1

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service

Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

Si il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, S.R.C. 1970, c. C-30, et ses amendements subséquents.

INVESTIGATING
THE APPLICABILITY OF GEOGRAPHIC INFORMATION SYSTEMS (GIS)
TECHNOLOGY TO RURAL DEVELOPMENT PLANNING IN KENYA

by

BENJAMIN NJORE MWASI, B.Sc(Hons)

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirement for the degree of

Master of Arts

Department of Geography

Carleton University

Ottawa, Ontario

November 1990

Copyright Benjamin N. Mwasi 1989

National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service Service des thèses canadiennes

OTTAWA, Canada
K1A 0N4

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-68839-4

Carleton University
Ottawa, Canada K1S 5B6

This thesis contains coloured
photographs and/or explanatory tables
which when microfilmed may lose their
significance. The hardcopy of the
thesis is available upon request from
Carleton University Library.

The undersigned recommend to
The Faculty of Graduate Studies and Research
acceptance of the thesis

Investigating The Applicability of Geographic Information
Systems Technology To Rural Development Planning In Kenya

submitted by
Benjamin Njore Mwasi, B.Sc (Hons.)
in partial fulfilment of the requirements for
the degree of Master of Arts

Thesis Supervisor

Chair, Department of Geography

Carleton University

October 25, 1990

ABSTRACT

The study looks into the applicability and the suitability of GIS technology to Integrated Spatial Planning as a means of facilitating rural development in Kenya. The objectives of rural development are identified and various strategies for achieving them discussed. The study emphasises the need for developing integrated systems of settlements as one of the prerequisites for rapid rural development. Data requirements for decentralized rural planning are identified and a framework for developing an appropriate database suggested. Possible GIS analyses relevant to the subject are discussed and examples given using SPANS software. The study concludes that rural development planning is a complex problem which can greatly benefit from the integration and analysis features of GIS technology. However for these benefits to be exploited effectively, a comprehensive database must be established and a multi-disciplinary planning team is required.

ACKNOWLEDGEMENTS

It is impossible to mention everybody who in one way or another helped in making this project a reality. There are, however, some who have contributed considerable time and expertise towards this research whom I would like to thank directly.

First, I would like to thank my supervisor Professor D.R.F Taylor for his assistance and guidance throughout the entire project. I feel indebted to Professor Mike Fox who rigorously read my work and pointed out many ambiguities I would otherwise never have noticed. My sincere gratitude is also extended to Professor Fiona Mackenzie for her willingness to discuss and criticize my work, from which I in deed benefited. My acknowledgements will be incomplete without mentioning Mr. Steve Prashker who introduced me to computer mapping and tirelessly worked with me throughout the, sometimes frustrating, process of applying this knowledge.

I would also like to thank my sponsors, Canadian International Development Agency (CIDA) and the Kenya Government, for making my study possible. Thanks to the people at the Kenya Embassy in Ottawa for their support.

To all others, I say thanks for whatever support they provided academic, moral or emotional. Last, but by no means least, I wish to thank my family and friends in Kenya for bearing with me.

TABLE OF CONTENTS

	Page
Acceptance Sheet.....	ii
Abstract.....	iii
Acknowledgement.....	iv
Table of Contents.....	v
List of Tables.....	vii
List of Figures	viii
List of Maps.....	ix
 CHAPTER 1: INTRODUCTION	 1
1.1 Background.....	1
1.2 Aims of The Study.....	2
1.3 Scope of The Problem.....	4
1.4 Concepts of GIS.....	9
1.5 GIS and Planning.....	10
1.6 Research Methodology.....	12
1.7 The SPANS System.....	18
1.9 Research Organization.....	18
 CHAPTER 2: RURAL DEVELOPMENT PLANNING.....	 20
2.1 Introduction.....	20
2.2 Decentralization and Multi-Level Planning....	21
2.3 Integrated Planning Approach.....	24
2.4 Local Participation.....	26
2.5 Rural Development Planning in Kenya.....	27
2.6 District Focus for Rural Development.....	31
2.7 Rural Development Policy.....	35
2.8 Conclusions.....	38
 CHAPTER 3: INTEGRATED SPATIAL DEVELOPMENT PLANNING	 42
3.1 Introduction	42
3.2 The Concept	43
3.3 The Planning Process	46
3.4 Land-use Planning	48
3.5 Resource Management	53
3.6 Settlement systems	56
3.7 Spatial Linkages	59
3.8 Conclusions	63

