# Designing a Land Information System for Rural Land Use Planning: An Assessment and Feasibility Study

## Scope of Work

Centre for Applied Social Sciences, University of Zimbabwe
Land Tenure Centre, University of Wisconsin-Madison

**Zimbabwe Land Reform and Resettlement Cooperative Agreement**
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## STUDY OBJECTIVES

The major goal of this study is to investigate the feasibility of constructing an LIS/GIS for the purposes of rural land use planning, through the integration of existing databases and layers.

The specific objectives include:

a. Assess and identify the necessary information to be included in a rural land use planning land information system.
b. Investigate/inventory the status of existing information databases that could, potentially, be integrated to form the core of such an information system.
c. Determine the technical or institutional issues (if any), which would impede the co-utilization of existing databases.
d. Define the structure of land information system for rural land use planning constructed from existing data bases (i.e. what layers would it contain) and specify what rural land use planning questions could be addressed with such an LIS.
e. Identify what information layers might be missing from an integration of existing data bases, and then evaluate (i) how important are one or more of these missing layers to a functional rural land use planning information system, and (ii) how difficult and expensive it would be to construct the missing data layers.

## BACKGROUND AND PROBLEM STATEMENT

### PREAMBLE

Management of information is an important task that is linked to the ability of institutions to make decisions, and manage land effectively. Important information about land relates to the characteristics of land resources and related capability of land to produce economically. This aspect of land management and planning relies on information on soils and soil chemistry, terrain, people's production culture and socio-economic objectives for agricultural production. Each of the aspects in the foregoing is related to many classes of information that can spatially be represented by a number of layers or related maps.

Information analysis and management is critical to the proper decisions on parcels to be redistributed and to whom they go. Classes of information important to this are parcel sizes, quality of land in terms of production potential, and other biological and chemical characteristics, and physical attributes of land. Ownership records that identify current ownership by name, economic group, and issues related to gender are important in the process of making decisions on parcel reallocation. The process requires up to date comprehensive records that are easily accessible to decision makers.

Marketing agricultural produce relies on information about production patterns, quantities of agricultural commodities produced, location of markets, and transport network between production centers and the markets. This is vital information that is required for various activities in economic planning. Analysis of transport networks and their unit costs needs to be linked to production activities at source.

Production planning in agriculture needs information on sources of various inputs that are needed by farmers. These include seed, technical services, irrigation water, fertilizers, and chemicals. Network analysis is important for all these applications of information technology.

Problems requiring information management services have become more complicated in the more recent times. Applications in agriculture now require high level analytical capabilities for which manual approaches have become almost irrelevant. Analysis of spatial landscape data needs to be integrated into analysis that has specific applications in economics, land management, and social planning. These are applications that are difficult to manage outside computerized land information management systems.

Computer applications have improved the quality of information management and its accessibility to users. Computers increased the capacity to store large amounts of data. Information in computers is easily accessible through query processes. Geographic Information Systems (GIS) are computerized systems that have a capability of storing attribute data that is linked to spatial dimension of land. This is a system that locates precisely the distribution of attributes across the landscape through a geo-referencing system. Data is stored in GIS with an additional aspect of the x and y location. In a GIS, the concept of mapping as traditionally known has been improved through the spatial dimension.

GIS can handle and manipulate many layers of data that are built on geo-referenced features and landscape characteristics. For land management issues, specific attributes could be stored using units of measure that are most suitable for the application in question. GIS has the ability to perform overlays that improves ability to analyze different layers of information for specific applications. In agricultural planning, for example, layers on soil nitrogen, soil texture, drainage, transport networks could be laid one on top of the other for effective agricultural planning. This allows for evaluation of soil potentials as well as analysis of access to the market at the same time. It is an important tool for improved decision making.

GIS displays information using a graphical user interface that allows for selection of desired views and formatting of views. Graphs of any form could be displayed representing specific attributes in a map. Attributes can also be displayed on a map in the form of text, numbers or selected color codes representing ranges of values and specific values. GIS makes display of information easier and more precise.

