AN INTEGRATED INFORMATION SYSTEM FOR DECISION SUPPORT IN SUSTAINABLE LAND USE PLANNING
A CASE STUDY OF KUNENE REGION NAMIBIA

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MARCH 2002
An Integrated Information System for Decision Support in Sustainable Land use Planning (A case study of Kunene Region Namibia)

By

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Thesis submitted to the International Institute for Geoinformation Science and Earth Observation (ITC), in partial fulfillment of the requirements for the Award of the Degree of Masters of Science in Geoinformation Management for Rural Development and Resource Management

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ABSTRACT

Land use planning and resource management problems are complex in nature and require the integration of data and information from different sources and disciplines. In Namibia land use planning is under the responsibility of the Division of Land Use Planning and Administration (LUPA) of the Ministry of Lands, Resettlement and Rehabilitation (MLRR). Currently the division bases its activities on the Land reform act (no.6 of 1995) and its main activities include the formulation of integrated regional land use plans and acquisition of farmland for the resettlement of landless citizens of the country.

This study focused on Kunene region of Namibia where a number of other organizations and stakeholders are also involved in land use and natural resource planning and management activities. However, limited region specific data, limited data collection and analysis tools, plus limited coordination among stakeholders hamper such activities.

The study was undertaken in an Information System Design and Development context. The Structured System Development Methodology (SSDM) was employed to explore the key players in the region, their data requirements, data availability and integration and to model information processes and data for land use and resource planning.

A prototype information system and Relational Database structure was designed towards the provision of land resource data required for land use and resource planning in the region. A user interface was also designed for the users to access and update the database.

Geographic Information Systems (GIS) spatial analysis and Decision Support Systems (DSS) multi-criteria evaluation were applied to evaluate the suitability and sustainability of the major potential land use alternatives in the region. The result of this analysis was not conclusive but rather served as a demonstration of the application of GIS and DSS in land use planning.
I would like to convey my special appreciation to the following for their valuable contributions towards this study.

The Dutch people and the Dutch Government who, through NFP funded the entire course. No words can say enough.

Dr. Herman Huizing, my primary supervisor who offered me excellent guidance and useful ideas without which this study would not have attained this level. His encouragements whenever things seemed hard, his dedication and commitment to my work will always be appreciated and remembered.

Ir. Kees Bronsveld, the co-supervisor for his constructive discussions and contribution to this study.

Dr. Iris van Duren for her devoted and committed fieldwork supervision. Her glamorous warm nature, jokes and laughter always inspired us.

Dr. Hein van Gils for the field work organization and useful insights and advice throughout the study.

All the Lecturers in ITC who taught us, your knowledge and skills always inspired and challenged us.

All other staff of ITC and DISH Hotel for the various services rendered, the warm and outgoing attitude plus the positive social bearing during our study and stay in Enschede. The service of the cluster managers was highly appreciated.

All the people in Namibia who in one way or another contributed to the success of this study. Special thanks to Ms Maria Kasita (Polytechnic Namibia), Ms Knick Knox (GIS laboratory, Polytechnic Namibia), Mr. S. Kapiye, Mr. C. Kwala and Mr. M. Karongee (Ministry of Lands, Windhoek).

All my friends, my course mates in the GIM course, and my colleagues in the computer cluster: Pandit (Nepal), Gulerat (Ethiopia), Lemmy (Zambia), Joe (Sierra-Leone), Perera (Sri-Lanka) and Wahyu (Indonesia), for their help, cooperation and encouragement. Those jokes always brought some smiles during tough times.

But above all, THANKS and GLORY to the ALMIGHTY GOD who enabled everything.
To Abbey for his love, patience and encouragement during my study and our son Lubaale, I missed you a lot

And

To my parents Mrs S.M. Nabaggala and Mr G.W Mukaaga for their parental love and dedication to educate me
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<th>Full Form</th>
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</thead>
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<td>Agro-Ecological Zone</td>
</tr>
<tr>
<td>DBMS</td>
<td>Database Management System</td>
</tr>
<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>DF</td>
<td>Data Flow</td>
</tr>
<tr>
<td>ER</td>
<td>Entity Relationship</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>ILWIS</td>
<td>Integrated Land and Water Information System</td>
</tr>
<tr>
<td>LRIS</td>
<td>Land Resource Information System</td>
</tr>
<tr>
<td>LUP</td>
<td>Land Use Planning</td>
</tr>
<tr>
<td>MAWRD</td>
<td>Ministry of Agriculture, Water and Rural development</td>
</tr>
<tr>
<td>MCE</td>
<td>Multi-criteria Evaluation</td>
</tr>
<tr>
<td>MET</td>
<td>Ministry of Environment and Tourism</td>
</tr>
<tr>
<td>MLRR</td>
<td>Ministry of Lands, Resettlement and Rehabilitation</td>
</tr>
<tr>
<td>NRSC</td>
<td>National Remote Sensing Centre</td>
</tr>
<tr>
<td>PRA</td>
<td>Participatory Rural Appraisal</td>
</tr>
<tr>
<td>RS</td>
<td>Remote Sensing</td>
</tr>
<tr>
<td>SSDM</td>
<td>Structured System Development Methodology</td>
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</table>
CHAPTER ONE

1. BACKGROUND

1.1. Introduction

One of the major global concerns is the problem of the declining land resources that are being threatened by the rapid human population growth. There is an increasing need to use resources in a sustainable way, increasing production but at the same time protecting the environment, biodiversity, and global climate systems. This requires careful land use/resource planning and decision-making at all levels. Land use planning (LUP) depends on the systematic evaluation of the land and water resources. Evaluation and the ensuing planning require basic data/information about the resources, the people and the institutional framework involved. Such data includes land resources, land use/cover, socio-economic data, policies, infrastructure, etc. For this reason, the need for development of land resource information systems to provide such data is necessary. In recent years Geographic Information Systems (GIS) have emerged as powerful tools in the management and analysis of large amounts of spatial and thematic resource data to provide key information needed to support land use/resource planning.

This study looks at how to design a GIS based land resource information system and database that can provide information to support decisions in land use and resource planning in Kunene region of Namibia.

1.1.1. The need for a land resource information system in Kunene region

There are a number of constraints regarding the effective use of land resource information in many developing countries. de Bie (Bie, 2000) outlines some of these as limited and restricted data availability, incompatible data formats, poor quality data, incomplete data documentation, high data costs, poor update frequency, lack of geo-referencing, etc. Notably in sub-Saharan Africa, these problems are made worse by limited skilled manpower and inaccessibility of some regions due to limited infrastructure and wars.

Namibia is a typical country in sub-Saharan Africa with such problems and a range of environmental problems including rangeland degradation and prevalent droughts (Directorate of Environmental Affairs - DEA, 2001) and (Talavera, et al, 2000). Kunene is one of the regions in Namibia where these problems occur, making rural development plans and conventional methods of agriculture difficult to implement. For this reason there is need for effective methods of analysing and evaluating the available land resources to provide accurate and timely information for monitoring and planning and on which to base sound decisions made by the different stakeholders.

1 Stakeholder is any individual or group with a legitimate interest in the land resources or liable to be affected by the changes in the way the resources are managed.
1.1.2. The major actors in Kunene

The major actors in land use/resource planning and management in the region are:

- Ministry of Lands, Resettlement and Rehabilitation (MLRR)
- Ministry of Agriculture, Water and Rural Development (MAWRD)
- Ministry of Environment and Tourism (MET)

1.1.3. Land resource decisions made in the Kunene region

The above organizations together with other stakeholders in the region need reliable and timely land resource information/data to make decisions e.g. on the following issues:

- The sustainable use and conservation of the natural resources
- Purchase of farmland for redistribution and resettlement
- Establishment of wild life conservancies
- Addressing the problem of land degradation

1.1.4. Major constraints to land use and resource planning in the region

The availability of information on which to base the above decisions is often hampered by inadequate region specific data due to:

- Inadequate tools for data collection
- Inadequate infrastructure including computers and software for processing and analysing the required data
- Inadequate trained manpower for data collection, processing and analysis

This research therefore aims at designing a prototype information system that can provide the necessary information/data for decision-making regarding land use/resource planning in the region. The proposed information system will focus on how to integrate spatial and thematic data from different sources and planning levels for coordinated and guided sustainable land use/resource planning.

1.2. Objectives and Research questions

1.2.1. General objective

- To design a prototype information system that can integrate spatial and thematic data to provide information for decision-making in land use/resource-planning issues at region level for Kunene region, Namibia.

1.2.2. Specific objectives

The specific objectives of the information system are:

- To assess the existing land use/resource planning framework and land resource information system of the region, and its institutional framework.
- To design a prototype information system framework and data base structure that can provide spatial and thematic data to support the evaluation and planning of land resources in Kunene region.
• To compare and assess the relationship between the LUP frameworks at the local level (Sesfontein Constituency) with that of the regional level (Kunene Region).
• To demonstrate the application of Multi-criteria evaluation and GIS analysis in LUP.

1.2.3. Research questions

<table>
<thead>
<tr>
<th>Specific objectives</th>
<th>Research questions</th>
</tr>
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</table>
| • To assess the existing land use planning framework and land resource information system of the region and its institutional framework. | i. What is the structure of the land use planning and natural resource management framework in Kunene region and who are the key stakeholders?  
ii. What are their objectives, priorities and information/data requirements? |
| • To design a prototype information system framework and data base structure that can provide spatial and thematic data to support the evaluation and planning of land resources at a region scale (Kunene region). | i. How can a prototype information system be designed and set up for sustainable land use planning?  
ii. What processes and data models can be incorporated into the system? |
| • To compare and assess the relationship between the land use-planning frameworks at the regional level (Kunene region) with that of the local level (Sesfontein constituency) | i. What are the land use planning procedures at the regional and local level?  
ii. How do the two levels interact, how can their processes, data/information be integrated? |
| • To demonstrate the application of Multi-criteria evaluation and GIS analysis in LUP. | i. What are the potential land use alternatives in the region?  
ii. What criteria can be used to evaluate their sustainability? |

Table 1.1: Research questions used to achieve the objectives of the study.

1.3. Research approach and context

The study was approached from a systems development context and based on the four major components of structured system development methodology i.e. Problem definition, System analysis, System design and System implementation (Hawryszkiewycz, 1998). In this research a system was considered to be a collection of people or organizations, processes and computers that work together to realise the objective of effective and sustainable planning of land resources. The figure below is a diagrammatic representation of the research approach indicating how the four main phases in the structured system development methodology were undertaken in this study.
1.4. **Research methods**

1.4.1. **Literature review**

Relevant literature was reviewed to build up a conceptual framework relevant to the study.

