SOCIO-ECONOMIC METHODOLOGIES
FOR NATURAL RESOURCES RESEARCH
BEST PRACTICE GUIDELINES

# GIS AND PARTICIPATORY APPROACHES IN NATURAL RESOURCES RESEARCH

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# INTRODUCTION

Geographical information systems (GIS) have an important role to play in natural resources (NR) research to support rural livelihoods, in particular, and pro-poor development more generally. In this Guide we do not attempt to address the whole range of issues associated with applications of GIS in development, but address specific questions relating to:

- stakeholder and beneficiary participation in the data collection process;
- participation in the planning process: assessment of planning and management options, conflicts and development scenarios;
- integration of social and natural science information using spatial databases in natural resources research and development.

A rationale is presented for the integration of GIS and participatory approaches, highlighting the needs for close interdisciplinary collaboration and the application of GIS to development processes through interaction with local stakeholders. The issues involved are illustrated by examples of participatory GIS applications, and by practical case studies in Brazil, Tanzania and Uganda, and Ghana (found at the end of the Guide), and literature-based examples from South Africa. The basic requirements for making effective use of GIS are discussed along with, in an interdisciplinary, participatory context, the methodological issues involved in data collection, integration of biophysical and socio-economic data, data management, and data feedback and availability to stakeholders. Areas for further research and development are considered and overall recommendations on best practice are made. A glossary of terms used in GIS and participatory approaches in NR research is provided at the end of this Guide along with a list of further reading and a contact list. Guidance is also provided on suitability and cost-effective choice of hardware and software for GIS and participatory approaches.

# GIS AND PARTICIPATORY GIS

## What is GIS?

A geographical information system is a computer-based tool for mapping and analysing spatially referenced data; the advantages and features of GIS are shown in Box 1. GIS can facilitate the understanding of spatial aspects of social and economic development by:

- relating socio-economic variables to natural resources and the physical world;
- providing a tool for targeting interventions and monitoring impacts at various scales and over wide areas; and potentially
- putting planning and research technology into the public domain to enrich – and enhance access to – information, to promote discussion and improve understanding of conflicting viewpoints.

As personal computers (PCs) and other information and communication technologies (ICTs) become more sophisticated, globalization of these computer-

**BOX 1: Geographical information systems – advantages and features of interest**

A geographical information system (GIS) is a computer-based tool for mapping and analysing spatially referenced data, i.e. data related to defined geographical space. GIS allows integration of disparate layers of information into a common spatial database, whether the data are related to an explicit geographical reference (e.g. latitude/longitude, grid) or to an implicit reference (e.g. a place name, road, environmental feature).

**Technical advantages in data management**

- Integrating common database operations such as query and statistical analysis with mapping, visualization and spatial analysis
- Integrating information from different sources and scales
- Allowing management of complex information and making it more accessible
- Ability to query with standard database management system tools (DBMS) as well as spatial tools
- Spatial interpretation, predictive modelling and strategy planning
- Rapid visualization, either on screen or as hard copy
- Ability to update spatial data, e.g. derived from recent aerial photographs, satellite imagery or ground survey

**Features of interest for socio-economic analysis and social development**

- Spatial perspectives with overlays of different types of data
- Facilitating the management of large datasets and the integration of different datasets
- Potential to incorporate stakeholder communication, debate, identification of conflicts; and trade-offs in land and resource use; a tool in developing consensual approaches to planning
- Empowerment of disadvantaged stakeholders with access to data and use as an advocacy and planning tool

based technologies promotes widespread availability, lower costs and new opportunities. Despite some scepticism about the sustainability of GIS technology transfer to the developing world, GIS is becoming a more accessible tool for storing and analysing information, mapping, visualizing and modelling development scenarios, and for monitoring progress and change. GIS can be applied at various scales and levels of complexity, and dedicated systems for application in a variety of specialized contexts could become as standard on the average computer as spreadsheets, word processors and databases.

## What is participatory GIS?

Participatory GIS is the integration of local knowledge and stakeholders' perspectives in the GIS. Stakeholders should also have access to GIS databases and products and be able to apply GIS and GIS products to development planning, resource management and advocacy. A variety of terms and acronyms are used by practitioners, such as participatory GIS (P-GIS), which is used throughout this Guide, GIS with participation (GIS-P) and community or stakeholder integrated GIS – but essentially these all refer to the same set of concepts and practices.

In considering participation, it is important to be aware of the distinctions and linkages between primary stakeholders (the ultimate beneficiaries, i.e. local communities and the poor) and secondary stakeholders (institutions involved in the delivery of assistance) in processes and projects which involve GIS. The direct users of GIS and its products – maps, forecasts, tables and conclusions about development options and scenarios – will generally be government institutions but also, increasingly, NGOs and community-based organizations. In the development of P-

GIS, it is primarily these intermediary 'bodies' that need to involve primary stakeholders in the development process, and to deploy GIS technology to help meet their needs.

There are potential benefits in developing participatory applications of GIS in the context of human-centred development models, such as the adoption of the livelihoods approach within DFID, and by other development agencies and donor commitments, to eradicate poverty.

### GIS in rural development

The principal applications of GIS in rural development are community land and resource mapping, the integration of local and scientific spatial knowledge, community-based natural resource management (CBNRM), area planning and environmental management and the management of pests and natural hazards. The applications may be more, or less, participatory according to the data collection and analysis techniques, the degree of stakeholder consultation and feedback and the level at which any management decisions are taken. Table 1 provides examples of the various participatory applications of GIS in NR research and development.

### Risks associated with use of GIS

Since GIS has generally been an expert-driven technology, which is controlled centrally by state agencies, scientific research institutions and private corporations, a number of risks have been associated with its deployment in the service of human-centred development. These include:

- Only expert knowledge or data that are readily available in digital form – as opposed to local knowledge – will be incorporated in GIS.
- Planning decisions will be made by experts and technocrats with access to GIS technology but without reference to those directly affected.
- Personal and community security may be violated if information supplied by local people is used by state authorities and developers without their knowledge, consent or understanding.
- GIS is relatively high cost and, unless safeguards are built in to ensure effective use, the costs are unlikely to be matched by real social benefits.

These risks are real, but they can be addressed by deploying GIS in institutional and policy contexts in which there is a real commitment to incorporating the needs and perspectives of local people in development research and in planning and resource management processes.

## FEATURES OF GIS AND REQUIREMENTS

### Types of information handled

Geographical information systems can be used to organize information for appropriate delivery at different scales and, therefore, it is sensible to consider the needs of users at different levels (national, regional, district and local) and to

## TABLE 1: GIS applications in natural resource research and development

| Local level NR system | Participatory methods | Role of GIS | Level of stakeholder involvement (HIGH/LOW) |
|---|---|---|---|
| **Community land and resource mapping; land delineation and advocacy** e.g. Mozambique community land delineation and registration project | • Participatory mapping<br>• Use of GPS with local land users | • Reconciliation of perceptual and conventional maps<br>• Digitization of participatory map information and aerial photographs<br>• Provision of base maps and digital imagery<br>• Production and updating of community land resource maps | • LOW for mapping only – may be confined to provision of local land and resource information<br>• HIGHER when maps are returned to communities and research is linked to advocacy and CBNRM |
| **Understanding and conservation of indigenous knowledge/ integration with scientific knowledge** e.g. Uganda/Tanzania soils research project (see Case Study 2 and Box 4) | • Listing, sorting and focus groups to explore farmers' soils categories<br>• Transect walks with GPS, household interviews, participatory mapping | As above **plus**:<br>• Integration of scientific land resource data with local datasets; visualization and mapping<br>• Overlay, comparison and analysis of geo-referenced transect walks and maps produced by farmers and scientists<br>• Use of GIS maps derived from high resolution aerial photos and local knowledge | • LOW but with extensive provision of local knowledge<br>• HIGHER if linked to farmers' participation in technology development and land management<br>• HIGHER if feedback to farmers what data/information are put into the system |
| **Community-based NR management** e.g. Northern Namibia Environment Management | • As above **plus**:<br>• Finer grained enquiry into local knowledge, resource use, seasonality, stakeholders' interests; tenure and access rights etc.<br>• Participatory planning methods | As above **plus**:<br>• Overlays of different stakeholders' perspectives<br>• Modelling and visualization of management scenarios | • Potentially HIGH but may be uneven<br>• Risks of inaccessibility of GIS products to local users and domination by local elite – active facilitation needed for map interpretation |
| **Environment management/regional planning**<br>Coastal environmental management e.g., Bahia Brazil (see Case Study 1)<br>Peri-urban environment management e.g. Kumasi NR Management Project (see Case Study 3) | • Participatory socio-economic survey<br>• Participatory mapping and zoning<br>• Stakeholder iteration of maps and proposals<br>• Stakeholder workshops and analysis | • Mapping of land cover and land use from aerial imagery<br>• Production of base maps<br>• Integration of data layers<br>• Inclusion of social data and stakeholders' information | • May be LOW, MEDIUM or HIGH according to attitudes of practitioners and institutional arrangements. Typical variables include:<br>• Commitments of state agencies to multi-stakeholder participation |