GIS allows for broader manipulation and analysis of information through its capability to do a wide range of operations. GIS can do mathematical and arithmetic operations. Information in the same spatial position can be manipulated through multiplication, addition, subtraction and division. It can also manipulate data laterally. Average nutrient

concentration in neighbouring cells or proximate positions could be calculated in that manner. It introduces a high level of flexibility in the way data can be used and manipulated.
Data manipulation capabilities of GIS can be used to give the application of parametric models a spatial dimension. Different parameters in the model can be calibrated into different layers. A model on forage production could be represented through layer giving numeric values of moisture availability, soil texture, and layers on individual nutrients, and these could be manipulated as per modelling procedure to produce a location specific production map.

The three dimensional terrain modelling capability allows GIS to handle data related to representation of landscape physical features. GIS applications are able to represent drainage in this way. This aspect is also used to represent concentrations of substances in pollution. Watershed applications have benefited most from this application.

GIS is widely used for temporal analysis. This is an important application in the area of natural resources management. The process involves storage of data showing condition of specific environmental phenomenon for selected time periods and performing overlays to determine trend. Overlays can also be done to relate specific land use activities to environmental condition.

**LAND INFORMATION MANAGEMENT IN ZIMBABWE**

Activities on managing data related to land management are mostly manual. The Office of the Surveyor-General handles data related to land use, aerial photo coverages of the nation, and is responsible for production of maps covering themes like agricultural production, relief, urban development, land classification, climate, and use. This is captured on analogue maps where information is entered manually. The department is however in the process of converting the hard copy maps into digital format.

Manual processes of managing map information present problems related to capacity of managing large amounts of information, and the difficulties of updating information. It is not easy to change information related to an individual parcel that appears with other parcels. If one farm changes ownership, a new ownership map would have to be generated to reflect the said change.

Manual maps and aerial photos do not allow for manipulation of data that leads to analytical activities for agricultural management. It generates large amounts of data for which there is no capability to perform integrated analysis. Analogue storage limits accessibility of data and is not capable of handling data manipulation processes. It is less capable of handling the new challenges in sophisticated information applications faced by managers in today’s world. Decision-making has become more complicated because of the nature of problems being addressed; globalization has created a strongly integrated world community where simple data manipulation processes have lost relevance and functionality.

Departments of Research and Specialist Services, Agricultural Technical and Extension Services, Natural Resources, Forestry Commission, National Parks and Wild Life Management all manage information relevant in their professional applications. Integration of all those data sets is important for land management in the production process. Analogue maps inhibit the rate at which this process takes place. It inhibits the capacity of integrated data management approaches.

Although institutions such as World Wild Life Fund, Forestry commission, some University of Zimbabwe departments, Ministry of Lands, National Parks and Wildlife management, SIRDC and many others have GIS installed and operating, there does not seem to be a simple point of entry for the end user to all this information. This is so because some producers are weary to make their information available in digital format. Intellectual rights and copyright laws pertaining to digital data exchange are not yet explicit, there is need to have a digital spatial data infrastructure for Zimbabwe.

Complexity of agricultural problems has increased in the recent years. Data on environmental management, market locations and access, irrigation water as an input has become more important in agricultural production. All this coupled with the current land reform calls for even more complex analysis. The information needed to analyse the relationships is available in disparate institutions that are now battling with interfacing the different data formats as well as implementing digital data exchange standards.

**REVIEW OF LITERATURE**

Geographic information systems (GIS) are computer-based systems designed to store, analyze, and display spatially referenced information. The ability of GIS to handle data in three dimensions makes it a relevant tool for analyzing information relating to landscape features and attributes (Aronof, 1989). Current GIS technology manages databases on feature attributes in linkage with graphic displays, and analysis of landscape applications into software packages that are user friendly (Kasturi et al., 1989).