1.4.2. **Fieldwork**

Fieldwork activity was carried out (23rd September-6th November) in Kunene region and Sesfontein area to get insight into the study area and obtain the necessary information. Data required for the research was collected from various key organizations involved in land resources planning and management through interviews, observation and secondary data collection. The following were the major focus of the interviews:

- The activities carried out by the various organisations towards land use and resource planning
- The kind of data they needed for these activities
- The methods used for data collection, update and the data sources
- The scales and formats required plus the frequency of data acquisition and update
- The methods of processing, storing, delivering and visualizing output data

1.4.3. **System design and development methodology**

The design of the proposed information system was based on the basic framework of system design and development described by Hawryszkiewycz (Hawryszkiewycz, 1998). The Structured System Development Methodology (SSDM) (Paresi, 2000) was adapted to design the proposed system and database.
Why the SSDM
The SSDM was adopted for this study because of its advantages relative to other methodologies. It:

- Has high recognition of user participation. During fieldwork the different stakeholders (including land use planners, farmers/land users, regional development councillors and other natural resource managers) in Kunene region participated by identifying the problems and constraints in the current system and giving ideas to what kind of system they require to solve their problems.
- Takes on the Top-Down approach and is flexible in design and techniques whereby the conceptual model of the system being developed can be broken down into manageable modules.
- Involves the use of tools like dataflow diagrams, and data dictionaries to document and describe the real world situation.
- Has iterative steps that allow reviews and changes to be made for improvements if necessary. The steps include
  - System strategy and planning (Problem definition & Feasibility study) *(Pre- and field work phase, plus chapter 1)*
  - System analysis *(Chapter 2)*
  - System design (Global and Detailed design) *(Chapter 3 and 4)*
  - System realisation (Testing, Installation & Implementation/Operation) *(Chapter 5)*

1.4.4. Other Information System Development Methodologies (ISDM) compared
Other alternative information system development methodologies were not preferred in this study. They include:

- **Soft SDM**: Are useful to structure fuzzy real world situations but cover only the system strategy and analysis phases, have few case tools and techniques to solve problems.
- **Socio-technical SDM**: Can be used to design social and technical sub-systems but cover only the analysis and design phases, have few case tools and techniques to solve problems.
- **Object Oriented SDM**: Covers all phases from strategy to operation of the system, has good techniques and tools and the advantage of uniting data and processes, but it is still in the infancy stage.
1.4.5. **Study area**

The study was done in Kunene region and Sesfontein constituency, Namibia. Sesfontein is one of the constituencies in Kunene region, which is one of Namibia’s 13 regions. Kunene lies approximately 17° and 21° South and 11° and 17° East. The Kunene River forms the boundary of the region to the North and also the boundary between Namibia and Angola. To the South it is bordered by Erongo region, to the Southeast is Otjozondjupa region, to the Northeast is Omusati and Oshana regions. The whole western border is the coastline of the Atlantic Ocean.

The region has one of the lowest human populations in Namibia with 64,017, over an area of 1,444,252 km², and a population density of 0.04/km² (1991 census figures). It is remote, marginal, and diverse in climate, topography, drainage, vegetation, water resources and cultural composition. The climate of the region varies from hyper-arid along the West coast, to arid in the central part, to semi-arid in the eastern part. Rainfall decreases westward from the semi arid part of the region towards the desert along the coast and also southwards. The region is frequently hit by droughts. Due to both low rainfall and geological formations Kunene is not well endowed with surface and underground water resources like most of the country. Figure 1.2 shows the location of the region and Sesfontein one of the constituencies in the region that was also focussed on in the study.

![Figure 1.2: The location of Kunene region and Sesfontein constituency](image)
The structure of this thesis

- **Chapter 1** gives the general introduction to the study, the objectives of the study, the research questions to achieve these objectives and the methodology of the research.

- **Chapter 2** gives an overview of the land use planning concepts in general and specifically in Kunene region. The current and potential stakeholders of the existing land resource information system are identified, together with their data/information needs, problems and bottlenecks. A comparative overview is made between the land use-planning framework at the regional level (Kunene region) and local level (Sesfontein constituency).

- **In Chapter 3** deals with designing a prototype information system for land resource planning and management; various processes and tools involved there in are modelled. A way of integrating local level data into the regional level database is suggested.

- **Chapter 4** looks at data modelling involving the design of a prototype database structure and user interface.

- **In Chapter 5** the application of GIS analysis and multi-criteria evaluation in land use suitability and sustainability assessment is demonstrated. Selected social and economic sustainability indicators of the potential land use options in the region are used as criteria for the evaluation.

- **In Chapter 6** Conclusions and recommendations are made.
CHAPTER TWO

2. ANALYSIS OF EXISTING LAND RESOURCE INFORMATION SYSTEM

2.1. Introduction

Information and technology and the competence to use them are essential for informed decision-making in land use/resource planning. GIS, RS, DSS are important tools that can be used for data collection and analysis for this purpose. This study involves the application of GIS and DSS analysis in land use planning and therefore it is important to first understand the concepts of land use planning. This chapter provides an overview of land use planning in general and particularly in Kunene region.

2.2. The conceptual framework of land use planning

Land use planning has been defined as:

*The systematic assessment of physical, social, and economical factors in such a way as to assist and encourage land users to select the land use options that increase the productivity, are sustainable and meet the needs of society (FAO, 1993).*

*A systematic and iterative procedure carried out in order to create an enabling environment for sustainable development of land resources, which meets the needs, and demands of the people. It assesses the physical, socio-econ, institutional and legal potentials and constraints with respect to an optimal and sustainable use of land resources and empowers people to make decisions about how to allocate these resources (FAO & UNEP, 1999).*

Land use planning involves the selection of land use alternatives based on Land Evaluation (LE). LE is a physical land assessment involving matching land requirements with the land qualities to assess land suitability. Guidelines for LE have been set up for different land use types (FAO, 1983, FAO, 1985, FAO, 1991) but some authors like (Anaman & krishnamra, 1994) consider some of these guidelines as having a top-down approach. In the current trend in land use/resource planning, emphasis is being put on the need for the active involvement and participation of stakeholders particularly the local level in decisions on land use and management (FAO & UNEP, 1999). The argument is that LUP should be a mechanism of decision support for policy formul-
tion, laying strategies and help land users to reduce the current problems of land use rather than a technical evaluation procedure. Some methods and tools to improve land evaluation for LUP have been suggested by Bronsveld (Bronsveld, et al, 1994) including the involvement of land users in the planning process, use of more flexible data processing methods, better procedures for selecting and describing land use types.

Effective planning and management of land resources requires timely and accurate information on the different aspects of land e.g. the different land use systems, their suitability, sustainability, potential, and the consequences of implementing each one of them depending on the level/scale of planning. Land use planning is generally applied at three interactive levels; national, regional and local level (FAO, 1993), where different priorities, planning strategies and kinds of decisions are made. At the national level e.g. general land use planning policies, priorities and legislation are set. At the lower levels the plans become more detailed e.g. putting in place water sources and infrastructure. Interaction, information flow and data sharing between the planning levels are important.

2.3. Overview of LUP in Namibia

In Namibia, LUP is the responsibility of the Division of Land Use Planning and Allocation (LUPA), Land Reform Directorate of the Ministry of Lands, Resettlement and Rehabilitation (MLRR). Like in many developing countries, the concept of LUP is generally still new in the country and to the people especially at the constituency level. The MLRR has embarked on a land reform program in the country to acquire and demarcate land for resettlement of its landless citizens. It has gone ahead with a land use planning strategy to address the various land use problems through the formulation and implementation of comprehensive land use plans. At the time of this study the plan for Kunene region was already finalized and that for and Caprivi was underway (Ministry of Lands, 1998). Establishment of a natural/land resources database is important in this strategy and this will be dealt with in chapter 4.

Currently there is no comprehensive land use policy in the country, no defined methodology for integrated regional LUP and LUP frame works/ structures are not well established especially at the constituency levels (Ministry of Lands, 1998) and (Ministry of Agriculture, 1994). LUP activities by the Division are based on the Agricultural (commercial) land reform act no.6 of 1995 and the National land policy. The main aim of the act is land reform by the state involving acquisition of agricultural land, allocation and resettlement. The acquired farms are evaluated for their suitability by the regional land use planners based on carrying capacity, size, infrastructure, price, and location and then demarcated into farming units for redistribution to the citizens. Appendix 2 summarizes the general current land use planning procedure undertaken by LUPA.
2.3.1. LUP in Kunene region

The regional office for the MLRR in Kunene is at Opuwo with four land use planners and 3 clerks. These are responsible for all LUP activities in the region including providing information and technical advice to land users and projects, implementing the agricultural land reform act no.6 of 1995, encouraging local participation in land use planning activities and building capacity for the LUPA in the region.

The following are the major objectives of the LUPA in the region:

- To coordinate and integrate various sectoral land use activities in the region
- To identify sustainable land uses in the region and guide the formulation of rural development plans for the optimal use of scarce and fragile natural resources in the region
- To provide decision makers with technical advice on the allocation and utilization of natural resources
- To collect and store natural resource baseline data in the region
- To acquire agricultural land for resettlement

Discussions with the regional land use planners revealed that formulation of land use plans, problem identification, goal definition and data collection takes place at the national level. The regional and local levels are involved by way of sensitisation and consultations to fill in information gaps during workshops.

2.3.2. Land use in Kunene region

The current land use in the region is mainly:

- Extensive grazing of large and small stock (semi-nomadic pastoralism, nomadic and commercial)
- Game/wildlife management
- Tourism (still a growing industry).
- Limited cropping of maize, tobacco, paprika and wheat mainly in the NE of the region and Hoanib catchments area (Ongongo, Warmquele and Sesfontein gardens).
- Mining and wood extraction

Table 2.1, (adapted from Ministry of Lands, 1998) shows the present land uses, their contribution to the economy and the related problems. Figure 2.1 shows the major land use of the region.
<table>
<thead>
<tr>
<th>Land use</th>
<th>Main requirements</th>
<th>Area covered</th>
<th>Contribution to the economy</th>
<th>Potential threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEDENTARY LARGE STOCK PRODUCTION</td>
<td>-Veld -Water -Vet. Services -Market -Hired and family labour especially in communal areas.</td>
<td>-Kamanjab and Outjo districts for commercial. -North and north central for communal</td>
<td>-Commercial market sales -Communal subsistence oriented</td>
<td>-Drought -Competition for grazing and water with wild life -Perennial grasses disappearing -Rustling in the north -Illegal fencing in the east -Bush encroachment</td>
</tr>
<tr>
<td>(commercial and communal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEDENTARY SMALL STOCK PRODUCTION</td>
<td>-Veld -Water -Vet. Services -Market -Family labour</td>
<td>- Whole region has small stock but more in the south.</td>
<td>-Market sales in both communal and commercial areas -Significant subsistence contribution in the communal sector</td>
<td>-Drought -Predation -Disease -Degradation of pastures</td>
</tr>
<tr>
<td>(commercial and communal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PASTORAL NOMADISM</td>
<td>-Big rangelands -Water at strategic places -Family labour -Vet services -Markets -Family labour</td>
<td>-The northern extremity of the region including areas along the Kunene river (key resource area)</td>
<td>-Significant to subsistence economy</td>
<td>-sedentarism due to availability of water -Degradation of pastures -Cultural threats -Rustling -Lack of markets -Disease</td>
</tr>
<tr>
<td>IRRIGATION</td>
<td>-Water in sufficient quantities -Good soils -Market</td>
<td>-Sesfontein area -Ugab and Huab valleys -North east (Etunda) -Dates near Khorixas</td>
<td>-Small gardens for subsistence -Etunda scheme and date palm for commercial purposes</td>
<td>-Water shortages -Wildlife destroys small gardens -Marketing difficult for such products</td>
</tr>
<tr>
<td>MIXED FARMING</td>
<td>-Good rainfall to support both grain cropping and livestock -Exploitation of mutual dependency of cropping and livestock</td>
<td>-Confined to the north east on a large scale -Smaller scale along Kunene river and north central around Opuwo</td>
<td>-Significant to subsistence economy</td>
<td>-Droughts -Illegal fencing</td>
</tr>
<tr>
<td>TOURISM</td>
<td>-Tourist attractions (wild animal &amp; plant species) -Tourist facilities</td>
<td>-North west and south plus along Kunene river commercial farming area</td>
<td>-No significant contribution to the local economy</td>
<td>-Environmental degradation -Lack of investment capacity</td>
</tr>
<tr>
<td>WILD LIFE MANAGEMENT (outside parks)</td>
<td>-Large ranges -Guarding against poaching -Little human interference</td>
<td>-South and north western area along skeleton coast park</td>
<td>-Has potential but still to be exploited systematically</td>
<td>-Competition with people and livestock -Poaching -Conflict with other land uses like cropping</td>
</tr>
<tr>
<td>MINING</td>
<td>-Mineral deposits</td>
<td>-Exploration in licensed areas</td>
<td>-Small scale mining could boost local economy</td>
<td>-Conflicts with other land users such as tourism and livestock production -Lack of infrastructure</td>
</tr>
</tbody>
</table>