| | | | |
|---|---|---|---|
| Watershed management<br>e.g. Tamil Nadu Catchment Forest Management (FAO, India) | | • Analysis of spatial data<br>• Stakeholders' communication: visualization and mapping of socio-environmental characteristics<br>• Mapping of overlapping stakeholders' interests<br>• Modelling of planning scenarios – potential tool for conflict reduction and consensus building | • Uneven stakeholders' access to and understanding of role of GIS<br>• Level of effective use of GIS with development and planning processes<br>• Level of data sharing amongst agencies involved |
| **Hazard management**<br>Crop protection/pest management Red Sea desert locust control<br>Livestock disease control – cattle management in tsetse-affected areas in Zimbabwe and Tanzania<br>Forest fire management in Nicaragua and Indonesia | Limited:<br>• At regional scale generally confined to local agent reports on hazard sightings and outbreaks<br>• Research at local scale may involve reconnaissance of local resource utilization, e.g. key informant interviews and participatory mapping, e.g. of grazing area, cattle density and migration | Fundamental:<br>• Modelling, monitoring and predicting hazard events and characteristics, e.g. pest population dynamics, fire outbreaks and control scenarios according to environmental conditions | • Institutional commitment and inter-agency planning meetings important especially at regional scale<br>• Local stakeholders' involvement generally LOW – confined to provision of monitoring information and local knowledge<br>• Demonstrable local benefits and involvement in hazard control required for local participation |

NR = natural resource, GIS = geographical information systems, GPS = global positioning systems, CBNRM = community-based natural resource management.

consider how data of different types and sources at various different scales can be managed. To be fully effective, GIS needs to link and map data derived from local knowledge, empirical surveys, topographical maps and satellite imagery or aerial photography at suitable scales for micro-level case studies (e.g. 1:5000 or 1:10 000 scale maps) and for wider overviews (1:50 000 upwards). Not all data will be susceptible to mapping. The integration of qualitative data into a common database, for example, by displaying a short text report or a scanned participatory sketch map via a hot-link, may ease its management and retrieval and set it in a geographical context.

Geographical information systems are useful as a tool for combining social and biophysical datasets to facilitate and allow an integrated multidisciplinary analytical approach to an holistic understanding of particular natural resource management questions. For participatory applications of GIS in any sort of planning management process, the crucial link is a spatial reference for all data entered into the system, i.e. to be from a specific place or derived from a particular physical area. An accurate spatial reference or geo-reference not only enables us to know exactly where we are but allows information about particular places and areas to be displayed, analysed and used alongside other geo-referenced data, including biophysical datasets.

## GIS technologies – software and hardware

### *Considerations in choosing the software*

Two types of GIS can be distinguished based on the way data are stored and represented – vector and raster systems. A vector data model represents space as points, lines or polygons that are geographically referenced. The raster model divides a space into equal sized cells (pixels) with attributes recorded as a numeric value for each pixel; remotely sensed data are an example of raster data. Vector and raster data models fulfil the analytical and representational requirements of a GIS but there are basic differences that should be considered when choosing a GIS. Both systems have advantages and disadvantages, not only in the type of analysis and modelling that is available in each concept, but also in practical terms such as data storage and computing time. Until recently, only a few top-end GIS software packages allowed both data model types to be used together efficiently but, increasingly, this possibility is now becoming available for PC and laptop use.

There is a wide range of GIS software available commercially, the capabilities and features of which change rapidly – as do the hardware requirements. However, the choice of software should be made according to the data being used and the outputs required. For example, if a project is concerned largely with remotely sensed data, a raster system would be more appropriate; if the source data are primarily based on traditional maps, and a high graphical output is required, a vector system should be chosen. Where local knowledge, participatory maps and participatory rural appraisal (PRA) findings are to be used with the GIS, and where maps and images are to be produced for stakeholder feedback and discussion, a vector system should also be chosen.

When analysis and visualization of remotely sensed information and traditional or participatory vector-based maps are required, software that integrates both should be considered. A number of packages, such as ARCVIEW, are now available relatively cheaply and, given the advantage of capability to use remote sensing data, generally provide the best software for P-GIS applications.

### *Considerations in choosing the hardware*

In choosing computer hardware, the three most important factors for running a successful GIS are memory, speed and storage. Hardware to input the data (digitizer, scanner etc.) as well as to output the data (printers, data exchange), and provide images and maps of sufficient size and scale should be an integral part of the system. Due to the visual nature of GIS outputs, the choice and availability of computer peripherals as well as the physical ambience and conditions in which the system is housed are important. In areas of uncertain or erratic electricity supply, back-up generators or an adequate uninterruptible power supply (UPS) system should be provided. Like the GIS software packages, the cost of computing hardware is falling as standards rise.

The availability of a functioning global positioning system (GPS) and trained users is generally crucial during the research process, in order to obtain accurate geo-references rapidly for any type of field information. GPS is now relatively cheap and should be used as essential ancillary equipment for any P-GIS application, especially where field level data are required to supplement and update secondary existing data sources. In some cases, where adequate data or maps are available in geo-referenced form, such as aerial photography or high-resolution satellite images, and all features of interest are readily interpretable by the primary stakeholders, a GPS may not be needed. For a fuller technical description of GPS see the Glossary of Terms.

Further guidance on GIS hardware and software and the likely costs can be found at the end of this Guide.

## Operating requirements

It is necessary to consider the principal tasks, skills and training requirements involved in using GIS.

### *Stages in setting up and use of GIS*

There are several stages that can be recognized in the setting up and use of GIS.

- Feasibility study – the use of GIS in a project needs to be planned carefully. Skills needed to build a user-friendly bespoke package for users of only the outputs of the system are different from those needed to put together datasets for use in a standard software package. In order to rationalize the capture and storage of information, this task should be given maximum importance and should include participation of all the stakeholders – full consultation will benefit the next steps.

- Planning and design – an implementation plan, including the system and database design, is needed – again with the full participation of all the stakeholders. The roles of the project team should be defined and the availability of an adequate skill base to implement the plan in a workable time frame should be checked.

- Development – software and hardware are identified and purchased (see guidance at the end of this Guide), databases are constructed and training undertaken. Operating protocols are also developed, especially for a large project.

- Implementation – the system is installed, data acquired and assimilated, and outputs produced. Installation should be in a suitable working environment, taking into account adequate space, good lighting and, if necessary, air-conditioning. Adequate precautions to protect the electricity supply should be taken (see above).

- Data acquisition can be considered in two main areas: background data, such as maps and biophysical data which may need to be digitized, and project-generated data. Simple measures, such as providing input forms for databases, standardizes and regularizes inputs – and checking and regular backup of data should be routine.

- In a GIS that has defined output needs, the means of analysis can also be standardized and user guides provided for the more casual users. This may require the GIS practitioner to have programming skills.

- Data presentation, often in the form of maps, charts and tables, is produced to a high quality by plotters and printers. If hard copy outputs are required for fieldwork, lamination is advisable for protection and providing a more durable surface for working on.

- Follow up and feedback – mechanisms are put in place for the system to be updated and maintained locally if required. The initial impact of GIS technology can be high – presentation of analyses is visually attractive. However, GIS technology moves fast and if a long-term role is envisaged in a community or institution, the sustainability of the system must be considered. For example, help must be in place for dealing with possible hardware and software problems, and a means of upgrading the system must be identified.

### *Skills and training requirements*

A range of skills and training requirements are required.

- Data collection and input – although sophisticated GIS skills are not required, tasks such as geo-referencing of field data and digitizing existing maps or aerial photographs can be quite time-consuming.

- Data outputs – general computer skills and an awareness of the capabilities of the GIS.

- GIS practitioner using standard software – an understanding of GIS data models, encompassing GIS design, database design, data capture methods, transformation techniques to enable data to be analysed in a common co-ordinate and projection system, interpretation and analysis of data, storage and backup procedures and provision and design of outputs.

- GIS practitioner providing a tailored GIS – all the skills of the above practitioner plus an ability to programme the chosen package.

- PRA researcher – an appreciation of the capabilities and limitations of spatial interpretation and analysis. A working knowledge of the GIS, including the best way to collect and present data for inclusion in the GIS.

## Institutional and sustainability issues

Geographical information systems are used in a variety of institutional contexts. The basic requirement for effective deployment of GIS in a developing country is an institution in which management commitment and resources are sufficient to ensure that staff have adequate skills, interest and resources to operate and apply the technology. To avoid dependence on data and technology imported from donor countries, the project requires an institutional and business environment in which baseline data and maps are available or can be purchased commercially. Combining GIS with a participatory approach requires a willingness to share datasets amongst institutional partners and an openness to stakeholder involvement in the development and application of GIS.

Sustainability is a key issue for project design if project support is to lead to any enduring capacity to operate and apply GIS (and see next section). Projects with a purely research focus are unlikely to lead to sustainable GIS capacity, therefore it is important for research projects to link effectively with projects and institutions which benefit from adequate GIS infrastructure and operating skills.