GIS computerizes the process of mapping. Like all maps, GIS graphics are effective tools for showing relational and positional location of features across the landscape. This is a function that all paper maps have. The ability to overlay different layers of features in a GIS graphics display environment enables analysis of issues across different maps. A communication map could be over-laid with a transport network map and so on. This improves the conceptual level and allows for more effective relational analysis. This capability has been useful in GIS analysis in citing waste dumps, dams and schools in urban areas in the developing countries (Environmental Systems Research Institute, 2000).

Applications benefiting from GIS data management and analytical capabilities are many and varied. It is a tool that can handle data from fields in economics, agriculture, and social sciences. The data is stored in a manner that it can be queried for various applications that include feature attribute display. GIS can perform calculations that are important in data analysis. The length of a portion on a road, river or other linear features can be calculated easily. GIS can also calculate areas of different shapes of features (Environmental Systems Research Institute, 2000).

Networking analysis in GIS has become an important application in looking at communication and transportation services. This function has an added capability to perform calculations along linear features. It has been used to determine shortest possible routes that expedite police and ambulance operations. Traffic distance is calculated in terms of time and traffic resistance. It has also been used to relate production centers to markets (Environmental Systems Research Institute, 1988).

GIS can handle data from a wide variety of fields that enable its application in economics, agriculture, planning, soil, vegetation, topographic features etc. GIS spatial modelling links a seamless database to spatial data. This is a function that effectively replaces the tedious process of overlaying various maps in land analysis (Wolfe and Neale, 1988).

The GIS seamless database is capable of handling calculations across different layers of data. This makes GIS an effective tool in landscape modelling. Model calibration can take place with each parameter being represented by a different layer of information. Soil erosion prediction can be done through creation of layers that represent soil texture, rainfall erosivity, vegetation cover, agricultural activity, and canopy cover to represent the Universal Soil Loss Equation that was developed by the United States Department of Agriculture (Mugabe, 1994).

Landscape applications relating human activities to different land capabilities have been done using GIS. Selection of land for cultivation has been done by calibrating soil, slope, and drainage layers to represent the different ratings indicating preferability across the landscape. The calibration of favorability for crop production was effectively used to allocate land to cropping on the basis of demographic changes (Mugabe, 1999).

Land use planning activities require three dimensional terrain representations of slope and other topographic features. GIS comes in handy as a land use planning and analysis tool because of its three-dimensional terrain representation capability (Muzik, 1988). Three dimensional digital terrain modelling in GIS has been very useful in watershed analysis where elevation and slope are important factors (Jenson and Domingue, 1988). Use of GIS in watershed analysis processes improves the quality of data input and display, and reduces the amount of time required in data compilation, manipulation and analysis (Hodge et al., 1988).

Landscape models are useful tools used in prediction of changes in the condition of phenomena on the basis of human activity. Aerial photos taken at different time periods provide a tool for analysing landscape changes related to land use and ecological phenomena (Avery and Berlin, 1985). Integration of aerial photo data and GIS modelling has enabled analysis increasing of the understanding of human impact on the ecosystem (Turner and Ruscher, 1988).

**METHODOLOGY**

The research processes would be keyed to the specific study objectives. These include:

1. Interview-based research with a set of pre-identified key informants at the national, provincial and local levels knowledgeable about land reform and resettlement, rural land use planning, and the likely information needs for these processes. The purposes of these interviews would be to (i) assess the interviewees perceptions of the requirements for a digital LIS/GIS for rural land use planning, (ii) assess their understanding of how by whom such a LIS/GIS would be used, and (iii) determine their understanding of what data bases already exist that might be integrated into such a system

2. An inventory of existing land information systems/geographic information systems and their data layers already developed by public, NGO and other organizations, which would have relevance for a rural land use planning LIS/GIS. It is already known that this task will include contact with the following public sector organizations and NGOs: Department of Research and Specialist Services, Forestry Commission, Natural Resources, SIRDC, WWF. Others will be identified through the research activity noted above.

