework could be developed through the selection and on-going use of site visits and community meetings that is fundamental to all livelihoods approaches. A principal initial aim of these is to provide the basis for a participatory assessment of the varying components that contribute to the livelihoods of communities and individuals within a study region. Subsequently, the sites provide a focus for more detailed participatory work confirming the validity and significance of those factors identified and ensuring that the diversity of opinion within the community is adequately represented.

The requirement that "information gathered in one area is, and should be, relevant to other areas"[5] suggests that participatory inquiry methods are most likely required, except in exceptional circumstances, in more than the identified minimum[6] of a single community[7]. While the conceptual framework associated with a sustainable livelihoods approach is well defined, at the practical level there exists less guidance on operationalising livelihoods approaches. Taking a geographical viewpoint, this appears especially true with regard to determining the number and location of site visits.

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[5] John Farrington and Crispino Lobo, 1997. Scaling up participatory watershed development in india: lessons from the indo-german watershed development programme. Natural Resources Perspectives, 17, Overseas Development Institute.

[6]DFID guidance notes methods

[7] Ian Goldman and Moscow Maruno, 1999. Khanya Managing Rural Change. Sustainable Livelihoods Resource Group. Proceedings of NRAC Conference, Sparsholt, Winchester July 1999. http://www.ids.ac.uk/livelihoods/nrac/zimsa.pdf

It is recognised that the value of participatory assessments can be increased by access to detailed knowledge of the area concerned[8] and some evidence exists of the value of using such knowledge with respect to site selection. Methods of site selection can be criteria based which will then depend upon access to relevant data sources. In one approach to making participatory development replicable over wide areas, detailed criteria are developed for the selection of villages for participatory investigation, with selection based upon both environmental and socio-economic criteria[5]. Additionally, the selection of geographic areas and subsequently zones where poverty is concentrated[9] can be derived by use of appropriate secondary data sources. These may include reports by NGOs, donors or government agencies, the published results of previous research in an area and government agency statistics. However, it is recognised that secondary data can be uneven in coverage, availability and accessibility and may be unreliable[6]. Given these difficulties, alternative more current data sources will have additional value providing relevant information can be derived.

Approach developed

A characteristic of peri-urban communities that can be measured from a satellite image is the built environment area (i.e. buildings and transport infrastructure). Figure 13a shows the village of Daku viewed at six different mapping scales using the SPOT panchromatic image. Inspection of the images indicates that this data source provides a reasonable basis for mapping village built environment area at scales of between 1:5000 and 1:10000. Figure 7 shows how the SPOT image acquired for the project was processed to derive a map of the peri-urban environment for 1997. The processing procedure involved a hierarchical approach to digital image classification. The built environment for peri-urban Kumasi can also be digitised from the 1:50000 topographic maps, dated 1972, available for the area in paper form. The scale of the topographic maps is compatible with the analysis of the SPOT image. Figure 6 shows how these two readily available data sources can be combined to allow an estimate to be made of the degree of village growth. An important advantage of the method is that the measurement of village growth can be derived for all the villages in the study

[8] Sustainable Livelihoods Guidance Sheets, 1.5 Links with Other Approaches, DfiD, http://www.ids.ac.uk/livelihoods/pdf/section1.pdf

[9] Diana Carney, Michael Drinkwater, Tamara Rusinow, Koos Neefjes, Samir Wanmali and Naresh Singh, November 1999. Livelihood approaches compared. http://www.ids.ac.uk/livelihoods/pdf/lacv.pdf

area. The derived data on village growth can be used in the development of criteria for village selection for participatory inquiry (e.g. Figure 8, where sample villages are selected based upon their size in 1972 and their degree of growth between 1972 and 1997). The implicit assumption, that changes in the built environment of villages are a useful surrogate measure reflecting the wider development issues affecting the peri-urban poor, appears reasonable but requires further evaluation.

Although village growth alone can be used to stratify villages for selection, additional factors can also be derived from analyses of satellite images. The scope for additional derived measurements depends upon the resolution characteristics of the available satellite image and the mapping scale of the derived product. Figure 5 demonstrates the potential use of the image for deriving additional information such as distance from the urban centre, distance from principal roads, the proximity of villages, the presence of forest reserves and the amount of cultivated land from this single image source. However, detailed assessments of the structure of the village built environment and natural resources base of the associated village lands are not possible from the image, due to the 10m spatial resolution and single panchromatic band.

This project has demonstrated a novel and repeatable approach to the issue of selecting locations for site visits, based upon the degree of village growth. In addition it has been demonstrated that a range of additional contextual information can be derived from a single satellite image source that can also be used within this context. The derived information covers the complete study area, is current, and can be made readily available from the GIS. In addition the reliability of the information can be easily determined.