Table 2.1: Present land use characteristics in Kunene region.
2.3.3. Environmental and resource problems in the region

The region is faced with a number of problems identified through interviews and discussions with the different stakeholders during fieldwork and from the available literature. According to (Ministry of Lands, 1998) natural resources and environmental problems in the region can be viewed as products of the interaction of the policy interventions or failures, local socio-economic structures, characterized by unequal access to resources, poor services and poverty. These include:

- Harsh environmental conditions with signs of land degradation especially around population centres (Talavera et al., 2000), which affects the communal areas and the region’s economy
- Inadequate water sources, intermittent droughts and very low highly variable rainfall (average annual rainfall is 100mm)
- Increasing pressure on natural resources due to population growth and expansion of settlements (Ministry of Agriculture, 1997).
• Land user/use conflicts e.g. for grazing resources with neighbouring communities especially in the dry season
• Sedentarization of nomadic farmers causing overgrazing in specific areas
• Lack of local markets and local buying power/ low prices for produce especially for livestock
• Low yields in irrigated gardens and inadequate funds by farmers to purchase farm inputs
• Strong belief and some cultural norms the region causes a negative attitude to land use diversification from the traditional livestock keeping (Ministry of Lands, 1998).

2.4. The existing land resource information system

In order to get a clear understanding of the stakeholders, processes and activities involved, the software and hardware used in land use and resource planning in the region, interviews and discussions were conducted (during fieldwork) with the key organisations involved. Relevant literature was also reviewed from various sources including reports from key ministries, consultancy reports and research papers.

2.4.1. Stakeholders analysis

The main stakeholders involved in LUP and land resources management in Kunene region are:
• The Division Land Use Planning & Administration (LUPA) of the Ministry of Lands, resettlement & Rehabilitation (MLRR)
• Ministry of Agriculture, Water & Rural Development (MAWRD)
• Ministry of Environment & Tourism (MET)
• The Natural Resource Information Service (NRIS) of MLRR
• The National Remote Sensing Centre (NRSC)
• Division of Mapping & GIS (DMGIS) of MLRR
• The Kunene North Farming Systems Research Unit (KNFSRU) of MAWRD
• Kunene Regional Council
• Kunene Land use Steering Committee
• Ministry of Mines & Energy (MME)
• Ministry of Health & Social Services (MHSS)
• Ministry of Local, Regional Government & Housing (MLRGH)
• Ministry of Works, Transport & Communications (MTWC)
• National Planning commission (NPC)
• Farmers/pastoralists and other land users.
2.4.2. Information and Data requirements analysis

The different stakeholders in Kunene region need various spatial and thematic data and information for various applications. The land use planners for example need:

- Topographic maps, soil maps, land use maps, etc to delimit and delineate land use problem areas
- Land tenure information, administrative information, land use suitability data, etc to plan the necessary interventions
- Farms data including prices and carrying capacity to purchase farms for resettlement of people

The table below summarizes the stakeholders’ main information/data requirements and the purpose for which they use it.
<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Mandate</th>
<th>Data/ Information requirement/need</th>
<th>Source</th>
<th>Required Scale</th>
<th>Frequency</th>
<th>Purpose/ Application</th>
</tr>
</thead>
</table>
| LUPA (MLRR) | •Acquisition of farm land & resettlement plans  
•Formulation of rural development plans  
•Formulation, integration & coordination of various land use plans  
•Collection and provision natural resources data | •Land use/land cover data  
•Farms and farm prices  
•Farming systems data  
•Soils and landscape units  
•Water sources  
•Crop & livestock data  
•Quarantine fences and cattle posts  
•Agro-climatic data  
•Infrastructure data  
•EIA data –Permission to Occupy Land (P.T.O)  
•Wildlife, protected areas & conservancies data  
•Epidemiological data  
•Aerial photos  
•Satellite images (Landsat TM)  
•Population data  
•Topographic maps  
•Settlements data  
•Land tenure | •NRIS  
•MAWRD  
•KNFSRU  
•MET  
•MHSS  
•NRSC  
•NPC  
•DMGIS  
•MLRGH  
•MLRR | •Regional  
•Constituency  
•Village  
•Constituency  
•Regional  
•1:78,000  
•1:30,000  
•30m * 30m resolution  
•1:250,000  
•1:50,000 | •When required  
•When necessary  
•When required  
•10 years  
•When required | •Determination of problem areas  
•Formulation of land use plans  
•Purchase of farms  
•Resettlement of people  
•For planning agricultural and extension services |
| MAWRD | •Responsible for agricultural & water development activities  
•Provision of information on natural resources  
•Provision of extension & technical service for sustainable agriculture. (The following is needed in addition to what the organization produces itself)  
•Population data  
•Topographic maps  
•Epidemiological data | •Population data  
•Topographic maps  
•Epidemiological data | •NPC  
•DMGIS  
•MHSS | •Regional  
•Village  
•Regional | •10 years  
•1.250,000  
•1.50,000  
•When required  
•When required |
<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Mandate</th>
<th>Data/ Information requirement/need</th>
<th>Source</th>
<th>Required Scale</th>
<th>Frequency</th>
<th>Purpose/Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>MET</td>
<td>• Wild life and natural resource conservation</td>
<td>(The following is needed in addition to what the organization produces itself)</td>
<td>• MAWRD</td>
<td>Regional</td>
<td>• When required</td>
<td>• For planning conservation and tourism activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Land use/land cover data</td>
<td>• NRIS</td>
<td>1:250,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ground &amp; surface water sources</td>
<td>• LUPA</td>
<td>1:50,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Crop &amp; livestock data</td>
<td>• Village</td>
<td>When required</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Infrastructure</td>
<td>• Veterinary data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Topographic maps</td>
<td>• DMGIS</td>
<td>1:250,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Aerial photos</td>
<td>• NRSC</td>
<td>1:78,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Satellite images (Landsat TM)</td>
<td>• 30m*30m</td>
<td>1:30,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Population data</td>
<td>• NPC</td>
<td>6 Months</td>
<td></td>
<td>• For decision making</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Epidemiological data</td>
<td>• MHSS</td>
<td>10 years</td>
<td></td>
<td>• For agricultural activities and tourism enterprises</td>
</tr>
<tr>
<td>MTWC MHRLG</td>
<td>• Infrastructure</td>
<td></td>
<td>• Regional</td>
<td>When required</td>
<td></td>
<td>• For planning infrastructure</td>
</tr>
<tr>
<td></td>
<td>• Topographic maps</td>
<td></td>
<td>• DMGIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Land use/cover data</td>
<td></td>
<td>• Regional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Agricultural &amp; Veterinary data</td>
<td></td>
<td>• Village</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Tourism data</td>
<td></td>
<td>• MET</td>
<td></td>
<td></td>
<td>• For planning purposes</td>
</tr>
<tr>
<td>Pastoralists/farmers and</td>
<td>• Management of communal lands, farms and tourists enterprises</td>
<td></td>
<td>• MAWRD</td>
<td>When required</td>
<td></td>
<td>• For agricultural activities and tourism enterprises</td>
</tr>
<tr>
<td>other land users</td>
<td></td>
<td></td>
<td>• NRIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• LUPA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kunene land use planning</td>
<td>• Coordinate land use planning activities in the region.</td>
<td></td>
<td>• Land use planning data</td>
<td>6 Months</td>
<td></td>
<td>• For decision making</td>
</tr>
<tr>
<td>steering committee.</td>
<td></td>
<td></td>
<td>• LUPA</td>
<td></td>
<td></td>
<td>• For land use planning</td>
</tr>
<tr>
<td>Kunene regional council</td>
<td>• Administrative roles of the region</td>
<td></td>
<td>• Land use planning data</td>
<td>6 Months</td>
<td></td>
<td>• For decision making</td>
</tr>
<tr>
<td></td>
<td>• Spearheads regional development</td>
<td></td>
<td>• LUPA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NGOs &amp; research institutions</td>
<td>• Various private activities</td>
<td></td>
<td>• User defined data</td>
<td>-</td>
<td></td>
<td>• For various user defined purposes</td>
</tr>
<tr>
<td>Other government agencies</td>
<td>• Various government activities</td>
<td></td>
<td>• User defined data</td>
<td>-</td>
<td></td>
<td>• For planning purposes</td>
</tr>
</tbody>
</table>

Table 2.2: The main stakeholders and their data/information requirements.
2.4.3. **Information problems and constraints**

Before embarking on designing a new system, it is necessary to understand the problems and constraints of the existing land resource information system as identified during the interviews and discussions with people in the key organizations and also from observations by the author. They are summarized in the following categories:

i. **Organizational/institutional constraints**
   - Individual data collection by the different organizations mainly for their own sectoral applications results into data duplication, redundancy and scattered data that are costly in terms of time and money.
   - Limited data sharing between the stakeholders despite the fact that they have almost similar information requirements.
   - The variations in the different methods for data collection, processing and formatting used by the different organizations cause data incompatibility.
   - Inadequate infrastructure e.g. roads and inadequate extension staff in a vast region makes service delivery poor.
   - Limited involvement of local stakeholders in land resource problem identification and the planning process.

ii. **Data constraints**
   - Inadequate/scanty region specific land resources data
   - Inadequate data documentation
   - Much of the data is stored as analog reports and statistical tables in cabin filing system and cumbersome to retrieve when required
   - Collecting and updating primary data is made difficult due to insufficient data collection tools.

iii. **Infrastructure**
   - Inadequate infrastructure e.g. computers, field tools/equipment like Global Positioning System (GPS), makes data collection, processing and update difficult
   - Inadequate trained manpower for data collection and processing resulting in sometimes un-reliable and contradicting data

2.4.4. **Hard ware and software capacity**

Like in many developing countries, the use of GIS in geo-information analysis is still new in Namibia and just starting to take pace. The MLRR, MAWRD, and MET have acquired some Personal Computers (PCs) and mainly use Arc View GIS (also ILWIS is used by MET) for analysis in natural resource monitoring and management in the region. However their scope of operation is still lim-
ited due to limited computer facilities and insufficient trained manpower. The NRIS has established a reasonable GIS laboratory composed of PCs operating on a windows environment and mainly uses Arc view, Arc Explorer and EnviroMapper GIS software for spatial and thematic analysis. They have well trained but limited staff for these tasks.

2.5. Towards understanding the problems in Kunene region

To try to understand the land use and resource problems in Kunene, a problem tree (Figure 2.2) was used to analyse their causes and effects.