3. Documenting the technical and institutional aspects of LIS/GIS identified in the task above, with special attention to the elements that would impede their integration into a system for rural land use planning. Technical and institutional elements include factors such as: scale of data, software format of data, zip-ability of data layers and whole systems, cost of data acquisition, availability/proprietary nature of data systems.

4. Construction of a theoretical/conceptual (realistic and practical) LIS/GIS for Rural Land use Planning, based on the information contained in the two steps above. Such a theoretical LIS/GIS would assume/show what an integrated (from existing, available and accessible) LIS/GIS would contain. Specification of the types of questions that could be addressed and analyses that could be conducted by such an LIS, with an eye towards the strengths and weaknesses of such a system.

5. Identification of the necessary "missing" layers from the theoretical LIS/GIS constructed in the above step; the identification of these layers would draw from the interview-based research noted above and another interview session to be conducted after identification of the gaps. A technical and economic assessment of the effort and cost to build such layers, and a cost/benefit assessment of the necessity/utility of including these layers. When this has been done it may show necessity of doing another set of interviews with key informants. This iterative process will be carried out to ensure all relevant data is collected.

**OUTPUTS**

1) Report on the status of existing LIS/GIS. This report to include both an inventory of these systems and a discussion of their technical and institutional aspects, with special attention to those aspects, which would impede their integration into a new system for rural land use planning.

2) Report on the feasibility of constructing rural land use planning LIS/GIS. This report would draw from the data included in the above report, and specify (i) the layers that could be included in an integrated system, and (ii) the types of questions and analyses such a system could and could not address. Included in this report as Section iii would be a discussion/analysis of the types of new layers that would need to be constructed in such a system (that, for example, are not available from existing system, for technical and/or institutional reasons or because they have not yet been constructed at all), and the feasibility (including cost) of developing such layers. This final section will also discuss how the types of questions and analyses that such a fuller LIS/GIS would be able to address.

**BUDGET**
Attached.

**SCHEDULE**
Attached.

**LITERATURE REVIEWED**


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Avery, T.E. and G.L. Berlin. 1985. *Fundamentals of remote sensing and airphoto interpretation*. Macmillan Publishing Co. New York.

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Muzik, I. 1988. *Application of GIS to SCS procedure for design of flood hydrographs. Modeling Agricultural, Forest and Rangeland Hydrology*. Proceedings of American Society of Agricultural Engineers, St. Joseph, Michigan, 494-500.

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# Designing a Land Information System for Rural Land Use Planning: An Assessment and Feasibility Study

**Budget**

April to September 2002

| | | Cost | Count | Unit | Total Cost | |
|---|---|---|---|---|---|---|
| LTC Budget | | | | | (US$) | |
| | Salary/benefits: Jacobs | 11,500 | .5 | Months | 5,750 | |
| | Jacobs airfare | 3,500 | 1 | Rt | 3,500 | |
| | Jacobs Per-diem | 148 | 10 | Day | 1,480 | |
| | Total LTC direct Costs | | | | 10,730 | |
| | Indirect Cost Recovery | 25% of Direct Costs | | | 2,683 | |
| | Total Costs | | | | 13,413 | |
| | | | | | | |
| CASS, UZ | | | | | | (ZIM $) |
| | Salaries | | | | | |
| | Phanuel Mugabe | 1000 | 6 | Month | 6,000 | 1,650,000 |
| | Wilson Magaya | 400 | 6 | Month | 2,400 | 660,000 |
| | Research Assistants | 200 | 6 | Month | 1,200 | 330,000 |
| | Secretarial | 200 | 1 | Month | 200 | 55,000 |
| | Transport | .365 | 2,000 | Kilometres | 730 | 200,750 |
| | Accommodation | 60 | 10 | | 600 | 165,000 |
| | Computer Use Fee – Campus GIS Lab | | | | 500 | 137,500 |
| | Supplies and communication | | | | 500 | 82,500 |
| | Total CASS Costs | | | | **11,905** | **3,273,875** |