Case studies documented in these guidelines benefited from project support in various ways:

- In a DFID-supported coastal environmental management project in north-eastern Brazil (Case Study 1), the partner institution had its own GIS capacity, which the project upgraded and expanded to cover the project area by installing new equipment, funding a local GIS technician, accessing aerial photography and satellite data, and providing consultancy support. A comprehensive database and set of maps of the project area are being produced for ongoing use, and the project's social development consultant worked with the technical planning team to promote a participatory approach. The state planning agency has begun to recognize the validity of local sources of information, to share data with other agencies, and to respond to stakeholder needs and priorities in applying GIS in the planning process.

- A research project combining scientific and indigenous knowledge of soils in East Africa (Case Study 2) relied upon GIS capacity with a European 'bias'. The emphasis was on methodological research using GIS rather than capacity development to make ongoing applications. This case illustrates the high level of expertise required to manage GIS databases successfully and use them as an analytical tool. Data entry and database management was mainly at universities with GIS expertise in Belgium and UK, while data analysis and integration with indigenous knowledge involved a significant input from the Natural Resources Institute (NRI) of the University of Greenwich. The developing country collaborators – agricultural universities, research station staff, local NGOs and extension officers in Tanzania and Uganda – had limited skills in data analysis using GIS and training given had limited impact.

- The Kumasi GIS for peri-urban natural resource management (Case Study 3) involved parallel systems, run in the UK and Ghana, developed by NRI and installed using project funds with data managers in each country paid by the project. In the final stages of a current project using the GIS, the host institute in Ghana is being encouraged to develop a plan to sustain the system for local use over the next two years. This will involve the development of GIS courses for local managers, planners and students, the commercial use of the data for local business (e.g. in tourism planning) and a positive commitment to publicizing the use of the GIS in future research.

## PROJECT DESIGN, PLANNING AND PREPARATION

### Importance of a multidisciplinary approach and participatory planning

The first consideration is to establish whether GIS is a relevant technique to use. Will GIS enable the production of new knowledge that can provide real benefits to stakeholders? In answering this question, it will be necessary to develop an interdisciplinary approach from the outset, and to consider how the products of GIS as a research tool will actually be used, the needs of different stakeholders and the role that different disciplines will play in the collection and analysis of data. If GIS offers relevant techniques, it does not make sense to design or commission projects in which social and natural scientists and GIS practitioners develop lines of enquiry independently of one another, seeking to integrate their findings and perspectives only at the end.

In assessing the relevance of GIS, it is critical to involve developing country partners and collaborating institutions. The key criteria for determining relevance and applicability of GIS in a given institutional context include:

- existence of institutional capacity to operate GIS
- demand/need for the application of GIS to the research or development problem
- presence of a data-sharing culture and possibilities amongst local agencies
- availability of baseline cartographic data
- at least some relevant thematic data in geo-referenced format
- relevance of spatial analysis – typically, in understanding spatially differentiated livelihood and production systems, area-based development and environmental processes, and/or micro-meso-macro links
- innovation and demonstration value of conducting data analysis and communicating results using the capabilities of GIS.

Typically, but not exclusively, these conditions might be met in middle-income countries or those with research and planning agencies, focusing on the needs of urban and peri-urban areas or more developed and populated rural areas. In project design, consideration of institutional capacity and infrastructure amongst the users is of major importance in choosing GIS software and hardware. Important issues to take into account are:

- financial – start up and running costs
- available institutional infrastructure to collect the data, operate and apply GIS, and to employ, train and retain suitable staff
- personnel – level, range and number of skills, and opportunities for ongoing training
- awareness of the capabilities of a system – and provision of suitable accommodation for it
- commitment to a feasible programme of staff training and awareness raising of GIS users

- data input – methods and means available
- output – methods and quality.

In view of these requirements, it remains difficult to maintain and operate GIS at local or district level in many developing countries because of inadequate infrastructure and skills. The more sophisticated the hardware and software the greater the difficulties will be.

## Selection of planning units and mechanisms for stakeholder involvement

Secondly, it is necessary to consider the specific objectives of the project, the scale at which it is to operate, and how stakeholder/community level information and involvement are relevant. If GIS does promise to add value to a project, how should it best be used and at what level?

Where a project examines location-specific issues, it is likely that local knowledge and participatory research and mapping will need to be conducted in order to generate information on NR and livelihood systems. Feedback of outputs, probably via clear, simplified large-scale maps and thematic map overlays, is also useful to validate results with the information providers or to enable their participation in applying the results.

Over wider areas, institutional participation and application of results become relevant in both research and technical co-operation (TC) contexts – and a P-GIS approach is especially relevant. It will be important to gather data at district or regional scale on the one hand and at local scale on the other, for instance, through in-depth micro-level enquiries in a number of representative sites. Partner agencies will need to be able to grasp the wider spatial relevance of micro-level knowledge and, where they are engaged in area planning and management, will need to develop links which enable participation of local stakeholders. The application of GIS may help by producing maps to share the findings amongst stakeholders, and by enabling appreciation of the spatial significance of local processes and research results. If participatory planning methods are to be developed or tested, institutional acceptance of stakeholder involvement and identification of opportunities to develop this are essential features, without which GIS is likely to remain a centralized and technocratic planning tool (see Case Study 1).

Once a project is initiated, researchers and project staff should consider the types of data needed, their likely uses, and the needs and opportunities for dialogue amongst the users. In planning ahead, local information and participatory data should be given equal weight with scientific information in developing the GIS, and survey methods should be designed accordingly.

It should be remembered that despite problems of quality and compatibility of data from different sources, maps incorporating different sources and types of information can create common frames of reference and facilitate dialogue. Maps are likely to provide useful tools for planning a survey, relating the human population of an area to its natural and physical features, and encouraging spatial thinking amongst investigators. An approach which proved useful in Brazil, as outlined in Case Study 1, was to incorporate existing knowledge of the project area into sketch maps as a visual aid in selecting sample sites. More detailed, accurate maps can be prepared as further data become available. A first task is likely to be the accurate spatial referencing of survey sites, human settlements and the boundaries of the areas of interest.

## SOCIO-ECONOMIC AND BIOPHYSICAL DATA COLLECTION

### Tools for collection of socio-economic and other qualitative data

The type of data needed, and the methodology and sequencing of data collection techniques depend greatly on the type and objectives of a particular project and what the outcomes will be used for.[1] The techniques for data collection suggested in Box 2 offer a range of tools that can be selected according to the specific objectives and nature of the project. In general, the tools used in conventional PRA are appropriate to gather data for use with GIS. Careful attention needs to be paid, however, to the sequencing of different tools, how the information is entered into the GIS and how different sources of information are linked together for analysis within the GIS. Spatial referencing of qualitative data should form a key component throughout the data collection process. Importantly, both the PRA and the GIS development process should work towards the same overall purpose and be planned accordingly. Consistency in the composition of the research team is also important, since this allows for regular cross-checks and feedback between the different data sources and team members.

### Socio-economic data sources

#### *Pre-existing or published data*

Secondary sources, i.e. pre-existing or published data, include PRA-derived data information and census information. Pre-existing socio-economic datasets may be extremely useful but in most cases they are not geo-referenced. Census information is likely to have a cartographic reference related to map units but this may be available at too high a level of aggregation to assist with local enquiry. Alternatively, it may be based on census districts which do not correspond with administrative or management units, such as local parishes, watersheds, agro-ecological zones or designated conservation areas (see Case Study 1).

Although pre-existing PRA data frequently relate to specific locations, they are also generally not geo-referenced. Where systematic PRA has been undertaken over wider areas, using specific criteria to obtain representative coverage and capture socio-economic and environmental diversity, it may be relatively easy to geo-reference and integrate with other datasets retrospectively. The use of key PRA findings within or alongside a good map displaying other features of interest, such as infrastructure and land use, may prove useful in developing a spatial understanding of, for example, the variation in livelihood opportunities and constraints across a project area. This was done in P-GIS case studies in north-eastern Brazil and in Kumasi, Ghana (Case Study 1 and 3).

#### *Social and economic baseline and diagnostic surveys*

These surveys are undertaken as components of the research or to support planning work. In the design of participatory survey work, it is advisable to geo-reference

[1] Examples of different types of projects are: research projects, land rights mapping, CBNRM, participation in land use planning and devolved local planning/advocating alternative plans.