![Figure 2.2: Analysis of the causes and effects of the land resource problems in kunene](image)

While the different stakeholders concerned can be able to solve the institutional problems, this may not be possible for the natural problems. Addressing the problems requires integrating socio-economic and biophysical data from different sectors and sources. The approach should be that:
• All stakeholders in the planning and management processes are identified involved and empowered especially those at the bottom social section because they bear a deeper understanding of the problems.

• The institutional structures that deal with land resource planning and management are strengthened

• Land use planning frameworks at all levels are integrated

• There is improvement in the management of the resources. Figure 2.3 indicates some of the objectives that can be aggregated into planning and management strategies by the concerned stakeholders in the region.

• These should be accompanied with enabling land management policies e.g. those dealing with land tenure

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**Figure 2.3: Goal hierarchy diagram**
Concluding remarks
From the system analysis in this chapter it was revealed that:

- Kunene region faces a number of environmental/land resource problems that are being addressed mainly by the MLRR, MAWRD, MET together with other stakeholders.
- In trying to deal with these problems, the organizations need and use spatial and thematic data but the prevailing organisational and data constraints restrict exploitation to full extent.
CHAPTER THREE

3. DESIGNING THE PROPOSED INFORMATION SYSTEM

3.1. Introduction

In the previous chapter, the existing land resource information system in Kunene region was ana-
lysed, the stakeholders, information requirements and problems identified. In reference to some of
these problems and the suggested management strategies (see Figure 2.3), a number of sugges-
tions are made to improve the current situation as indicated in the table below.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Suggested improvement /Strategy</th>
<th>Achievement by suggested improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land use or land resource problem identification</td>
<td>• More involvement of the local people in land use planning and resources problem identification e.g. by using PRA methods</td>
<td>• The system and information used will become more transparent to the people and thus more acceptable</td>
</tr>
<tr>
<td></td>
<td>• The system and information used will become more transparent to the people and thus more acceptable</td>
<td>• The people understand their local problems better and can suggest better solutions</td>
</tr>
<tr>
<td></td>
<td>• Expansion of data sources to include primary data collection in the field, The internet</td>
<td>• With expanded data sources, verification and diversification in analytical software use, reliable, region specific data will become more available</td>
</tr>
<tr>
<td></td>
<td>• Validation and verification of data collected from field surveys and secondary sources, procedures and steps of data processing and output data from the system</td>
<td>Internet provides cheap source of data for example satellite data from which land use/cover maps can be processed</td>
</tr>
<tr>
<td></td>
<td>• Expansion on use of GIS analysis and diversification in other software use e.g., DSS, and statistical packages</td>
<td>• With expanded data sources, verification and diversification in analytical software use, reliable, region specific data will become more available</td>
</tr>
<tr>
<td></td>
<td>• Coordination among the main organizations during data collection and processing and sharing of common data</td>
<td>• Coordination will streamline communication and information flow among stakeholders</td>
</tr>
<tr>
<td></td>
<td>• Digital storage of data file for easy retrieval</td>
<td>• Organizations will be able to identify and maximize the use of the available data, data duplication and redundancy will be reduced in addition to saving money and time in collecting data which is already available</td>
</tr>
<tr>
<td></td>
<td>• Creation of metadata and better data documentation and record keeping</td>
<td>• The organizations can pool resources to acquire infrastructure like data collection tools</td>
</tr>
<tr>
<td></td>
<td>• Record keeping and data documentation will be improved, the time taken to retrieve data from analog files when required will be reduced and office space occupied by filling cabins will be saved</td>
<td>• With a Meta data, data sharing becomes easy</td>
</tr>
<tr>
<td></td>
<td>• Expansion to include digital maps, charts, graphs and reports also available on diskettes medium</td>
<td>• The information products will become easy to understand and interpret by the users.</td>
</tr>
</tbody>
</table>

Table 3.1: Suggested improvements in the current system
3.2. The proposed system architecture

To promote coordination and data sharing between the different organizations in the region (for effective use of the available data, reduction of data duplication, redundancy and overhead costs), the proposed system architecture is composed of an integrated computerized database structure in a federated homogeneous database environment (Radwan, 2001). The different organizations can access the data in the centralized database in a unified way to solve a particular problem. In addition to this individual organizations can have independent local databases for sectoral applications. The figure below represents the architecture of the proposed system. Adapted from (Bishir & Radwan).

![System architecture of the proposed information system](image)

Figure 3.1: System architecture of the proposed information system

The proposed system is GIS based given the fact that:

- Much of the data to be used in the region have a spatial dimension, the analysis of which requires using GIS abilities for data collection, processing, analysis, storing, retrieving, visualization and dissemination to the users.

- Natural resource planning and management problems in the region are complicated and require good manipulation and analysis. GIS has this capability e.g. by overlay operations and can be queried for various resource applications with questions like “what, where, when and what if?” on which various decisions can be based.

- Land use/resource planning in the region requires an integrated approach combining biophysical, social, and economic data from different sources. GIS tools are capable of this integration and combining spatial and thematic attribute layers to solve real world problems.
3.3. **Process modelling**

To design the proposed system, the Structured System Development Methodology (SSDM) (Paresi, 2000) was adopted because of its advantages relative to other methodologies (see section 1.5.3). (System development methodology refers to predefined steps with tools to design a system). This section structures and defines the functions and processes of the proposed information system and how they interrelate. It is on the basis of these that the technical design and system implementation can be based.

The basic requirements of the process model are the data inputs, outputs, processes and data stores. Data Flow Diagrams (DFD) were used to structure these components. System Development Workbench (SDW) software (developed by Cap Gemini) was used for structuring of the system.

### 3.3.1. Description of the components of a DFD

DFDs are important tools used to analyse and model systems. Below is a description of the components of a DFD and Figure 3.2 shows their symbolic representation.

- A **process** is a procedural component of the system which operates on the data by physical computation, transformation or changing its state e.g. by validation.
- A **terminator** is an external entity of the system showing a data origin and ultimate recipient of the data produced from the system.
- A **data store** represents a logical file where data resides. Data stores are passive and so data cannot flow between two data stores without going through a transforming process.
- A **Data flow** indicated by an arrow shows the direction of flow of data through the system.

![Figure 3.2: Symbolic representation of the Components of a DFD](image)

### 3.3.2. Context of the system

A system has got a system boundary to define the system components. All “aspects” outside its boundary but affecting its functioning are its external environment. The boundary of the proposed system was defined using a context diagram (Figure 3.3). This shows the proposed system as a single process with data flowing to and from the external entities/terminators (data sources and users). These are the different stakeholders, both current (indicated in section 2.4.1) and potential...
in Kunene region at 3 levels: the national, region and local. They provide and receive different types of user specified data/information from the system.

Figure 3.3: Context diagram showing both the current and potential stakeholders

3.3.3. Top level analysis

The top-level analysis shows the main processes in the proposed system, the data flows in between and the data stores. The system was decomposed into four main components/processes as can be seen in Figure 3.4.
3.3.4. Data dictionary for processes, data flows and stores

For good data documentation and record keeping the details of the processes, data stores, and data flows should be well described and documented. Tables 3.2 and 3.3 describe the data stores and the processes in the top level respectively.

<table>
<thead>
<tr>
<th>Number</th>
<th>Store name</th>
<th>Description of the stored data</th>
<th>Used by process</th>
<th>Updated by process</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>•Raw data archive</td>
<td>•Land resource data e.g. land use/cover data, socio-economic data, biophysical data, etc collected from different sources is stored for further retrieval and analysis</td>
<td>•Land use suitability and sustainability assessment</td>
<td>•Data collection and input</td>
</tr>
<tr>
<td>ii.</td>
<td>•Processed data archive</td>
<td>•Processed land use and other resource data e.g. land use suitability maps, land use potential, etc</td>
<td>•Land use suitability and sustainability assessment</td>
<td>•Land use suitability and sustainability assessment</td>
</tr>
</tbody>
</table>

Table 3.2: Description of the data stores in the top level
Table 3.3: Description of the processes in the top level

3.4. Integration of local and regional planning processes and data

The process of planning that promotes the interaction and participation of all stakeholders e.g. local land users, decision-makers, professional and technical staff is very important (FAO & UNEP, 1999). The different levels of planning should interact as much as possible and information should flow through in all directions.

In this section, the study looks at how planning process and data/information at the local level (with reference to Sesfontein Constituency) can be integrated with that at the regional level to guide the land users, and decision makers through the process of choosing the best land use options in Kunene.

3.4.1. The local level (Sesfontein constituency)

Sesfontein is one of the six constituencies in Kunene region. It covers the Sesfontein-Khowarib basin. Most of the human population is concentrated in the communal areas of Sesfontein, Warmquelle, Otjindakui and Khowarib attracted by water availability from springs in the area.
Much of the constituency is a wilderness area with very little commercial activity other than tourism. Land use is mainly subsistence agriculture of which livestock farming is the major one supported by some subsistence cropping. Due to low rainfall, rain fed agriculture is not possible. Like elsewhere in the region, the constituency faces environmental problems already discussed in section 2.3.3. A detailed land use plan has been formulated for Sesfontein by the MAWRD to guide development of the constituency as part of the natural resource management for sustainable utilization of natural resources (Ministry of Agriculture, 1997).

At the constituency level are land use planning committees with representatives at the regional land use planning board. The committees participate in the following ways:

- Guide and assist when specific tasks are being done in the their areas and giving insight into the areas.
- Fill in information gaps to the data that already exists
- Present maps of their own perception and ideas on land use scenarios in their area.

The local level should be involved in process number 1 (“Problem Identification and analysis”) of the proposed system. This will improve the level of user involvement compared to the current situation. The Figure 3.5 illustrates how this can be done. Problems are identified at the local level and local goals are set. These are merged at the regional level and alternatives are developed. The national level funds the implementation of the plans and also provides guidelines and policies that direct the planning at the lower levels.

---

**Figure 3.5: Integration of local and regional database for land use planning**
3.4.2. Data requirements at the local level of planning

While the region level is mainly concerned with longer term planning and has to consider government policy and other operational factors like the budget, this may not be the case with the constituency level which looks mainly at the short term planning. The following table summarises the data required and used at the constituency level during land use planning.

<table>
<thead>
<tr>
<th>Data required</th>
<th>Available scale/level</th>
<th>Derived information /Purpose</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographic base map</td>
<td>1:25,000 1:50,000</td>
<td>Basis of the land use plan</td>
<td>Division of Mapping &amp; GIS (DMGIS)</td>
</tr>
<tr>
<td>Forest / vegetation cover map</td>
<td>1:100,000</td>
<td>Assessing soil type/vegetation relationships</td>
<td>National remote sensing centre (NRSC) Ministry of Environment &amp; Tourism (MET)</td>
</tr>
<tr>
<td>Soil map</td>
<td>1:750,000</td>
<td>Delineation of soil units</td>
<td>Ministry of Agriculture, Water &amp; Rural Develop-ment (MAWRD)</td>
</tr>
<tr>
<td>Aerial photos (1996) Satellite images</td>
<td>1:78,000</td>
<td>Derive land use/cover changes</td>
<td>DMGIS NRSC</td>
</tr>
<tr>
<td>Local Land use /cover maps and land resources</td>
<td>Village</td>
<td>Present land use/cover</td>
<td>Community generated</td>
</tr>
<tr>
<td>Proposed land use zoning</td>
<td>Village</td>
<td>The proposed land use by the community</td>
<td>Community generated</td>
</tr>
<tr>
<td>Basic land capability</td>
<td>Village</td>
<td>Basic capability of land</td>
<td>Community generated</td>
</tr>
<tr>
<td>Local Infrastructure map</td>
<td>Village</td>
<td>Insight into available markets, transport and services</td>
<td>Community generated</td>
</tr>
<tr>
<td>Village boundaries</td>
<td>Village</td>
<td>Village boundaries</td>
<td>Community generated</td>
</tr>
<tr>
<td>Indigenous knowledge</td>
<td>Village/constituency</td>
<td>Insight into cropping and livestock suitability, social structures and traditional practices</td>
<td>Community</td>
</tr>
<tr>
<td>Community based &amp; NGOs</td>
<td>Constituency</td>
<td>Organizations that can take part in planning and implementing the land use plans</td>
<td>Community</td>
</tr>
</tbody>
</table>

Table 2.5: Data requirements for land use planning at the constituency level.