Participatory Inquiry and Rapid Rural Mapping

Relevance to development issues

The task of defining specific and appropriate poverty reduction activities and developing successful pathways that will encourage and promote their uptake indicates that a participatory framework of inquiry is desirable. One of the aims of participatory inquiry is to ensure that the problems identified as forming the basis for

the project are prioritised by direct involvement of local communities. In addition, any potential solutions are identified, developed and implemented with the full participation of the relevant land users and other identified stakeholders. The philosophy of participatory inquiry emphasises explicitly the complex social, economic, political and planning dimensions that are explicit within the concept of sustainable livelihoods.

The general aims of adopting a participatory inquiry approach are laudable, but may not necessarily strengthen the capability to successfully meet the project objectives, within constraints of resources and time. There is evidence to suggest that the enthusiastic application of participatory inquiry is often undertaken in the absence of careful survey design and data collection that may ultimately weaken the conclusions of any social analyses applied to the data[4]. The same criticism may be applied to other forms of resource survey.

Recent critiques[10][11] of the sustainable livelihoods approach, within which participatory inquiry is a central tenet, also provide some interesting challenges. Although such approaches are well defined conceptually, there appears insufficient practical guidance on field level implementation. Questions remain regarding the procedures for defining resource levels, data types and methods of collection. A real requirement appears to be the development of practical and cost-effective tools that can encompass the complex linkages between the natural resources base and the social and economic conditions of communities. Finally, the reduced emphasis on "environmental sustainability and poverty alleviation"[12] that may sometimes be characteristic of sustainable livelihoods approaches may need addressing more fully in the context of peri-urban systems. The procedure of rapid rural mapping developed within this project has relevance to these issues.

Approach developed

[10] Diana Carney, 1999. Approaches to sustainable livelihoods for the rural poor. ODI Poverty Briefing No. 2. http://www.oneworld.org/odi/briefing/pov2.html

[11] Koos Neefjes, 1999. Oxfam GB and Sustainable livelihoods:lessons from learning. Proceedings of NRAC Conference, Sparsholt, Winchester July 1999. http://www.ids.ac.uk/livelihoods/nrac/oxfam.pdf

Within this project the term rapid rural mapping is used to indicate the collection and processing of aerial digital photographic (ADP) image data to image-maps and the subsequent use of such maps to aid collection of data on both natural resources and social and economic resources. The rapidity with which this type of mapping can be undertaken (i.e. completed within a time frame of a month or two) means that it can be integrated within the typical life cycle of most development initiatives.

Advantages of the use of aerial digital data as the image map source are that it provides a suitable and efficient basis for the production of image maps at large scales due to the achievable pixel resolution of ~0.25 m and can be obtained in false colour form. A standard false colour composite product generated from green, red and near-infrared light provides an unusual perspective to the first time user mainly due to the typical dominance by red shades of vegetated areas. Although this might be considered a disadvantage with respect to incorporation of the image maps within a participatory inquiry exercise, there appears to be little formal evidence that this reduces the ability to interpret and use the maps, once a basic level of explanation is provided. In fact, during the surveys undertaken in Swedru and Pease a number of local people demonstrated an ability to identify specific locations on the image maps.

Figure 13b shows the village of Daku represented at six different scales by an ADP image mosaic with 1m spatial resolution. Figure 13c shows the same village at the same mapping scales but with ADP image data at 23cm spatial resolution. Comparison of these figures with Figure 13a shows that achievable mapping scales for the built environment area can be increased to 1:1000 or 1:2500 depending upon the resolution of the ADP data from the 1:5000-1:10000 scales characteristic of SPOT panchromatic data. In addition, more detailed assessments of the structure of the village built environment and natural resources base of the associated village lands are evidently possible from these images.

During an initial phase of the project it was demonstrated that image maps at large scale can be produced rapidly from the ADP archive by use of the geo-referenced SPOT image. Further, the map products could be interpreted by trained field staff into a variety of information products that would have value in supporting the development of poverty reduction activities at village level. The products produced

included a detailed map of the built environment of the village of Swedru (Figure 14), the first delineation of the boundary of the village lands and a map of the land under agriculture (Figure 10). Further detailed mapping of the natural resources base was also undertaken, although not within a participatory framework. During a second phase of the project a greater integration of the technical methods with the social and economic issues affecting the poor was sought. The results of these investigations provide evidence that the more explicit incorporation of image maps within the general framework of participatory inquiry has considerable value.