## BOX 2: Tools for quantative data collection

- **Secondary socio-economic data, literature and project reports** National census information compiled by national and regional governments, and research conducted by other organizations and institutions can provide important background information. This sort of information can play a key role in identifying areas to work in and in the selection of survey units. However, such information is often outdated and complicated to link with other data due to non-spatial references and possible differences in scale and scope.
- **Participatory mapping** This is useful for exploring community members' spatial conceptions of their natural and social resources, land boundaries etc. A widely applied tool in P-GIS due to its spatial focus. However, there is a need for integrated use with other tools to put into context and understand local spatial perceptions. For linking with other databases within the GIS, it requires a fair level of spatial accuracy. Perceptual mapping can be done in several steps, starting with a free-drawn map, followed by mapping based on photo maps or uniform base maps developed from aerial photographs and topographical maps, to allow for consistency and spatial accuracy for use within the GIS. Close participatory observation and making notes about the actual mapping process is likely to help with the process of analysis.
- **Semi-structured interviews** These allow the participants more scope to investigate what people know and to follow up topics of interest as they arise in the discussion, and can be used with groups and individuals. A wide range or mix of criteria can be applied to select participants: gender, age, level of education, area of residence, socio-economic status, size and nature of land holding etc.
- **Focus group interviews** Group interviews provide exchanges between participants with differences of opinion that can often lead to greater insights into people's perceptions. Care is required over the composition so that as many as possible feel free to express their opinions, especially those with less status who may be better interviewed in a separate group or individually. They can take place at different stages during data collection, data entering and data analysis for cross-checking and feedback.
- **Key informants interviews** 'Experts' – those identified by local people as having specialist knowledge – may be interviewed, taking care that they are not confined to those with formal education and access to scientific and/or outsider knowledge.
- **Field visits and transect walks** These combine observation and discussion and are useful in allowing the participant/respondent to point things out *in situ*. They may also provide a more relaxed atmosphere than a group meeting, making communication easier. Qualitative information should be geo-referenced with a GPS to allow spatial reference and overlays of thematic maps during analysis within GIS.
- **Participatory observations** These are useful for comparison of actual practice to the norms presented in group discussions or interviews. As with transects, qualitative data can be geo-referenced to support analysis at a later stage.
- **Diagramming, ranking exercises and games** These can be used to elicit local perceptions, definitions and classifications. Tools include ranking of importance, comparing characteristics using pair-wise ranking diagrams, seasonal calendars and network diagramming.
- **Local classification systems/taxonomies** This can be a difficult area as it requires an understanding of social and anthropological principles of research in combination with linguistic skills. Notion of multiple realities should be well understood. It involves the identification of local terms, then asking local people to sort and group the categories, identifying common features and contrasts in the context of the wider language and cultural system.
- **Cultural expression** The content of songs, poetry and speeches on celebrations and public occasions can reflect significant messages and social values.

Source: Adapted from Warburton and Martin (1999)

survey sites in advance or as the enquiry proceeds. The use of good maps – even sketch maps – will prove invaluable in identifying survey sites and in devising sampling strategies which reflect important spatial variables, such as population concentration, agro-ecological features, and access to markets, services and labour markets. The accuracy and usefulness of the maps can be improved as work progresses using the GIS, for example, to capture previously unknown local settlements and markets, and changing land uses.

### *Local and indigenous knowledge and perspectives*

Another source of socio-economic data is local and indigenous knowledge and perspectives derived from location-specific participatory enquiry, and includes mapping exercises and interviews. One of the main requirements for successful application of P-GIS is the input of multiple sources of knowledge provided by and generated from the stakeholders involved, with a particular emphasis on local knowledge. Local people's knowledge (LPK) includes the complex of practices and decisions made by local people and is shaped by and interlinked with technical, cultural, political and social knowledge. It is based on experiences passed from one generation to the next but, nevertheless, it changes, adapts and assimilates new ideas; it can be quite location-specific and may vary among individuals according to age, gender, socio-economic status, ethnicity, area of residence etc.[2] It is important to consider the epistemological differences between local knowledge and so-called scientific knowledge during the design and implementation of data collection and analysis throughout the project cycle.

## Biophysical data sources

Biophysical sources of data[3] fall into three broad categories:

1. Cartographic and other published datasets
2. Remotely sensed imagery – including aerial photography/videography and satellite data
3. Empirical survey data and ground-truthing (or on-site validation) of remotely sensed data.

Secondary data sources, which include publications in digital form, can also include:

- topographic maps
- digital elevation models
- climatic and agro-meteorological data
- soil survey information
- geological information
- vegetation and land cover maps
- information about agro-ecological zones.

On-site validation and biophysical field survey may provide opportunities for involving local enumerators and key informants in generating local knowledge and information through participatory techniques, such as group discussions, perceptual mapping and transect walks using GPS. These techniques can be used to gather ethnobotanical information about resource utilization, environmental change, land access and ownership, user conflicts, relative local values and socio-economic importance of different species. This approach is useful for validating, interpreting

[2] For a more detailed discussion on local knowledge and participatory approaches see Warburton and Martin (1999).

[3] Detailed guidance on the collection of primary or secondary biophysical datasets for GIS is not provided – nor is guidance on the use of remote sensing imagery and data available from published sources or commercial suppliers.

and updating, for example, aerial photography and remote sensing information, and understanding the socio-political and management implications. There are significant opportunities here for better integration of ecological and land use survey work into rural development planning process, and for developing fuller partnerships with local people, but these are frequently missed. The employment of local community members as enumerators can also provide incentives for wider local participation in survey work and management processes arising. (See Case Studies 1 and 3.)

## Quality control of GIS data

The quality of GIS products is often judged by the final appearance of the printed output which can be visually appealing and can disguise poor quality of data. The use of inaccurate or unreliable data in GIS will, however, lead to defective maps and inaccurate analytical conclusions. In some instances, the only data that are available have to be used and it is, therefore, important that the quality of all data is acknowledged and understood by users of a GIS. Adequate procedures need to be in place for deciding which data are worth using – and in what form. Some of the common sources of error are shown in Box 3.

### BOX 3: Factors affecting the quality of GIS data

**The quality of spatial data depends on:**

- how recent the data are and how up to date
- datasets in time series being comparable with datasets over the period of survey
- completeness over an area
- using different data layers that are comparable in scale
- scale used being suitable for the study in hand
- formats of different datasets being compatible
- project having copyright or licence rights over the data being used
- suitable datasets being available within the project budget
- suitable density of field observations being made
- locational accuracy of field observations being suitable for the scale used
- attribute data being entered accurately and in a way that provides sensible analysis and outputs

**In addition:**

- topological accuracy must be maintained within and between spatial datasets
- meta data are to be accurately entered and stored with the data
- all inputting should be checked
- choice of data model should be suitable for the project
- account must be taken of imprecise and sometimes contested nature of boundaries
- the risk of observer's bias must be acknowledged
- limitations of the computer processing and analysis must be understood

**Errors specific to GIS may be generated by:**

- problems in integrating and classifying data using map overlays based on datasets with different formats and levels of accuracy
- inconsistent or imprecise use of logic in data interpretation and spatial analysis
- error propagation and magnification during data transformation
- choice of mathematical models and datasets in interpolating non-empirical information.

Source: Derived from Burrough and McDonnell (1998)

# INTEGRATION AND ANALYSIS OF SOCIAL AND BIOPHYSICAL DATA

## Rationale for integrated research

Within applications of P-GIS, participatory and perceptual mapping is a widely practised tool as it easily digitized and stored within the GIS. However, qualitative data collected through participatory and perceptual mapping tend to be spatially inaccurate. This can be corrected by proper sequencing of the mapping process, starting with free-drawn maps which can then be reconciled with uniform base maps developed from aerial photographs and topographic maps (Mather *et al.*, 1998). However, maps should not be used as a single tool to collect and explore local knowledge, since they do not allow for more complex concepts and interactions or 'triangulation (Chambers *et al.*, 1989). An integrated approach using different tools for collection and analysis of both spatial and non-spatial data will enhance an in-depth understanding of locally produced perceptual maps and reflect different stakeholders' perspectives and realities of the same land area, for example, those of farmers, gatherers of forest produce, private developers, and local government planners.

Uncritical rapid questioning and recording of qualitative data and local knowledge may lead to misunderstanding, misconceptions and distorted results during the analysis within the GIS until more detailed work can be done (see Box 4).

In addition, regular feedback with the local communities about the research process and preliminary results not only improves their understanding of local perceptions, but also gives them a sense of ownership of the process by the local communities. It

### BOX 4: Exploring local soil categories in Uganda

The integration of different methodologies (e.g. mapping, transect walks, focus group discussions and individual interviews, sorting tasks etc.) made it possible to reach an understanding of how farmers' expressions of their knowledge, and the soil categories used, relate to the particular location and social setting of the interview, discussion or observation and its sequence in the research process. Some categories were brought up in some exercises and not in others. Not surprisingly, mapping tasks appeared to elicit farmers' definitions of land areas, while the sorting interviews and focus group discussions elicited nuances in characteristics of the actual soils, and the transect walks generated location-specific, detailed descriptions.

The term *eitela* is a good example. In Wera village, Uganda, the first attempt at participatory soil mapping using aerial photographs resulted in large areas of the village being designated as *eitela* (this term describes an upland area – often bushy and left uncultivated for a while – and is not a soil type as such but a land use description that includes different soil types). During the sorting task, farmers went into more detail as they grouped their different soil types, explaining the grouping criteria and the similarities and differences between them, and produced a different understanding of what the concept *eitela* actually means. Most farmers involved in the sorting task drew this distinction between *eitela* and soil types, and this was further clarified in the focus group discussion. A later map drawn by the farmers who had been involved throughout the research process did not include *eitela*.