3.4.3. Data compatibility and conversion

With the data requirements identified at both levels, data integration is possible but the problem of spatial data incompatibility due to the different scales and formats of data from different sources may arise. Wang (Wang.M & Howarth, 1994) and (Weibel.R & G.Dutton, 1999) suggest some solutions in multi-scale and representation environment, including spatial aggregation and disaggregation of data.

Data integration from higher level of detail (constituencies), to the lower level of detail (Kunene region) can be achieved by generalisation e.g.

- Neighbouring settlements in a constituency map are combined into bigger settlements
- Detailed road structures in community generated road maps are eliminated by simplifying intersections and removing minor branches
- Neighbouring similar land use/cover units are merged into bigger ones
- Ms Access Database management system (DBMS) is compatible with information exchange tools like ODBC that will take care of the differences in data formats and speed up exchange. This is further illustrated in sections 4.3 and 4.4.

3.5. Implementing the proposed system

3.5.1. System ownership and maintenance

Since LUP is mainly the responsibility of the MLRR, the proposed system and database should be maintained by the MLRR in the region in co-ownership with the other key organizations (MAWRD and MET).

3.5.2. Data sources for the proposed system

The table below indicates the main data sources for the proposed system

<table>
<thead>
<tr>
<th>Data provider</th>
<th>Mandate</th>
<th>Output</th>
<th>Scale/ availability</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRIS MAWRD KNFSRU</td>
<td>• Provision of information on natural resources and farming systems • Provision of extension &amp; technical service for sustainable agriculture.</td>
<td>• Farms and farming systems data • Infrastructure (Roads, Schools, Health facilities, etc) • Land use/land cover data • Soils and landscape units • Ground &amp; surface water sources • Crop &amp; livestock data • Quarantine fences and cattle posts • Veterinary data • Agro-climatic data</td>
<td>• Region scale • Constituency level • Village level</td>
<td>• Arc view shape files</td>
</tr>
<tr>
<td>MET</td>
<td>• Wild life and natural resource conservation</td>
<td>• EIA data – Permission to Occupy Land (P.T.O) • Protected areas, wildlife &amp; tourism data • Conservancies data</td>
<td>• Regional level</td>
<td>• Analog forms • Arc view shape files</td>
</tr>
<tr>
<td>NRSC Internet</td>
<td>• Provision of remote sensing products</td>
<td>• Aerial photos: 1996 • NOAA Satellite data • Landsat TM and MSS satellite images</td>
<td>• 1:78,000 • 1:30,000 • 30m * 30m resolution</td>
<td>• Image data</td>
</tr>
<tr>
<td>NPC</td>
<td>• Planning for economic activities • Provision of demographic and agricultural statistics</td>
<td>• Population data</td>
<td>• National &amp; regional scale</td>
<td>• Analog reports</td>
</tr>
<tr>
<td>DMGIS (MLRR)</td>
<td>• Provision of maps and survey data</td>
<td>• Topographic maps</td>
<td>• 1:50 000 • 1:250 000</td>
<td>• Analog maps</td>
</tr>
<tr>
<td>MHSS</td>
<td>• Provision of health and social services</td>
<td>• Epidemiological data</td>
<td>• User defined</td>
<td>• Analog reports</td>
</tr>
</tbody>
</table>

Figure 3.6: Main data providers and their mandate
3.5.3. Hardware and software requirements

Setting up the proposed system will require development of reasonable infrastructure in terms of computers, software, etc and well-trained manpower to handle the different tasks involved. The proposed system will be built onto the existing system and implemented in GIS (ARC VIEW and ILWIS) software together with Ms Access DBMS. This is realistic because as mentioned earlier, the major organizations have already achieved some level in the use these GIS software for resource data analysis but requires expansion for better applications.

3.5.4. Data quality and control

Data and information has quality when it meets the needs and expectations of its users (Hawryshkiewycz, 1998) and (Paresi, 2000). According to (Longley.P.A, et al., 1999), data quality can be differentiated in space, time and theme, of which several components of quality include accuracy, precision, consistence and completeness.

Good decision-making for resource planning in Kunene requires good quality information. Data quality assessment in the proposed system will be undertaken in process number 4 (“Data output and quality control”) and is intended to improve on the current data quality. The assessment involves:

- **Accuracy (spatial, thematic and temporal) assessment.** One way of doing this will be by ground truthing and verifying the data and its sources. E.g. in the process of land use/cover mapping, the responsible staff select a sample of point locations and compare the land cover/use classes assigned to these locations by the classification procedure, with the classes observed on source at these locations.

- **Timeliness, reliability, consistence, correctness, completeness and the way of presentation of output products** will be some of the indicators of the correctness of the processes and procedures of data processing. These will be verified by getting feed back from the data/information users in the region on their satisfaction regarding those aspects.

- **Additionally procedures for data access and sharing should be outlined by the major organizations (MLRR, MAWRD, and MET) in terms of:**
  - Who should have access to the data?
  - Under what terms and conditions is the data to be accessed or shared?

3.5.5. The metadata

Metadata (data about data) described in a standard metadata format (with common terminology and definitions) will improve the problem of inadequate data documentation identified in the existing situation. Metadata will internally help to monitor the status of the data sets and also provide the necessary descriptive information (e.g. content, quality, condition, currency, etc) for understanding and accessing the datasets by the users. Key developments in metadata standards for
digital spatial data sets have been made by different bodies like the International Standards Organization (ISO), the Comité Européen de Normalization (CEN) (CEN, 1996) and the American Federal Geographic Data Committee (FGDC) Content Standard for Digital Geo-spatial Metadata (CSDGM) (FGDC, 1998). The table below shows the information categories of Metadata contents specified by FGDC-CSDGM and CEN. Metadata can be developed using Arc Catalog/ Arc info 8.0. Software.

<table>
<thead>
<tr>
<th>Metadata standard</th>
<th>Categories of metadata contents/Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGDC-CSDGM (1997)</td>
<td>Identification</td>
</tr>
<tr>
<td></td>
<td>Data quality</td>
</tr>
<tr>
<td></td>
<td>Geo-spatial data organization</td>
</tr>
<tr>
<td></td>
<td>Geo-spatial reference</td>
</tr>
<tr>
<td></td>
<td>Entity and attribute</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
</tr>
<tr>
<td></td>
<td>Metadata reference</td>
</tr>
<tr>
<td>CEN (1996)</td>
<td>Data set identification</td>
</tr>
<tr>
<td></td>
<td>Dataset overview</td>
</tr>
<tr>
<td></td>
<td>Dataset quality indicators</td>
</tr>
<tr>
<td></td>
<td>Geo-spatial reference system</td>
</tr>
<tr>
<td></td>
<td>Extent (geometric and temporal)</td>
</tr>
<tr>
<td></td>
<td>Data definition</td>
</tr>
<tr>
<td></td>
<td>Classification</td>
</tr>
<tr>
<td></td>
<td>Administrative metadata</td>
</tr>
<tr>
<td></td>
<td>Metadata reference</td>
</tr>
</tbody>
</table>

Table 3.4: The categories of metadata contents for spatial data.

**Concluding remarks**

- Setting up the proposed system requires the major organizations to acquire more infrastructure in terms of computer hardware, software and more trained manpower to handle the different tasks involved for better performance.
- Coordination between all stakeholders is desirable in order to streamline information flow for better communication and cooperation.
4. DATABASE DESIGN

4.1. Introduction

Although the major stakeholders in Kunene have computerized systems, the scope is still limited and most of the data is still stored in the traditional analog formats. This situation can be improved by setting up a database. Date (Date, 1983), defines a database as a computerised record keeping system. The database should have non-redundant data that can be accessed and shared by multiple users and or for different applications (Howe, 1989). The advantage of such a system in Kunene will be that:

- Large volumes of resource data can be compacted for easy storage
- Processing the data becomes speedy
- It becomes easier to maintain the data files
- Reliable information becomes available most of the time

The process of database design goes through a number of steps illustrated in Figure 4.1, adapted from (de By, 2000): collection of data requirements and analysis, functional analysis, conceptual design, logical database design, and physical database design. In parallel with these steps, application programs are designed as database transactions corresponding to the high-level transaction specifications. In this study, the first step was covered during fieldwork, and the second step was addressed in the previous two chapters. The rest of the steps will be discussed in this chapter.

Figure 4.1: Steps in database design
4.2. Spatial data modelling and GIS

Geo information systems are used to store and process data referring to the earth's surface. These data contain both thematic and geometric/spatial information and can be represented in raster or vector form. There are 2 ways of linking thematic and geometric data (Molenaar, 1998).

- In the **field approach** terrain objects are represented in the form of attributes, the values of which are considered to be dependant on the position and the thematic information is directly linked to geometric data.

- In the **terrain feature/ (terrain) object structured approach**, terrain objects can be defined with a location/position, a shape and several geometric characteristics. Object identifier links thematic and geometric data indirectly to it.

These approaches are illustrated in the diagram below. Adapted from (Molenaar, 1998).

![Figure 4.2: The two basic structures of spatial data](image)

Three types of data can represent geographical phenomena:

- Geometric data that refers to the extent of an object's location, and can be represented as a point, line or area (polygon). Topology (neighbourhood) is also an important aspect of the object.

- Thematic data consisting of attributes classified in a systematic way.

- Object dynamics referring to the changes to an object in reference to time (temporal aspects).

4.2.1. Data representation

Geometric land resource data in Kunene region is stored in both vector and raster format.

- In the raster format data is represented by a set of cells located by their coordinates e.g. land use/cover, soil maps, etc.

- In the vector format the geographical features are stored as x-y coordinates. The geometric elements in the database are represented as:
  - Point objects e.g. settlements, water points, etc and for these, only the position (x, y co-ordinates) data is stored.
  - Line objects e.g. roads, rivers, cordon fence, etc for which position, shape and length are stored.
Area objects e.g. constituencies, soil units, Land use units, etc. For these the position, shape, the size of the area and the length of the perimeter are stored in the database.

4.3. Data Modelling

This involved modelling thematic data in which data was abstracted from the real world (Kunene) at three different levels (conceptual, logical and physical data modelling). Entity Relationship (ER) database modelling was adapted for the proposed GIS database. The ER modelling takes on a top-down approach whereby the global conceptual model is broken down into manageable modules. Microsoft Access software was used as a Relational Database Management system (RDBMS) for the following functions: To;

- Handle the relatively large data sets in the regional database
- Allow concurrent access and use of the data in the database by different users (organizations) at the same time
- Guard against errors in the database by ensuring integrity of the database. In the designed database the properties of the desired data for each field were specified and if data with wrong properties is entered, it is rejected by the DBMS.
- Allow users to query the database and retrieve the desired output
- Allow integration of different data formats e.g. a land use map in ILWIS can be converted to Access Database file and then converted to other formats like Arc View shape files, Excel files, etc.