The value of mapping in this context is not new since land use maps, social maps and transect walks are recognised as key participatory methods. Figure 15 shows a copy of the participatory sketch map obtained during a PRA exercise conducted with representatives of the village of Swedru. Typically participatory sketch maps are drawn by one individual representing the community under the direction of the other participants. One of the main uses of such sketch maps is, as a facilitating mechanism to highlight and localise issues considered important by the community.

Not surprisingly however, given the nature of the exercise, many of the features will be incorrectly located and the representation of scale distorted. Unless the use of size of a feature as an indicator of importance is explicitly incorporated into the process of map construction, assumptions made by some practitioners regarding this aspect of the interpretation of such maps will be very difficult to validate.

A particularly noticeable characteristic of the sketch map for Swedru is the very poor representation of the natural resources base. Such maps typically offer an incomplete and generalised representation of the main features. Since an accurate scale cannot be assigned to the map it cannot be used for quantification. Ultimately such maps provide a partial visual impression of current knowledge that is likely to confirm what the participants already know.

Figure 14 shows an image map of Swedru, comprising the village lands and built environment. Also shown are some enlargements of specific features. The use of such image maps within a participatory inquiry activity is likely to require some initial training. The level and nature of this training requires further definition, although

some evidence of the capabilities of villagers to quickly become accustomed to interpretation of large-scale image maps was obtained during the field work.
The ADP derived image maps can be used as a facilitating mechanism, to highlight specific issues and to accurately localise those issues. Since the image maps are accurately scaled they can be used for quantification. Within a participatory framework the image maps can be used to structure transect walks, prepare resource and social maps and determine access to resources and facilities. The image maps provide a more complete visual impression of the current situation and are more likely than the sketch maps to provide an indication of what the participant doesn't know already. In particular the ADP image map provides a substantial amount of detail in regard to the natural resources base of a village.

Within the peri-urban interface the explicit representation of the natural resources of an area as represented by image maps may provide a more powerful catalyst for stimulating the participatory inquiry process than conventional techniques. This may be especially true if an historical image map is available together with a current image map. Evidence has been produced within this project that this is true both at institutional level (as evidenced during a workshop involving the collaborators from UST, and other institutional representatives from Kumasi) as well as at community level (as evidenced during questioning of Kotei/Tweneduasi village members). Figure 20 shows two image maps of the villages of Kotei and Tweneduasi located in the south east of Kumasi, adjacent to the University of Science and Technology (UST) campus. The aerial photograph image dates from the late 1960s, while the ADP image map is dated at 1997. A substantial amount of change has occurred in regard to the available natural resources base in the vicinity of these villages, primarily in terms of erosion of natural resources due to housing development. The housing is mainly for people from outside the village. Although villagers knew of these developments, the scale of the change was not appreciated. The evidence of change provided by the imagery was an important catalyst in promoting the exchange of information about the associated impacts on the villagers and a considerable wealth of information was obtained during a short period of time. The information was also gathered in a way that was unlikely to lead to a widespread raising of expectation amongst the village community in regard to improving circumstances. This element can be a problem in

regions where multiple research projects involving detailed participatory inquiry processes are focused.

An additional benefit deriving from the availability of the imagery is in providing confirmatory evidence of some of the statements offered by the interviewees. An example is provided by the survey undertaken within Kotei/Tweneduasi. Some of the village lands to the south of Kotei have not been developed due to an on-going dispute over ownership. This zone is readily apparent on the image maps.

The availability of the image maps provides a source of information that is both objective and transparent. Evidence of the value of these characteristics was obtained during discussions about the currently 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 of the situation agreed.

Summary of Findings and Proposals for Additional Work

Main findings

- Socio-economic-natural resource linked issues will not be solved without objectivity, transparency and quantification of information
- Appropriate use of geographical information is vital to achieve these requirements
- Geographical Information is crucial for:
  dimensioning of problems
  dimensioning of solution
  estimating benefits
- Defining the geographical frame of reference is a vital component of any project in which location information is to be collected and diverse data sources are to be analysed within a Geographical Information System
- Appropriate definition of the geographical frame of reference can be achieved by use of satellite images of the study area

- A satellite image also provides a source of contextual information that is current and complete in terms of coverage, availability and accessibility.
- Contextual information derived from satellite images can have value in developing an analytical framework to aid the scaling-up of development initiatives
- Large-scale image maps can be readily derived within a short time frame from an aerial digital photographic survey
- Image maps used during rapid reconnaisance surveys act to stimulate discussion and to promote information exchange in relation to the socio-economic circumstances of those individuals interviewed.
- Information can be gathered without undue raising of local expectations of rapid beneficial development
- Evidence exists of considerable misunderstanding of appropriate use of GPS by social and natural resource scientists