Another example of the limitation of participatory mapping as a single tool was the exclusion of localized soil units, such as fields located on previous homesteads or anthills, as they are rather small units and are difficult to map. Although limited in coverage, these soil types play an important role within the local agricultural production systems due to their high fertility.

Source: Derived from Case Study 2

allows them to have a certain level of control over the information entered and used within the GIS throughout the process, thereby limiting potential conflicts and securing future community involvement (and see section on Feedback and Accessibility of Data).

## Integrated approach to data collection and GIS analysis

Qualitative data are not readily suited to modelling and spatial analysis. However, qualitative enquiry can lead to the ranking or scoring of resource availability or quality, livelihood opportunities, socio-economic well-being, poverty indicators and development problems etc., across different areas and between different groups. The results can be visualized and mapped, and overlaid with available quantitative or secondary data, such as population or health information, rainfall data, landholding size, and land cover information (see Box 5).

Biophysical data are often already available in a geo-referenced format as they are mainly obtained from remote sensing, aerial photography or cartographic sources, linked to a GIS. However, socio-economic and qualitative datasets are generally not geo-referenced, and are therefore more difficult to integrate with quantitative sets within the GIS and, as a result, are less susceptible to spatial modelling. For successful integration, there is a need for an integrated and iterative approach during data collection in which a GPS should play a significant role in gathering spatial references for qualitative datasets.

There are various ways in which qualitative information can be integrated and combined with physical, environmental and other quantitative datasets within the GIS:

- entering qualitative data in a text database that can be linked with spatial references – this is especially important as a means of tracing whose knowledge has been elicited, documented and incorporated into the GIS;[4]

- hot-linking spatial maps to descriptive texts;

- use of perceptual maps that are spatially referenced and linked to a qualitative text database for in-depth information and clarification (e.g. in the case of fuzzy boundaries and multiple meanings of local perceptions – 'good grazing land', classifications of natural resources etc.);

- geo-referencing transect walks to allow for spatial reference of qualitative information/local knowledge on, for example, natural resources management;

- entering qualitative data in structured databases containing tabulated, scored or ranked qualitative information, and video and audio clips recording oral histories and local people's views and knowledge – this type of database can be plotted by spatial queries and multiple overlays using other thematic maps stored within the GIS.

[4] Where personal or location-specific information is included in a database, data security, confidentiality and intellectual property rights issues may arise, especially if the information is to be published, networked or somehow sold on.

### BOX 5: Exploring local soil categories in Uganda

Through participatory mapping, the community provided information on the location and type of their water sources, their specific uses (such as household consumption, watering cattle, washing and laundry) and their state of repair. Hydrological surveys gave information on the chemical quality of water. Both databases were combined by overlaying thematic maps, and information on the quality of water used for livestock and human consumption was obtained. Additionally, the number of damaged water points could also be identified more efficiently.

This provides a clear illustration of how a qualitative enquiry on resource availability and quality can be mapped and visualized within the GIS.

Source: Cinderby, presentation at workshop *Geographical Information Systems and Participatory Methods*, NRI, Chatham, July 1999.

In some cases it is necessary to analyse the data before they are mapped, for example, by scoring and ranking the indicators or variables in question and assessing the spatial significance, coverage and variation in the data. This can be undertaken independently and loaded into the database, or done by a spatial analyst using the GIS to undertake the analysis and reflect it in a mapped form.

## Problems and challenges in integrated data collection and analysis

Data integration problems commonly arise as a result of failure to reconcile datasets within a common spatial and temporal framework, which allows for the differential data accuracy and reliability. For example:

- Use of outdated biophysical or socio-economic datasets in multiple overlays with more recent qualitative observations (e.g. derived from a village PRA) can result in a distorted analysis and lead to biased recommendations. Both datasets need to be validated by making qualitative observations over a wider area (scaling up the PRA, and ground-truthing the older datasets) and obtaining new survey data (e.g. from aerial photos or high resolution satellite images).

- In some cases, qualitative data can include multiple perceptions and fuzzy boundaries that are impossible or difficult to reference spatially. Despite the prima facie difficulties, this problem should be treated positively in both informational and planning terms. Technical possibilities of, for example, establishing hot-links to text databases can assist in linking the information to the GIS, but the key question is whether or not imprecise data and multiple perspectives can be actively used and incorporated within the analysis. Generally, users are tempted to reduce multiple perspectives into a single and easily understood one. However, it is worth seeking to change this, since simplification for the purpose of computerized mapping may mislead users, leading to inappropriate interpretation and action.

- Imprecision of information (see Box 6) is no justification for omission. The use of fuzzy logic techniques enables handling of qualitative data rather than reducing the data to restrictive quantitative classes within GIS. Fuzzy logic or fuzzy set theory allows individual pieces of data to be members of different overlapping sets – and uses possibility instead of probability as a statistical technique.

### BOX 6: Use of boundaries

If stakeholders perceive the boundaries on maps as accurate, rather than fuzzy, it may lead to conflict between different groups, for example, some communities used the lines they drew on maps to lay claim to communal land and to try to prevent other groups from entering 'their' subsistence area; this triggered local conflicts about access and ownership of land. In other cases, communities and other stakeholders decided not to define and include boundaries of communal/private land in order to avoid such boundary disputes. Therefore, there is a need fot capacity building to understand the limits of any analysis within the GIS to avoid such conflicts emerging.

Source: Cinderby (1999)

- Importance of cross-checking data with local communities before entering into the GIS. In some cases data may need to be analysed before being mapped, for example, scoring and ranking social well-being, natural resources quality, problems and needs, and key resources. This analysis can be done by the research team but the results should be presented to the local communities for feedback before being entered and used within the GIS.

## DATA STORAGE AND MANAGEMENT

It is necessary to match technical GIS development and operations sequentially to the different tasks. At the outset, sketch maps or simplified maps produced using GIS overlaying key features may be very important, even if their locations are not fully accurate. Subsequently, a project may need to obtain participatory sketch maps from the field, topographical and thematic maps, and digital images, and reconcile these to a consistent scale. The next stage is likely to involve entering into the database the detailed empirical information, collected by the project, about resource use and socio-economic and biophysical features, and the production of maps to represent this information spatially.

The most developed uses of the GIS will be as a data analysis tool and subsequently a planning tool. Social and natural scientists will need to work closely with GIS specialists to determine the best approach to data analysis and the representation of results in maps and other graphical forms (e.g. combination of point-specific socio-economic datasets from particular villages alongside maps of resource utilization and physical infrastructure). The quality of graphical and mapped outputs of GIS is particularly important in relation to the need for feedback of data, as discussed in the next section. As an analytical tool, GIS can also contribute significantly to the discussion of spatial relationships and, for instance, to the evaluation of planning options in written outputs.

In developing and managing a GIS database:

- It is essential to build on existing data/information sources and existing GIS systems. Always seek existing digital sources of data since data entry is the most expensive and time-consuming element in GIS development.

- Collaboration in data exchange may lead to wider inter-agency and interdisciplinary collaboration. Digital base datasets derived from the project should be made more widely available to a variety of end users.

- Meta data (i.e. data about available datasets and sources) should be documented, giving the source and ownership/copyright of the data and agreements relating to their use. All in-country standards that exist on recording meta data should be adhered to. It is essential to track errors, omissions and imprecise features – for subsequent improvement – so these can be included in the meta database.

- It is important to track changes in the data and processes applied to a dataset (file names, projection changes, attribute joins, analyses). If there is no provision for this in a meta database, a separate processing file should be kept.

- Secure backup systems should be in place – backups should be regular and, if possible, stored in a different location from the GIS.

- Most GIS can use data directly from spreadsheets and databases. Some GIS can have direct access to statistical packages, such as ARCVIEW and S-Plus – S-plus also has a spatial statistics package that links directly with ARCVIEW.

## FEEDBACK AND ACCESSIBLITY OF DATA

### Data display and feedback for participatory discussion

In order to communicate spatial information to stakeholders, good, clear accessible maps are essential. There are a number of basic principles:

- Do not rely on computers alone. Printed maps may be more versatile than GIS computer files for permanent display, especially in remote locations. A notebook computer can be useful to manipulate and display data in an interactive discussion, but images will need to be projected if viewed by more than a few people.

- Maps should be produced in large format – A2 or A1. For discussion purposes and depending on complexity, A3 is probably the minimum size for practical use even by researchers and technicians.

- Overlays should be clear, restricted to the most important variables and main features, eliminating 'noise' or irrelevant detail. Avoid providing too much information in a single map. Different overlays can be produced to highlight different features.

- Use of colour should be clear – avoid using shades of the same colour, indistinct juxtaposition of colours, and complex shading or hatching to illustrate different features. Natural, realistic colour should be used where possible, for example, green for vegetative features, blue for aquatic, brown for degraded land or urban settlements.

- Map legends and symbols should be clear, simple and always made available with a map.

- Clear simple graphics produced by a GIS are a useful adjunct to a map, or can be included in it if visually not too complicated.