Entity Relationship Diagrams (ERD) were used as modelling techniques. An ERD shows individual entity occurrences and their relationships in a database. Entities and their relationships were selected and assigned attributes. Data were presented in form of tables corresponding to entities such as Agro-Ecological Zones (AEZ), constituency, farmer/land user, infrastructure, etc.

With the data inserted into the various tables, queries can be performed using the Structured Query Language (SQL) to show how the various aspects of land resources relate, e.g., to assess relationships among biophysical, and socio-economic data in the region. The relational database tables allow both integration and updating of data thereby increasing its quality and its use for resource/land use planning.

Description of key words:

- **Entity**: An object or “thing” that exists (physically or conceptually) independently in the real world and can be uniquely identified.
- **Attribute**: A characteristic or property that describes an entity. A key attribute (primary key) is a unique characteristic with distinct values used to uniquely identify an entity.
• **Relationship**: The association between two or more entities and is governed by (cardinality) constraints\(^2\) that determine how entities combine in a relationship.

The figure below shows how the constraints are represented in a relationship:

![Relationship diagram]

**Figure 4.3**: Relationships between the entities in the conceptual model

The following processes/relationships can be recognised among the entities of the designed Kunene database:

- **Object classification**: Categorizing objects into classes according to their attributes. Objects in the same class have similar attributes and differ from those of other classes. The relationship between the object and the class is “is a”. E.g. borehole is a water source. Rivers, boreholes, wells, water springs all belong to the class water sources.

- **Object association**: Objects are put in a set on the basis of relationships that are not necessarily exhaustive or exclusive. The relationship between the object and the association is called “member of”. E.g. farmer is a member of the Constituency.

- **Class generalisation**: The process of obtaining less detailed spatial description of individual classes with common properties by merging them to higher-class levels. From bottom up the hierarchy, the relationship is called “is a”. E.g. Livestock farming is a land use type.

- **Object aggregation**: Elementary objects can be put together to build up more complex objects/classes forming an upward hierarchical relationship called “Part of”. E.g. Sesfontein constituency is part of Kunene region.

**4.3.1. Conceptual modelling**

In a GIS application, this phase involves deciding which terrain objects/features from the real world and their classification structure should be represented, the thematic, and geometric descriptions they should have in a database (Molenaar, 1998).

The conceptual model of the proposed Kunene database was used to perceive and abstract the entities that are important for land resource use/planning and the relationships among them. User data requirements, a detailed description of the data types, their relationships and cardinality constraints...
The constituency was considered to be the smallest spatial unit for which the socio-economic data is collected. It has infrastructure and several spatial units (Agro ecological zones-AEZ) for which biophysical data is collected. The land use activities are also investigated through the AEZ. The figure below represents the conceptual schema of the database.

Figure 4.4: Conceptual schema of the Kunene land resource database

4.3.2. Logical design

During this phase the conceptual model of the region database was transformed from the high-level data model and implemented using Microsoft ACCESS software.

Enterprise rules

The following rules were set up to govern the set up of the Kunene land resource database:
1. A constituency is the smallest spatial and administrative unit for land use planning
2. A constituency belongs to one region but a region can have many constituencies
3. A farmer belongs to one constituency but a constituency can have many farmers
4. A farmer can have many socio-economic data
5. A farm belongs to one farmer but a farmer can have many farms
6. A constituency can have many AEZ that can have many biophysical characteristics
7. A constituency can have many land cover/use types (LUT) that can have many land use requirements and many land use purposes

4.3.3. Mapping the conceptual design onto the physical design

This is the stage when the data is entered in the computer and the file organizations are specified. Through a relational schema, the conceptual schema above was mapped onto a relational in-
stance. The tables were normalised to eliminate repeating groups and redundancy by creating additional tables from the main entities of the basic conceptual structure. After defining the entities, their relations together with the attributes and domains as shown in the skeleton tables below, they were transformed into the ERD (Figure 4.5) developed using Ms Access DBMS.

Skeleton tables:

**CONSTITUENCY** (Const\_Name, Area, Perimeter, Num\_farmers, Tot\_Pop, Males, Females, Children, Pop\_density, Year)

**FARMER** (Farmer\_ID, Name, Const\_Name, HH\_Size, Activities, Income, Year)

**FARM** (Farm\_ID, Area, Perimeter, Owner\_ID, Const\_Name, Farm\_use, Acquisition, Acquisition\_Date, Registration)

**AEZ** (AEZ\_Code, Description, Soil\_code, Slope\_%, Rain\_range, Avg\_Rain, Evaporation, Grow\_Period, Min\_Temp, Max\_Temp, Suitable\_LU, Suit\_Class, Const\_Name)

**SOIL** (Soil\_Code, AEZ\_Code, Type, Depth, Texture, Soil\_PH, Drainage, Phys\_Description, Chem\_Description)

**LANDCOVER** (AEZ\_Code, Veg\_Cover\_Type, Dom\_Species, Veg\_Use)

**LUT** (AEZ\_Code, Present\_LUT, Requirements, Purpose, Year, Potential\_LU, Potential\_LU\_Requirements)

**INFRASTRUCTURE** (Code, Type, Name, Location, Function, Const\_Name)

**BOREHOLE** (Code, Type, C\_Date, Depth, Diameter, Status, Yield, C\_Year, L\_Stock, S\_Stock, Humans)

**WATER SOURCE** (Source\_Code, Type, Yield, Status, Yield, Status, Location, Const\_Name)
4.4. Linking the spatial and thematic database

The spatial and thematic resource data in the designed Kunene database has to be linked up for better analysis and visualization of the desired output. This link is provided by an interface with connectivity functions to other related databases. The thematic database designed in MS Access was linked up with the spatial data in Arc view GIS through the Open Data Base Connectivity (ODBC) function as illustrated below.

E.g., the theme “AEZ” in the MS Access database has the attributes of Agro ecological zones including AEZ code, growth period, soil code, etc. These attributes can be linked with the spatial data in Arc view GIS through their key identifiers e.g. with the “LAND USE POTENTIAL” map that shows the land use potential for the Agro ecological zones as shown in the graphic below.
4.5. Towards implementing the database

After inserting the correct values for the attributes in the various tables, the thematic database is ready for use to retrieve the required information. Performing queries by use of Structured Query Language (SQL) used in relational databases does this. For instance the land use planners in Kunene region may want to get information on “the functional boreholes in the region”. This information can be derived from “BOREHOLE” theme of the designed database. In the traditional analog data storage, obtaining such information from the files would take up a lot of time and in the process data may get mixed up. In the automated database, it takes a short time using the Ms Access SQL statement shown in the query below (Figure 4.8). Figure 4.9 and Figure 4.10 below show the design view and the results of the query respectively.

```
SELECT Borehole_CODE, Borehole_Type, Borehole_Depth, Borehole_Yield, Borehole_Status
FROM Borehole
WHERE ((Borehole_Status) Like "F");
```

Figure 4.8: An example of SQL query executed in Ms Access
The spatial database can also be queried to display the desired information in both map and table form. The graphic below (Figure 4.11) shows an example where the spatial database implemented in “Arc view” is queried to show areas with the potential for “Tourism (mainly eco-tourism)".
4.5.1. User interface

User interface refers to the way a computer program presents and receives information from the users in response to user request. It hides the complexity of the database, and lessens the chances of inadvertently degrading database integrity (Sondheim, M., et al., 1999). A user interface was prototyped for the Kunene database to enable users access and update the database easily. It also provides a connection to Arc View GIS application. The graphic below shows some of the forms in the database designed in edit/add mode for accessing and updating data in the database.

Figure 4.11: Arc view GIS has and supports a relational data model

Figure 4.12: Graphic of some forms for accessing and updating the database
Concluding remarks

- The database was limited by lack of sufficient data specific for Kunene region. However, it was tested with the available data e.g. as indicated in the query example in section 4.5. To be able to query the designed database for the desired output data, the right values have to be inserted in the various tables.
CHAPTER FIVE

5. APPLICATION OF GIS ANALYSIS AND MCE IN LAND USE PLANNING

5.1. Introduction

The environmental problems (see section 2.3.1) in Kunene require a collective, participatory approach of all the stakeholders including policy makers, decision makers, local farmers/pastoralists and other land users. Sustainable Land use and resource planning, together with land use diversification should be considered for some solutions. Great importance should be attached to the decisions on whether or not a particular land use system is suitable and sustainable in the region or not, recognizing the potentials and limitations of the resource base. For both non-renewable resources like minerals and renewable resources such as the rangelands and wild life, the best way and time to use them should be determined ensuring that social together with biophysical systems are maintained.

The guiding principles when planning and selecting the optimal land uses for the region should be derived from the goals and objectives of the MLRR (see section 2.3). The following attributes can be used to make decisions in this respect depending on the performance of each land use option in each of the attributes.

- Provision and maintenance of food security
- Reduction of the high environmental risk in the region. Opportunities for diversification have to be sought rather than land use intensification.
- Provision and maximization of income
- Provision and maintenance of infrastructure for land use and extension work
- Strengthening institutional capacity
- Reduction of population pressure
- Increase in employment provision
- Adherence to the conservation rules and regulations (e.g. National parks not to be developed) and land laws of land redistribution

In this chapter, the study focused on the need to assess the suitability and sustainability of the potential land use alternatives in the region. Land use suitability and sustainability assessment is undertaken in process 3 (“Land use suitability and sustainability assessment”) of the proposed system. The current land use and its characteristics are already described in section 2.3.1. GIS
(ILWIS) and Decision Support System (DSS- DEFINITE) software were used for the evaluation. The figure below is a schematic representation of how this was approached.

![Schematic diagram](image)

**Figure 5.1: Schematic summary of steps taken in land use suitability and sustainability assessment**

### 5.1.1. Data used

The input data used in this analysis are summarized in the table below.

<table>
<thead>
<tr>
<th>Input data</th>
<th>Source</th>
<th>Description/Contents</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital land use map (1998) of Kunene region</td>
<td>MLRR &amp; NRSC</td>
<td>Land use map with 12 land use classes.</td>
<td>The map was obtained in digital format in &quot;Unknown&quot; coordinate system. To be able to perform analysis like area calculations, it was re-projected from Geographic, degrees to Projection UTM, metres. The legend was edited from analog source map by the author.</td>
</tr>
<tr>
<td>Digital land use potential map (1998) of Kunene region</td>
<td>MLRR &amp; NRSC</td>
<td>Land use potential map with 7 land use classes</td>
<td>The map was obtained in digital format. It was also re-projected as above and the legend was edited from analog source map by the author.</td>
</tr>
<tr>
<td>Socio-economic data</td>
<td>NPC</td>
<td>Livestock and Human population statistics</td>
<td>Socio economic data was obtained from various sources as indicated. Most of the data available was based on approximations.</td>
</tr>
<tr>
<td></td>
<td>MLRR &amp; MAWRD reports</td>
<td>Agricultural statistics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MET</td>
<td>Wild life data</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Financial figures, etc.</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1: Summary of the data used in the analysis
5.2. Land use suitability assessment

In this section GIS analysis was used to come up with land use suitability maps for Kunene region. A qualitative land suitability evaluation was previously done for the region by the MLRR (Ministry of Lands, 1998) taking into account soils, vegetation and socio-economic factors and using Agro ecological zones as land mapping units (the details of the methodology of this evaluation were not available to this study). Land use potential was categorised into seven classes as shown in the map below (Figure 5.2) and the area available for each land use is indicated in Table 5.2. Based on this previous evaluation, further analysis and assessment was done in this study.