Salaries:

- Prof. H Jacobs; 0.5 months of his time for the initial study has been budgeted. Harvey Jacobs' work came to an end after the initial design of the study
- Dr. P Mugabe (PhD Rangeland ecology); 6 months of his time has been budgeted, he is the key resource person for the feasibility study
- W Magaya MSc. Geographic and Land Information Systems Student
- Accommodation has been budgeted for envisaged trips to Bulawayo to collect data

## Schedule of Activities 2002

| | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| **Activity** | | | | | | |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| Report 1 | | | | | | |
| D | | | | | | |
| E | | | | | | |
| Final Report | | | | | | |

**KEY**

Reports

Activities

Notes :1st Report is due on 31 July 2002

Final Report is due on 30 September 2002.

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Framework of Activities

| **OBJECTIVES**<br><br>Components of research design | **Objective 1** | **Objective 2** | **Objective 3** |
|---|---|---|---|
| Variables<br>*What new information is required?* | Existing L/GIS Databases &Perceptions on: the requirement for digital L/GIS, how & who will use such information | An inventory of existing LIS/GIS and their data layers already developed. | Identifying the technical and institutional issues involved in combining the databases |
| Type of Study<br>*How will this information be collected?* | Interviews | Records, interviews, internet, one group meeting with the key informants for the inventory then go beck to these same people after the inventory for other meetings to fill the gaps. (Have an iterative process) | Records, interviews, internet, literature |
| Data Collection Techniques<br>*What tools are needed to collect it?* | Interviews, going through handbooks & records. | Structured interviews, records, going through handbooks | Structured interviews, going through handbooks, records. |
| Sampling<br>*How many objects /subjects are included?* | Key informants at National provincial & local levels on land reform & resettlement & rural landuse planning | All institutions in Zimbabwe deemed to have LIS/GIS relevant for rural land use planning. | GIS & digital data institutions |
| Plan For Data Collection<br>How will the data be collected? | Visits to informants | Visits to NGOs, Trusts, Dep't of Research & Specialist Services, Forestry Commission, SIRDC, WWF. Also have a group discussion with key personnel from these | UZ-Geoinformatics & Surveying Dept, Geography Dept, Holistic Information Systems, Forestry Commission, and others |

| | | | |
|---|---|---|---|
| | | departments at CASS. | |
| Plan For Data Processing & Analysis<br>*What will be done with data collected?* | Reporting on the interviewees perceptions, understanding of LIS and the information to be included | Data integrity checks, report on the existing databases and where they are and their metadata bases | Analysed, for compatibity, intechangeability, portability and integrity |

| **OBJECTIVES**<br><br>Components of research design | **Objective 4** | **Objective 5** |
|---|---|---|
| Variables<br>*What new information is required?* | Construction of a theoretical/conceptual (practical and realistic) LIS/GIS for Rural land use planning. | Identification of necessary missing layers from theoretical LIS/GIS |
| Type of Study<br>*How will this information be collected?* | Internet, catalogues, Literature review, records, interviews | Interviews, records |
| Data Collection Techniques<br>*What tools are needed to collect it?* | Internet surfing, literature reviews, Interviews with organisational systems analyst. | Iterative process of interviews, going through handbooks & records |
| Sampling<br>*How many objects /subjects are included?* | All the users and contributors to the information system | All the missing layers |
| Plan For Data Collection<br>How will the data be collected? | Interviews, Internet services, library, | Structured interviews with key informants |
| Plan For Data Processing & Analysis<br>*What will be done with data collected?* | Checking compatibility among models. Draw up flow charts to show information propagation within the system. Design the theoretical/conceptual LIS | Cost benefit analysis. SWOT analysis of the envisaged LIS. Then other interviews thereafter. |