Although there is concern and discussion about the intelligibility of maps to primary stakeholders who may not be visually literate, a growing number of people are capable of interpreting a map – a basic skill which should be promoted. The use of readily recognizable images, such as aerial photographs, and the reconciliation of locally produced maps with topographic maps and aerial photography or high resolution satellite imagery data, can aid interpretation. A common visual understanding, amongst local residents, researchers and planners, of the spatial features of an area may also be a prerequisite for joint understanding and management. Moreover, clarity and accessibility in map production will make them accessible to all stakeholders. Too often, highly complex maps produced by specialists using GIS are incomprehensible even to visually literate professionals.

Providing feedback and maps to local communities and information providers serves a number of useful purposes, including:

- validation of survey findings and maps produced
- generation of additional information and understanding of stakeholder perspectives through discussion
- promotion of local involvement in a planning and management process
- communication of information to decision-makers
- encouragement of discussion of planning scenarios and resolution of potential resource use conflicts.

## Control of GIS technology and accessibility of products to local communities

A key factor in the successful implementation of P-GIS lies within the partnerships created between all participants involved – spatial analysts, social scientists, government officers, NGOs and local groups. Availability of and access to spatial referenced data/GIS can contribute to capacity building for environmental management at local level, and help empower local communities. Through visualization, GIS can be a useful tool to increase understanding of all participants and foster constructive discussions (see Cinderby, 1999).

Although accessibility of GIS to the community or even local ownership and control of the system may be desirable, the problems of operating GIS at local community or district level – costs, lack of skills, and maintenance problems – mean that 'community integrated' GIS is relatively untested and, in most cases, a long way off. The use of GIS may sometimes be useful in promoting institutional collaboration and responsiveness to primary stakeholder perspectives in otherwise closed, disabling institutional contexts, as occurred in the Brazil case study. However, as remarked at a P-GIS workshop, GIS, like PRA, is only as good as the institutions which use it, and its applications will only be as participatory as the local politics permits (Robert Chambers, personal communication, 1988). If the planning process is not responsive and accessible to local people, GIS alone will not change the situation.

Secondary stakeholder participation in GIS development can also strengthen ownership or projects and project outputs: common interests in GIS and its data products can provide incentives for institutional collaboration. However if agencies, involving or representing the poor and marginalized groups, are not involved in planning and development, there are serious risks that GIS will remain a top-down, expert-driven system, which centralizes and does not divulge spatial information for public use.

Technical investment in GIS development and in data collection processes, however participatory this may be, is not enough. For P-GIS to be effective, the responsiveness of institutions to social need is fundamental. Institutions developing GIS for development purposes need to reach out to local stakeholders and develop new opportunities and mechanisms to involve them in research and planning processes. This must be done prior to or in parallel with GIS development.

The main area where a combined, sustained effort to reach out and use GIS both to analyse data and visualize stakeholder viewpoints – and is likely to pay off in terms of sustained benefits – is in projects addressing participatory area management. These could include CBNRM and participatory forest management, protected area planning and management projects, watershed-based and area-focused rural development programmes, as well as educational planning and management.

## AREAS FOR FURTHER DEVELOPMENT

### P-GIS as a process tool

While GIS development should not be treated as an end in itself, P-GIS and its products have a number of potential applications as a process tool in research planning and planning contexts:

- provision of a common frame of reference to enable more consistent interpretation between stakeholders
- giving participatory planning authentic spatial references
- driving discussions amongst different groups and between communities and planners
- assistance in providing visual aids to involve non-literate people in the planning process
- enabling early identification of issues requiring conflict resolution
- provision of a visual and analytical tool in developing appropriate plans and frameworks for an area management
- strengthening stakeholder ownership of projects and project outputs
- raising issues of access to information validates local information and can support advocacy work
- linking local and district level information, and encouraging planners and officials to recognize and respond to community needs and aspirations.

### Principal applications and further development of P-GIS

There is clear scope for application and further development of P-GIS in a number of areas:

- planning and monitoring for locally based CBNRM and common property resource management in a number of areas, including developing participatory management plans for collaborative forestry, rangelands and wildlife, wetlands and aquatic resources;

- watershed or protected area management, especially where the objectives include both socio-economic development and environment/NR management;

- decision-making and planning for agricultural services and extension support – analysis of recommendation domains to enable targeting, and tailoring support according to the characteristics of farming systems and local agro-ecological and market conditions;

- planning and monitoring for area-based rural and urban development programmes, not confined to NR sectors but extending to health, educational and basic infrastructure planning.

In addition, there are potential uses of P-GIS in country strategy or sector-level planning applications which donors and governments could take up in the project and programme design process. This, however, requires the existence of an adequate GIS database reflecting key stakeholder perspectives and knowledge and overall diversity over the target area.

## Research needs

Although stand-alone methodological research into P-GIS is not recommended, its successes and weaknesses, and the lessons arising from ongoing and future applications can be monitored and drawn together.

A number of methodological and communications aspects would benefit from further investigation in the context of ongoing applications and further NR research:

- effective use of perceptual information and local knowledge in scaling up for the management of wider areas, for example, in catering for the needs of different farmer and pastoralist groups and other resource users across a watershed or district;

- use of GIS and GIS maps as effective visual aids, alongside other methods, and the further development of practical guidelines;

- application of P-GIS methods to the identification, management and resolution of natural resource and planning conflicts;

- GIS for area-based projects taking a livelihoods approach, and as a management tool to monitor livelihood change and development;

- role of GIS as a monitoring and evaluation tool for area-based development programmes, especially in a multi-agency, multi-stakeholder context.

## P-GIS and the livelihoods approach

There is particular potential to explore the usefulness of P-GIS approaches in operationalizing the sustainable livelihoods (SL) approach to development and poverty eradication, which espouses the principles of people-centred stakeholder participatory development. The spatial perspective which GIS provides can assist in prioritizing, targeting and tracking the impact of interventions designed to improve livelihoods and reduce poverty by:

- visualizing and mapping of capital asset availability over geographical space and change over time;
- enabling an understanding of how vulnerability factors, socio-historical processes, and the effective reach of policies and service delivery institutions have differential impacts on different areas;
- using GIS as an overall cross-sectoral monitoring tool for progress in promoting SL and poverty eradication, incorporating a variety of indicators, such as incomes, food security measures, access to land, water supply and sanitary conditions, access to basic services, animal and human health, employment, market development and trade flows (see Case Study 3).

Effective application of GIS to target areas, or even whole countries or regions, can help in monitoring and visualizing change and, thereby, measuring progress. Charting the geographical impact of the livelihoods approach requires the development of spatial indicators of livelihood diversity, vulnerability, and access to livelihood assets (land, natural resources, infrastructure, markets, social institutions, skills and human resources etc.), in addition to conventional poverty indicators. How far participatory methods are needed to derive this information, and how far it is susceptible to spatial, visual representation will vary from place to place and according to scale.

Notwithstanding the methodological work that will be involved in making successful developmental and participatory applications, GIS undoubtedly provides a powerful tool for agencies committed to making a difference for the poor, and to strengthening dialogue in planning and environmental management.

# CONCLUSIONS

In setting out the lessons of recent participatory applications of GIS, and in examining how the technology can be applied successfully by responsible development practitioners, some important general conclusions can be made regarding the basics of good practice with P-GIS.

- Just as spatial analysis should not ignore society, social science should not ignore physical space. In applying GIS, social science, natural science and spatial analysis should be planned and implemented in co-ordination, and an interdisciplinary approach encouraged.
- In making effective applications, the development of the participatory process, at community or institutional levels, is at least as important as the development of GIS as a tool. The values of good participatory practice should be applied, with regard to ownership, expectations, iterative validation, communication, feedback

and sustainability. Institutional aspects of the use of both GIS and participatory methods are critical.

- If the use of GIS is cost-effective, P-GIS adds considerable value at little extra cost. However, adequate time, resources and expertise will be needed for participatory data collection (this should not cost more than a PRA study without GIS); and the iterative development of maps,. plans and conclusions with stakeholders need to be budgeted.

- A P-GIS approach has considerable potential in prioritizing and monitoring for SL and poverty elimination. There is a case for well-planned regional investments in systems for planning and monitoring rural (or urban) development and progress in poverty reduction in priority areas, using GIS and linked to programmes to promote accountable effective delivery by local government and sectoral planning agencies.

Finally, the risks of relying on GIS should be recalled:

- Once information finds its way into maps and computerized databases, there is a tendency for users to regard it as immutable fact, even though it may be erroneous and partial, as for example, a single stakeholder's perception of where a boundary ought to lie.

- GIS technology may be treated as an objective tool for scientists and planners to decree top-down, once and for all solutions to development problems, behind closed doors, without input from primary stakeholders.

- Unless an integrated interdisciplinary approach is adopted from the start in relation to data collection and analysis, the usefulness of GIS will be limited in addressing real world development problems.