![Map of Kunene region showing the potential land use](image)

Figure 5.2: Map of Kunene region showing the potential land use

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Hectares ('000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agropastoralism (Large &amp; Smallstock+ Grain cropping)</td>
<td>4.17</td>
</tr>
<tr>
<td>Pastoralism (Large &amp; Smallstock)</td>
<td>15.30</td>
</tr>
<tr>
<td>Pastoralism (Smallstock &amp; Ecotourism)</td>
<td>37.32</td>
</tr>
<tr>
<td>Pastoralism (Smallstock &amp; Largestock)</td>
<td>24.06</td>
</tr>
<tr>
<td>Pastoralism (Smallstock)</td>
<td>3.79</td>
</tr>
<tr>
<td>Tourism &amp; Game (Ecotourism &amp; Non-consumptive game utilization)</td>
<td>99</td>
</tr>
<tr>
<td>Tourism (mainly Ecotourism)</td>
<td>57.88</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>143.51</strong></td>
</tr>
</tbody>
</table>

Table 5.2: Area available for each potential land use in the region
For the analysis to be manageable in this study, the land use potential map with the seven classes was reclassified into four major land use options: (“Agropastoralism”, “Ecotourism”, “Largestock” and “Smallstock pastoralism”) for assessment.

The Table below shows how the reclassification was done and the Figure 5.3 shows the reclassified output map.

<table>
<thead>
<tr>
<th>Original class</th>
<th>New class assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agropastoralism (large &amp; small stock + grain cropping)</td>
<td>Agropastoralism</td>
</tr>
<tr>
<td>Pastoralism (Large &amp; Small stock)</td>
<td>Large stock pastoralism</td>
</tr>
<tr>
<td>Pastoralism (Small &amp; Ecotourism)</td>
<td>Small stock pastoralism</td>
</tr>
<tr>
<td>Pastoralism (Small stock &amp; Large stock)</td>
<td>Small stock pastoralism</td>
</tr>
<tr>
<td>Pastoralism (Small stock)</td>
<td>Small stock pastoralism</td>
</tr>
<tr>
<td>Tourism &amp; game (Ecotourism &amp; Non-consumptive game utilization)</td>
<td>Ecotourism</td>
</tr>
<tr>
<td>Tourism (mainly Ecotourism)</td>
<td>Ecotourism</td>
</tr>
</tbody>
</table>

Table 5.3: Reclassification of the land use classes

![Reclassified land use potential map of Kunene Region](image)

Figure 5.3: Reclassified land use potential map

Below is a description of each the four major potential land use options.
1. **Agropastoralism**

In this scenario, large and small stock are reared together with grain cropping of maize, millet, sorghum plus Paprika and wheat. The crops grown are mainly rain fed but around the Sesfontein-Khowarib area, there are some small-irrigated gardens. Cropping has the least potential in the region due to shallow soils, low water holding capacity, stones, surface crusting and salinity (Talavera et al., 2000). Only in the NE part of the region in Ruacana constituency is where the land is moderately suitable (S2) for grain cropping (Ministry of Lands, 1998). Related advantages are:

- The crop component of this pastoralism system serves to increase food security. Though small quantities of grain are produced mainly for home consumption, it can go a long way to help the local people to save some income, which would otherwise be used to buy grain from shops.
- All the residues after harvesting are fed to the animals.

2. **Ecotourism**

This option is mainly Eco-tourism, together with Consumptive and Non-consumptive game utilization. It involves conservation with optimisation of benefits from wildlife species of both plants and animals. In a region where high profits and benefits from agricultural developments are not likely, long term local employment and income generation may be created through the development of conservation and tourism. The activities of the people shift from purely subsistence to include wage earning and other benefits from community-based tourism. The MET has introduced a new government policy promoting the establishment of conservancies. Related advantages include:

- It has a conservation component that is in line with government’s plan and regulations concerning protecting the fragile ecosystems and setting up of conservancies
- It creates employment for the labour force of the growing tourism industry in addition to giving skills to the people. In 1994, about 2100 people in Kunene region had jobs related to tourism (Barnes, 1995).
- Additional income is got from the sale of locally made handcrafts.
- It can make use of under utilized areas such as rock formations that cannot be used for other land uses but that can provide scenic landscapes

Shortcomings related with this option though are:

- The high conflict with other land uses including predation of livestock and destruction of crops in gardens. About 360 conflicts are reported in the region annually (Talavera et al., 2000).

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3 Conservancy is community based management, conservation and utilization of wildlife and other resources within a defined geographical area.
• The tourism component requires high investment costs to set up facilities like hotels and tour operations. Many of the local people may not afford this type of investment.

3. **Largestock pastoralism**
   This involves rearing of mainly large animals, cattle. The cultural functions attached to cattle by the different cultural groups in the region raises the value of large-stock compared to small stock (Talavera et al., 2000).
   - The main hindrance is lack of markets due to the restrictions that animals coming from North of the region cannot easily cross the veterinary cordon fence to the southern markets due to animal disease implications.

The accuracy of information related to livestock numbers is questionable as livestock move in and out of areas and farmers are reluctant to disclose how many they have (Talavera et al., 2000), but about 251,113 cattle are estimated to be in the region (DVS, 2000).

4. **Smallstock pastoralism**
   Involves rearing small stock comprising mainly goats, sheep and donkeys. The region has better potential for this option than for large-stock because of the predominance of bush over the herbaceous species over which small stock utilize 70% (Ministry of Lands, 1998). The estimated number of small stock in the region is 348,721 (DVS, 2000).

5.2.1. **Criteria/constraints for selection of each option**
   For the appraisal of these options, the following terms of reference were considered:
   - For “Agropastoralism” selection was considered only in areas where current land use is Agro-pastoralism or irrigated agriculture. Expansion of cropping is not realistic because of the water constraints and generally limited cropping tradition in the region (Ministry of Lands, 1998).
   - For “Agropastoralism”, “Large” and “Smallstock pastoralism”, selection was not considered in gazetted areas including national parks and forests, as the boundaries of these cannot be de-gazetted.
   - For “Ecotourism” selection was considered only in the areas where current land use is wildlife and national parks. Wildlife based tourism has a great potential in the region but due to space limitations and peoples’ attitude, areas without wildlife at the moment will be difficult to restock as this would require de-stocking some livestock (Ministry of Lands, 1998).

Based on the above criteria, “map calculation” and “overlay” operations involving logical and conditional statements were executed in ILWIS GIS software to obtain maps where each option should be considered for selection. The maps are shown in the figure below.
Figure 5.4: Suitable areas for the four major land use classes considered for the evaluation.

As it can be seen from the maps, some areas are suitable for more than one option e.g. the areas suitable for large stock are also suitable for small stock, so a decision had to be on which one to select for that particular area. This was done by using the “Cross” function in ILWIS which involved comparing and selecting among the land use alternatives for each area. During the comparison:

- Areas that were suitable for both “Small” and “Largestock pastoralism” were assigned to “Largestock pastoralism” because it was assumed that if such an area can support the production of grass for grazing of large stock it could as well support the growth of bush that is required for the browsing of small stock.
- Areas where “Ecotourism” was intersecting with other land use were assigned to eco-tourism because such areas are protected and cannot be converted into another use.
- Areas that were suitable for both “Agropastoralism” and “Smallstock” or “Largestock” were assigned to “Agropastoralism” because all the three classes can fit in such an area.

The output map was further over-laid and compared with the reclassified land use potential map to obtain the final land use plan map (Figure 5.5). The same procedure of crossing and comparison as explained above was used.

- Areas suitable for “Largestock” (in the output suitability map) but classified (in the reclassified land use potential map) as being best for “Smallstock” were assigned to “Smallstock pastoralism” because such an area can't be assigned a more intensive use but rather a less intensive one. “Smallstock pastoralism” is less intensive.
5.3. Land use sustainability assessment

In order to be meaningful, planning for the resources should be sustainable i.e. the land use option(s) selected for implementation should meet the needs of the present without compromising the ability of the future generations to meet their needs. After the spatial analysis of the suitability of the potential land use options in the previous section, this section looked at a thematic assessment of the sustainability of these options. Selected social and economic indicators of land use sustainability were combined into a Multi-Criteria Evaluation (MCE) by a DSS to obtain a ranking of the alternatives based on their performance in the evaluation criteria. DSS are management information systems that support decision makers e.g. planners, analysts, managers, etc in the decision making process (Sharifi, 2001). They enable the decision maker to explore the problem environment by provision of data and models appropriate to the decision and also generate and evaluate alternative solutions.

5.3.1. Concept definition

Land use sustainability

Sustainability is the concept of assessing the overall state and productive performance of an agro-ecological production system over time in a way that it meets the needs of the present without
compromising the ability of the future generations to meet their needs (Smyth & J.Dumanski, 1993).

A sustainable land use should meet the pillars of sustainable land management by combining technologies, policies and activities aimed at integrating socio-economic principles with environment concerns. These pillars include (Smyth & J.Dumanski, 1993):

- Maintaining of production/services
- Reducing the level of production risk
- Protecting the potential of natural resources and preventing degradation of soil and water quality
- Being economically viable and socially acceptable.

When considering land /resource use sustainability it is important to bear in mind that sustainability:

- Is multi-scalar in that it has temporal and spatial variations and should be considered for a stated period of time and specific spatial dimension/scale (local, regional, national or global).
- Differs in meaning among specializations or disciplines e.g. ecologists, economists, agronomists, etc, look at it with different perspective. This can be seen from the varied definitions and concepts of sustainability by different authors as identified by (Kruseman, et al., 1994) and (Zinck & A Farshad, 1995).

**Measuring land use sustainability**

Some guidelines for analysis of land use sustainability have been given by FAO (Smyth & J.Dumanski, 1993). Sustainability is complex and cannot be measured directly, therefore appropriate indicators have to be selected and used (Zinck & A Farshad, 1995). Indicators are attributes of a particular land use that affect its performance, can be predicted in connection to environmental pressures and reflect the environmental status or change in condition due to the land use. Sustainability indicators can be grouped as:

- Social
- Economic
- Environmental/ecological/land quality indicators. Land quality indicators have been placed within a policy and management context as the Pressure-state-Response framework (Pieri, et al., 1995) and in this context, they measure pressure upon the resources, the effects of such pressure on the state of the land quality and the response of society to such changes.

Criteria and thresholds have to be employed for measuring the sustainable indicators:

- **Criteria** are standards or rules that govern judgment on environmental conditions.
- **Thresholds** are levels beyond which a system undergoes significant change and the levels are no longer tolerable or acceptable.
5.3.2. Socio-economic land use sustainability indicators in Kunene region

The following socio-economic indicators were used to assess the sustainability of each of the four land use options.

i. Economic

Economic sustainability relates to the supply-and-demand mechanism that stimulates production and aims at creating a local economic system that is less demanding to the ecological sustenance of a given land use system. The following indicators can be used to evaluate economic sustainability of the land use options in the region.