## CASE STUDIES

### Case Study 1: Use of GIS for coastal environmental planning and management in north-eastern Brazil

Land use in the project area is complex and dominated by a small number of major landowners and developers. The area is a mosaic of major tourist investment projects; private nature reserves, including Atlantic forest fragments, wetlands and dune systems; extensive farmland (coconuts and cattle); urban areas; *loteamentos* (land sold for housing, holiday homes and small-scale tourist development); pine and eucalyptus plantations (for pulp, cellulose and sawn-timber markets); and limited small-scale farming.

The project GIS, originally intended as a centralized planning tool, is developing an up-to-date, database of the project area for thematic mapping and analysis of spatial data. A participatory socio-environmental survey has been made in the pilot area; and a series of local stakeholders' consultations has been held, with the aim of developing a consensus-based planning programme for environmental protection and socio-economic development. There are good opportunities to incorporate the outcomes of social and participatory enquiry in the GIS and thematic maps, and to apply the GIS in support of stakeholder participation in planning in a number of related areas.

## Case Study 1 *cont.*

**Overall project planning and co-ordination**

- Different state institutions and other sources have contributed data to the GIS and the integrated database will be made available for stakeholders' use as a focus for institutional collaboration.
- Development of maps using GIS has promoted an interdisciplinary approach, spatial thinking by social scientists, and more user-oriented approaches by physical planners. Social development critique of early map products enabled the development of more accessible, user-friendly versions.

**GIS as a tool to assist survey planning**

- The GIS enabled the reconciliation of census data with administrative and planning units within the area, and rural settlements identified and described by participatory fieldwork were geo-referenced and incorporated in the GIS to develop a population sampling frame for surveys.
- Aerial photographs and participatory sketch maps were used to develop maps to assist in sampling in towns, and for use in urban environmental management.

**Integration and management of diverse datasets**

- Socio-economic datasets including human settlements, populations, roads, land ownership and basic services were added to baseline (1:250 000) topographical maps.
- Ranked information generated by PRA and sample surveys, including livelihood activities, and poverty indicators (income levels, capital asset, environmental health, service access and literacy data) was incorporated and represented visually.
- Selected datasets were then overlaid to produce integrated 1:100 000 scale maps, e.g. including settlements, population, principal livelihoods activities with land ownership, and land cover.

**Maps to promote stakeholder participation**

- The GIS enables organization of information at different scales for display and feedback to decision-makers and stakeholders at different levels; this is particularly useful to promote understanding amongst state agencies and municipalities, and at community level.

Promising applications of a participatory GIS approach include:

- comparison of poverty and environmental indicators across and between different zones and locations within the project area
- identifying potential extractive reserves (for fishing, shellfish and plant fibre resources) and developing local management plans with users and landowners
- small-scale ecotourism development and planning with local business people
- refining and improving larger-scale maps (1:25 000) of local river catchments and village peripheries through discussion with local people – and making them available to community groups as a visual aid for local development and environment projects.

Principal lessons learned to date include:

- value of using GIS to integrate socio-economic and spatial perspectives from the beginning
- importance of fostering an enabling institutional environment if a centrally operated GIS is to become an effective tool for participatory planning
- the need for longer time frames to allow for the development of appropriate institutional arrangements and the GIS database itself.

## Case Study 2: Combining scientific and indigenous knowledge of soils using GIS in Uganda and Tanzania

One of the project's main objectives was to develop methodologies for comparing and combining scientific and indigenous knowledge of soil and land resources using GIS as an integration domain. GIS was used for spatial analysis of the soil data, collected through scientific soil surveys, and of indigenous knowledge of soils and land resources, explored using social-anthropological and participatory rural appraisal techniques. GIS proved to be a useful tool for integrating and combining both sets of information although methodological and practical issues, such as data collection and its sequencing and continuous availability of GPS/GIS equipment during fieldwork, need careful consideration. The critical link between the work on local knowledge and the scientific survey was geo-referencing the observations. However, a proper functioning GPS was not available throughout the fieldwork and, therefore, not all information gathered could be successfully integrated and analysed within the GIS.

Furthermore, exploring indigenous knowledge is a delicate process as the use of GIS tends to focus mainly on spatial analysis, e.g. through use of perceptual maps. This research illustrates clearly that there is much benefit in a detailed and carefully sequenced process of exploring local people's knowledge, drawing on different tools and contexts. It was only through the combination of group discussions, individual household interviews, transect walks and participatory mapping that an in-depth understanding of local soil classifications and the differences in cognitive processes began to be developed.

This information is very relevant for supporting and improving the analysis done within the GIS. In addition, existing GIS techniques can be used creatively to integrate different datasets, such as hot-linking text files to perceptual and scientific maps, and overlays of geo-referenced household information and local soil categories with scientific land resources maps.

Additional lessons learned are, in brief:

- close integration is important – detailed investigation of farmers' categories and concepts with physical observations and use of base maps, photographs and GPS must all be integrated;
- consistency in the participating groups is needed – the composition both of the farmers' groups involved in the study and of the research teams should be consistent;
- phasing is important – detailed indigenous knowledge studies, to enable in-depth understanding of categories and content, should precede serious attempts to consolidate this knowledge through farmers' mapping;
- research involved an important learning process for all participants – it is important that the research team has training to develop a thorough understanding of GIS and its potential before starting the fieldwork.

## Case Study 3: Participatory land use planning in two villages in Kumasi, Ghana

One of the issues arising from previous research in the Kumasi region is the lack of participation by local people in land use planning. The final phase of the Kumasi Natural Resources Management Research Project used the findings of previous research and mapping information in the KUMINFO GIS to develop two pilot projects in the villages of Swedru and Aburaso.

The objective was to enhance land use planning by:

- increasing participation of local stakeholders
- promoting the sustainable use of natural resources in the planning process
- considering environmental issues in the planning process
- taking into account inter-village, watershed and regional issues at village level planning
- developing linkages between the village and district and regional planners and other professionals so that the villages may benefit from appropriate professional inputs.

Activities undertaken with chiefs and elders to discuss the planning process:

- geo-referenced copies of aerial imagery were printed
- meetings held with chief and elders, women, men, youth, poorer groups to map the natural resources and other features on the images

### Case Study 3 *cont.*

- the maps were used to identify problems
- meetings with district planners and other professionals to invite their involvement
- ideas were pooled to develop a village plan
- modest initial funds provided, and action research facilitated finding, the necessary technical experts
- final maps were digitized into KUMINFO.

Reactions to the use of the images and maps:

- many local people could interpret the images and could locate their own homes, farms, water sources etc., and there was considerable interest in identifying other features such as ridges, valleys streams and developments.
- the maps encouraged common perception of the same resources and helped to reduce conflicts due to misunderstandings, for example, over boundaries.
- because of overhanging or dense vegetation that sometimes obscured the paths and small streams, the images proved more difficult to interpret in the less used areas.

Village level action was then prioritized and an agreed practical project identified to the satisfaction of all groups in each village – in Aburaso, the provision of a public hand-dug well and, in Swedru, the protection of a stream by tree planting. Both communities formed project implementation committees. Experts from the local district water and sanitation team and the Land and Environmental Management Office became involved and both projects are now self-sustaining. District planners have shown interest in this approach, although with mixed reactions.

The research team concluded that the GIS-produced images enabled the villagers to consider planning actively for the natural resources around them for the first time. The process, supported by the GIS mapping exercise, showed villagers that the loss and degradation due to development were not inevitable, and that interventions and the wishes of the groups normally excluded from decisions were taken into account to identify beneficial small-scale interventions. Moreover, the GIS developed has the potential for similar applications more widely around Kumasi and to provide a tool for extending and scaling up dialogue amongst local communities, chiefs, planners and local government officials.

## CONSIDERATIONS IN CHOICE OF P-GIS HARDWARE AND SOFTWARE

Guidance is provided on the technical requirements for spatial analysis of complex datasets, participatory mapping and maps to communicate geo-spatial issues effectively to stakeholders.

- It is often impracticable to have complicated software and hardware at the community level and there is great danger in placing the technology in an ill-prepared local institution.

- Available software ranges from expensive fully comprehensive systems suited to serious GIS laboratories to desktop display GIS with limited analysis and integration functions, some of which are free. Costs of the software also vary considerably and costs of maintaining an upgrade strategy can be prohibitive, especially after project support has finished.

- The choice of software should be made at the planning or inception stage of a project – it should not be considered *ad hoc* as the project advances. The software should be adequate for the project, but should not be overbought either in complexity or price.

- The version of GIS software and ancillary software (word processing, spreadsheets and databases) should not be changed during the life of a project unless all stakeholders agree to change – and adequate funds are available for a universal change.

- Most software now runs using PC technology and can be used on a laptop computer in the field – both may be considered for data collection – and there are portable data-loggers for collection of GPS data and attribute data. However, these options are of little long-term use when the provision of electricity is non-existent or intermittent.

The choice of GIS software and hardware should always be considered in relation to several factors:

- analytical needs of the project
- institutional capability, in human, physical and sustainable resources
- costs of the hardware and software (see table)
- costs of training.

## Use and acquisition of software

In general, several principles can be applied in the use and acquisition of GIS software and hardware.