• Regional government budget expenditure to support the infrastructure of a given land use e.g. for borehole construction, dip tanks, constructing cordon fences, etc and extension services like extension worker including veterinary drugs.
• Income and benefits from the products and services of the land use type. Includes the region's income, availability of markets for the produce, and employment provision.
• Local investment cost required for the land uses. Investment costs of e.g. labour and input materials e.g. drugs, (re) stocking, etc.

ii. Social

Social sustainability requires that a land use, its products and methods of production are acceptable to the people. It requires the stakeholders at the different levels of social aggregation to participate collectively with common perspectives and goals for an equitable distribution and access to the opportunities and services the land provides. Ensuring social sustainability in Kunene region requires a social framework which will create empowerment and control to the local people over the natural resource base for example by defining and ensuring rights to resources like land, water, grazing, wild life, etc. The following indicators can be used to evaluate social sustainability of the land use options in the region.

• Food security in the region. Food security includes the quantity of grain and livestock to support the human population.
• Institutional capacity of the region. Includes farmer: extension staff ratio, number of farmers'/land users' associations.
• Human and livestock population pressure on the land resources in the region
• Conflicts among livestock farmers over rangeland and water use, and over who pays for property and livestock losses caused by wild life.

The evaluation and assessment was based on the different stakeholders' preferences/priorities and terms of reference as expressed during interviews and discussions during fieldwork, and from available literature from the concerned organizations. The stakeholders were put into 2 groups according to their priorities and preferences.
- The “Public view” is the group of stakeholders with more interest and priority in the provision of social services in the region. These include MAWRD department, the regional development council and the regional land use planners.

- The “Private view” represents a group of stakeholders with more interest and priority in economic undertakings in the region. These include e.g. the conservancy committees, the farmers' associations and traders.

Tables 5.3 and 5.4 below indicate the stakeholders' priorities for selected attributes of the evaluation criteria as expressed by different actors in the region (scores 1-3, from low to high).

<table>
<thead>
<tr>
<th>Actors</th>
<th>Social sustainability</th>
<th>Economic sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Institutional capacity building</td>
<td>Food security</td>
</tr>
<tr>
<td><strong>PUBLIC VIEW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water and Rural development dept</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Regional development council</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Regional land use planners</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>PRIVATE VIEW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservancy committee</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Farmers Associations</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Traders</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 5.4: Priorities as expressed by different actors at the region level.

<table>
<thead>
<tr>
<th>Actors</th>
<th>Social Sustainability</th>
<th>Economic Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PUBLIC VIEW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water and Rural development dept</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Regional development council</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Regional land use planners</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>PRIVATE VIEW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservancy committee</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Farmers</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Traders</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 5.5: Summary of stakeholders' priorities
The figure 5.6 below shows the evaluation criteria tree and Table 5.5 summarizes the criteria and their units of evaluation.

![Evaluation Criteria Tree Diagram]

Table 5.6: Summary of the social economic indicators and their units of evaluation

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Measurement unit</th>
<th>Assessment unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ECONOMIC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Budget expenditure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilities</td>
<td>N$/yr</td>
<td>Region</td>
</tr>
<tr>
<td>Extension services</td>
<td>N$/yr</td>
<td>Region</td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region income</td>
<td>N$/yr</td>
<td>Region</td>
</tr>
<tr>
<td>Markets availability</td>
<td>Number</td>
<td>Region</td>
</tr>
<tr>
<td>Employment provision</td>
<td>Man-year</td>
<td>Region</td>
</tr>
<tr>
<td><strong>Investment cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour costs</td>
<td>N$/yr</td>
<td>Farm/establishment</td>
</tr>
<tr>
<td>Material inputs cost</td>
<td>N$/yr</td>
<td>Farm/establishment</td>
</tr>
<tr>
<td><strong>SOCIAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional capacity</td>
<td>Number</td>
<td>Region</td>
</tr>
<tr>
<td>No. of farmers /land users associations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock/Animal: People ratio</td>
<td>Animals/person/year</td>
<td>Region</td>
</tr>
<tr>
<td>Quantity of grain: People ratio</td>
<td>Kg/person/year</td>
<td>Region</td>
</tr>
<tr>
<td>Population pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock/Animal: Land</td>
<td>Livestock/Sq km</td>
<td>Region</td>
</tr>
<tr>
<td>No. Of Conflicts</td>
<td>No./yr</td>
<td>Region</td>
</tr>
</tbody>
</table>

Table 5.6: Summary of the social economic indicators and their units of evaluation
Sufficient actual data for Kunene region was not available for the evaluation therefore (-/+++) scales/units and scores for some of the evaluation criteria were used. In such a case the scores were assigned on this basis depending on whether the alternative land use is assumed to score very low (-), low (+), high (+++) or very high (++++) for a given evaluation criterion. The figures used for the evaluation attributes were approximate figures derived from various sources and literature including (NPC, 1999/2000, Talavera et al., 2000, Barnes, 1995, Ministry of Lands, 1998). The criteria were then combined in a multi criteria evaluation of the sustainability of the land use alternatives. This involved assigning scores to each land use alternative in a given evaluation criterion.

5.3.3. Standardizing the scores and weighting of the Criteria

During the evaluation, standardization was done due variations in the scales used. Maximum standardization was used because there was no sufficient data for the evaluation criteria, so the standard was set between the minimum and maximum scores of the criteria.

For the generation of the weights for the criteria, “Weighted summation” and “Pair wise comparison” methods were used. Pair wise comparison was used because it is based on the principle of relative importance of the evaluation criteria, which is also reflected in the stakeholders’ preferences.

5.3.4. Evaluation based on the “Public view”

Based on the “Public view”, social sustainability is more important and was given more weight (0.75) as compared to economic sustainability (0.25). The table below shows the standardized score matrix based on this “view”.

![Figure 5.7: Standardized effects table based on the “Public view”](image)

Beatrice N. Nabwine, ITC, Enschede, March 2002
Ranking
After the assignment of weights, the alternative land uses were ranked according to their performance in the criteria. The alternative that scored highest was ranked in the first position. This was “Agropastoralism” followed by “Largestock pastoralism, then “Smallstock pastoralism”. “Ecotourism” ranked last. The results of this ranking are shown in Figure 5.8 below. This graph also shows the relative performance of each alternative in each group of evaluation criteria. E.g. “Ecotourism” scored highly in economic criteria (0.93) but scored low in social criteria (0.29). The ranking of the alternatives depends on the stakeholders’ priorities that are reflected when assigning weights to the criteria.

Figure 5.8: Ranking of the alternatives based on the “Public view”

5.3.5. Uncertainty and Sensitivity analysis
During the evaluation there was inadequate information on the aspects of the decision problem that could have caused uncertainties in the priorities, criteria, and assessment methods. Uncertainties in the evaluation were determined by performing sensitivity analyses. Sensitivity analysis shows how a change in one criterion score influences the final result of the evaluation. It includes:

- Weight sensitivity analysis; sensitivity is performed on the reliability of assigning weights to the criteria.
Score sensitivity analysis; sensitivity is performed on the reliability of assigning scores to the criteria for each alternative

After the ranking of the alternatives, a sensitivity analysis was performed for each “view” to determine the reliability of the results of the ranking. Figure 5.9 below shows the results of sensitivity analysis on the weight (0.75) assigned to social criteria for the “public view”. The graph shows that “Agropastoralism” ranks in the first position if the weight given to social criteria is above 0.67. With the weight between 0.39 and 0.67, “Largestock pastoralism” is the best option. And if the weight is lowered further below 0.39, then “Ecotourism” becomes the best option. This means that the result of the ranking is reliable as long as the weight assigned to the social criteria is above 0.67.

Figure 5.9: Sensitivity analysis for weight (0.75) assigned to social criteria based on “Public view”

5.3.6. Evaluation based on the “Private view”

The “Private view” regards economic sustainability in the region as priority compared to the social sustainability. The table below shows the score matrix based on this “view”.
Figure 5.10: Standardized effects table based on the “Private view”

Ranking
Evaluating the alternatives based on the “Private view” ranked “Ecotourism” in the first position followed by “Largestock pastoralism”, then “Smallstock pastoralism”. “Agropastoralism” was ranked last because although it performed well in the social criteria (0.74) it did poorly in the economic criteria (0.42).

Figure 5.11: Ranking of the alternatives based on the “Private view”
Sensitivity analysis
A sensitivity analysis was also performed for this “view” for the weight (0.75) assigned to the economic criteria. This showed that “Ecotourism” ranks in the first position as long as the weight given to economic criteria is above 0.66. If the assigned weight is between 0.35 and 0.66, then “Large-stock pastoralism” ranks first. Assigning a weight less than 0.33 makes “Agropastoralism” to become the best option.

Figure 5.12: Sensitivity analysis for Weight (0.75) assigned to economic criteria based on “Private view”

Concluding remarks
- Because of lack of adequate data specific for Kunene region, many assumptions and approximations were made in the analysis and therefore the results are not conclusive and may not reflect the actual situation in the region. However, the analysis demonstrates the application of GIS and DSS tools in land resource analysis for land use planning and other applications.
- The “DEFINITE” software that was used as a DSS has the capability of allowing the combination of various criteria for evaluation and also under different opinions or priorities. This can allow for comparisons of results. It also allows sensitivity analysis in case of uncertainties in the priorities and performance scores of the alternatives in the different criteria.
6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The general objective of the study was to design a prototype information system that can integrate spatial and thematic data to provide key information necessary for decision-making in land use planning and natural resource management issues for Kunene region.

- The existing institutional framework for land use planning and natural resource management in the region was analysed and several stakeholders were identified, the main ones being the MLRR, MAWRD and the MET.
- The study revealed that the region is faced with a number of environmental and resource problems that the MLRR and other key sectors are trying to address. For this purpose they need and use land resource data. However, they are faced with data and information constraints that affect optimal land resource analysis. These were highlighted in section 2.4.3.
- The study attempted to address some of the constraints by suggesting a number of ideas and designing an information system and database structure. These are generally dealt with in chapters three and four.
- A user interface was also designed for the database to enable the users to access and update data easily.
- The relationship between the land use-planning frameworks at the local level (Sesfontein constituency) with that of the regional level (Kunene region) was compared and assessed and a way of integrating planning processes at both levels for better decision-making was suggested.
- Some analytical tools were applied to assess the suitability and sustainability of the potential land use alternatives in the region.
  - Suitability assessment was based on the land use potential of the region and selected suitability criteria. The analysis came up with a land use allocation plan map suggesting areas where particular land use alternatives may be allocated. The analysis revealed that much of the region is suitable for Smallstock pastoralism.
  - Land use sustainability assessment was based on a multi-criteria evaluation of social and economic indicators of the potential land use alternatives in the region. From the "social point of view" of the analysis, Agropastoralism was ranked as the most sustainable and the least was Ecotourism. From the "economic point of view", Ecotourism was ranked as most sustainable and least was Agropastoralism.
6.2. **Recommendations**

In order to improve the current situation in the region, the following propositions are made:

- Cooperation among the organizations and all stakeholders should be encouraged because the problems of land use planning and resource management are diverse in nature requiring multidisciplinary and combined effort from all concerned. The participation of farmers/pastoralists and other land users in the planning processes should be encouraged and the regional land use planners should try to incorporate indigenous knowledge into the planning and management of the resources.

- Communication and information flow among the stakeholders should be encouraged. The products from the system should be disseminated to the end users for example by extension services, workshops, reports and Internet.

- Data sharing among various organizations will not only strengthen the cooperation but will also reduce data redundancy, duplication and costs incurred in data collection and processing. Data sharing necessitates proper data documentation, quality control mechanisms and streamlining data sharing procedures.

- Expansion of infrastructure in terms of computer hardware and field data collection tools, exploration of more analytical software and tools, together with staff training will enable effective information/data analysis for sustainable planning and management of the natural resources in the region.
References
Appendices