1. To answer the needs of a national or regional institute where data, especially base biophysical data, can be shared between many users and several projects, a top-end system should be considered. This will require a commitment to continue training and technical support on the part of donors as well as a considerable institutional commitment on behalf of the recipient. Such institutional development support will almost certainly be beyond the scope of a limited research project.

2. Where a top-end GIS already exists and the local institutional framework allows, projects should seek to use the technical and physical support this might allow. While there may still be a commitment to project provision of a 'field' or 'project' GIS, the use of existing resources, even on an 'agreement' basis cuts the cost of acquiring base data and hardware (e.g. large format plotter and digitizer).

3. For research projects, the software and hardware will usually be PC- or laptop-based. It is important, however, to provide adequate means to input and output data. Unless digitizing is required in the field, local and project support services should be sought before a digitizer is bought. Such equipment is probably unjustified within a research project time frame unless it can be justified for local institutional strengthening. A similar argument applies to a large format plotter (A0). Smaller format (A3) printers give excellent output with most GIS software.

4. How the outputs are to be used within the participatory context should be considered at the planning stage. If paper 'products' are to be used in the field, a useful piece of hardware is a laminator – this not only provides protection but

### Cost of software and hardware

| | SOFTWARE | | | HARDWARE | |
|---|---|---|---|---|---|
| | Examples | Costs – basic | Cost of software and extensions | Type | Costs |
| Top end | Intergraph MGE<br>ArcInfo<br>SPANS | £10 000+ | £15 000+ | Workstation, e.g. unix, NT | £4 000 |
| Middle range | ARCVIEW<br>Mapinfo<br>Tactician<br>ILWIS | £1 500 | £5 000 | PC<br>Laptop | £2 000<br>–£3 000 |
| Bottom range | IDRISI<br>Mapmaker<br>Maptitude<br>Atlas | <£1 000 | n/a | PC<br>Laptop | £2,000<br>–£3 000 |
| Free | Arc-explorer<br>Mapinfo viewer | 0 | 0 | PC<br>Laptop | £1 000 |
| | | | | PERIPHERAL HARDWARE | |
| | | | | A0 plotter | £4 000 |
| | | | | A3 printer | £400 |
| | | | | A4 printer – inkjet | £100 |

also enables the product to be written on with a non-permanent marker (e.g. chinagraph) during discussions.

5. The ownership of data generated by project should be considered. Where a community has access to even limited hardware, access to a free GIS viewer can be provided so that data can be used locally.

## GLOSSARY OF COMMON TERMS AND ACRONYMS USED

| | |
|---|---|
| attribute | non-geographic data associated with a spatial element (point, line, area) in a GIS |
| base maps | topographic and thematic maps that form a background to the spatial analysis in a GIS |
| CBNRM | community-based natural resource management |
| DBMS | database management system – a set of computer programs for organizing information in a database; typically contains routines for input, verification, storage, retrieval and combination |
| fuzzy boundaries | perceptions on boundaries of, for example, land ownership might differ among the different stakeholders involved or boundaries of soil categories might be based on observations and estimations during scientific soil surveys |

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| fuzzy logic | fuzzy logic or fuzzy set theory allows individual pieces of data to be members of different overlapping sets. It uses possibility instead of probability as a statistical technique; the result is a graduated boundary rather than a crisp linear one |
| GIS | geographical information system/s – a computer-based tool for mapping and analysing data related to space; GIS allows for the integration of disparate layers of information into a common spatial database, whether the data are related to an explicit reference (latitude/longitude, grid) or to an implicit reference (e.g. census tract name, road, environmental feature) |
| GPS | global positioning system – a device for determining geographical location anywhere on the earth's surface, using electronic receivers to obtain latitude, longitude and altitude data from satellites in geo-stationary earth orbits. GPS can be especially useful when map coverage is limited and/or out of date. It also enables addition of specific information relevant to particular projects such as the distribution and location of schools, water wells, soil types and emerging settlements. GPS is used increasingly in data collection exercises as it is a cheap and user-friendly. Portable GPS consists of a hand-held receiver used to receive signals from satellites to reference the points at which specific features are located. This information is displayed and stored in the hand-set and can be downloaded into a computer system. Although GPS is cheap and easy to use in the field, its main limitation is accuracy – a result of in-built errors of 10–30 metres due to interference from US Defence satellites. By using a local base station on well-located objects, such as a road junction or established buildings, it is possible to use differential GPS measures to improve accuracy and correct for these errors. The use of a base station involves higher costs and skills required to set it up, so it is worthwhile to consider the level of accuracy required according to the nature of the data to be collected and the objectives of the project |
| ground-truthing | verification of remotely sensed data by inspection and correlation in the field |
| hot-linking | hyper link between related pieces of information; a hot-link allows non mapable data to be referenced to a geographical feature (point, line or polygon) and then retrieved and displayed by the click of a button. Almost any information can be handled this way and can include text files, charts, tables, pictures, photographs and video clips |
| livelihood | comprises the capability, assets and activities required for a means of living |
| livelihoods | starting point is an holistic analysis of people's livelihoods across sectors, areas and social groups, recognizing the |

| | |
|---|---|
| | multiple and overlapping realities, dynamic linkages and changes over time |
| LPK | local people's knowledge – includes the complex of practices and decisions made by local people and shaped by and interlinked with technical, cultural, political and social knowledge. Local knowledge is based on experiences passed from one generation to the next, but nevertheless it changes, adapts and assimilates new ideas. It can be quite location-specific and may vary among individuals according to age, gender, socio-economic status, ethnicity and area of residence |
| meta data | data about available datasets and sources |
| network diagram | represent the multiple inter-relationships between e.g. the many components of farming, livelihoods systems or internal and external linkages |
| NGO | non-governmental organization |
| NR | natural resources |
| overlay | (noun) data plane containing a related set of geographic data in digital form; (verb) process of stacking individual digital representations of various spatial data so that each position in the area can be analysed in terms of these data |
| P-GIS | participatory GIS – integration of local knowledge and stakeholders perspectives in the GIS; stakeholders should also have access to GIS databases and GIS products, and be able to apply GIS and GIS products to development planning, resource management and advocacy |
| participatory mapping | ideally participants' free drawn maps showing particular features of relevance to their livelihoods, e.g. natural resources, their village, social resources (aspects of social relations and household distribution) |
| participatory planning | involvement of a community in planning the use of a common resource, identifying common goals towards the management of the resource and implementing a plan to achieve those goals |
| PRA | participatory rural appraisal – empowerment-oriented development appraisal that is initiated by an external multidisciplinary team, using qualitative research methods, in order to help a local community conduct an efficient assessment of its own situation, including problems and potential |
| photo/image maps | aerial photographs, aerial images or satellite images which have been geographically corrected and probably overlain with key topographic data to provide a map output |
| pixel | smallest unit of information in a raster (grid cell) map or in a scanned image |

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| ranking exercises | evaluation of particular properties according to the criteria of the participants, e.g. farmers' preference for maize varieties. Farmers' own criteria are listed in the left-hand column, then the attributes of the different varieties discussed. Local materials such as stones and beans can be used for scoring, providing a quantitative expression of preferences |
| remote sensing | acquisition of data by a means of a remote sensor; usually refers to satellite or airborne acquisition of raster imagery or photographs |
| seasonal calendar | a graphical device with the months of the year on the horizontal axis and a set of activities, such as farming operations or livelihood and employment activities, on the vertical key. The activities and their timing are derived from wider group discussion and the technique is useful to obtain an understanding of farming and livelihood systems in a community. It can illustrate patterns of labour and income over the year of different social groups within the community (gender, age, wealth and ethnicity) |
| sorting interviews | obtaining an understanding of local classifications and their interrelationships. Concepts of, e.g. soil types or trees, are sorted and grouped by local participants into categories, individually identifying common features and contrasts in the context of the wider language and cultural system |
| stakeholders | persons, groups or institutions with interests in a project programme. Primary stakeholders are those ultimately affected, either positively (beneficiaries) or negatively (those involuntarily resettled). Secondary stakeholders are the intermediaries in the aid delivery process. Stakeholders include both winners and losers and those involved or excluded from decision-making processes. Key stakeholders are those who can significantly influence, or are important to the success of the project |
| thematic map | map containing data related to a specific theme, e.g. soils, population density, land suitability etc. |
| topographic map | map showing the surface features of the earth's surface, e.g. roads, contours, rivers etc. |
| transect walks | systematic walks to explore local practices; researchers observe, ask questions and listen, and farmers talk and describe their land, natural resources and farming systems (how and why they do things) |
| UPS | uninterruptible power supply – a device for stabilizing the electrical input to computer hardware, protecting against power surges and storing energy for protection against power cuts |
| workstation | a mini computer or high level PC, often networked to other computers |

## INSTITUTIONAL CONTACTS

### Photomaps

Nepal photo-map work is being considered for expansion to most of the community forest area of Nepal, and is being taken up by other bilateral projects under the co-ordination of DFID's Nepal-UK Community Forestry Project.

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