CHAPTER 4: DATABASE DEVELOPMENT	65
4.1 Introduction	65
4.2 Database Concepts	66
4.3 Data Collection and Data Capture	67
4.4 Database Creation	68
4.5 Data Quality	71
4.6 Data Requirements	78
4.7 Conclusions	95
CHAPTER 5: DATA ANALYSIS TECHNIQUES.....	97
5.1 Introduction	97
5.2 The Spatial Analysis Process	98
5.3 Land-Use Analysis	99
5.4 Resource Analysis	119
5.5 Settlement Systems Analysis	125
5.6 Spatial Linkages Analysis	133
5.7 Conclusion	137
CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS.....	139
6.1 Observations and Conclusions	139
6.3 Prospects for Implementation	141
6.4 Recommendations	143
REFERENCES	145

LIST OF TABLES

Table 4.1 GIS Data Forms.....	68
Table 4.2 Data Capturing Techniques.....	68
Table 4.3 Common Sources of Errors Encountered in Using GIS	78
Table 5.1 Indexing Overlay Input File	110
Table 5.2 Area Analysis: Cross-Tabulation	112
Table 5.3 Area Analysis: Single Map	130

LIST OF FIGURES

Fig.1.1 GIS Project Implementation	15
Fig.2.1 The Mall Project Cycle	34
Fig.3.1 Components of Rural Development Planning	48
Fig.4.1 Levels of Data Abstraction	69
Fig.4.2 Integrated Resource Concept of a Region.....	70
Fig.4.3 A Hierarchy of Needs for Modelling Error in GIS.....	73
Fig.5.1 The Analysis Process	99
Fig.5.2 Querying Quadtree Classes	127
Fig.5.3 Neighbourhood Calculation	132

LIST OF MAPS

Map 1.1 Kenya: Administrative Boundaries.....	6
Map 1.2 Taita: Administrative Boundaries	8
Map 5.1 Annual Rainfall (Contour)	103
Map 5.2 Annual Rainfall (Potmap)	103
Map 5.3 Slope Map	105
Map 5.4 Aspect Map	105
Map 5.5 Maize Cultivation Suitability Map	113
Map 5.6 Divisional Boundaries	113
Map 5.7 Temperature/Rainfall Ratio	118
Map 5.8 Altitude Zones	118
Map 5.9 Urban (Service) Centres	131
Map 5.10 Proximity To service Centres	131

CHAPTER 1

INTRODUCTION

1.1 Background

More than three quarters of the Kenyan population live in the rural areas. These areas produce the bulk of food, most of the nation's exports and many of the raw materials needed by the industrial sector. Compared to urban areas, living standards in these areas have tended to be lower in terms of quality and quantity of socio-economic services and infrastructure facilities available. This has greatly contributed to the migration of large numbers, often of the most productive people, into the urban areas, draining the rural areas of their productive capacity. There also exists a large inter-regional disparity in living standards and levels of development. These problems are further exacerbated by rapid population growth (estimated at 3.9 per cent per annum) and the increase in environmental degradation due to excessive or improper resource extraction. In spite of these problems, the rural production sector still forms the largest component of the private sector activity and it will therefore remain the focal point of national development strategy for years to come (Government of Kenya, 1982).

Rural development is concerned with improving the production, distribution and consumption of natural and socio-economic resources. The main goal of rural development planning is therefore the realization and maintenance of an equilibrium between socio-economic and ecological systems (Ahmad and Muller, 1982). To achieve this goal, it is necessary to identify and if possible quantify the complex relationships and mutual effects of the various elements of the environment and analyze them within a common framework. Such a framework, it is argued, could be provided by information systems.

Information systems are defined as "mechanisms for regularly collecting, analyzing and using relevant information as a basis for making decisions on actions to take" (Gecola, 1988: 424). These systems are designed to supply decision makers with information necessary for taking rational decisions. Their overall function is to transform data systematically into reliable information and to present this information to decision makers in easily discernible forms. Information systems provide an integrative framework for multidisciplinary data analysis and hence a basis for more comprehensive decision making (Nijkamp and Rietveld, 1984).

1.2 Aims of The Study

The aim of this study is to investigate the applicability and suitability of using geographic information systems (GIS) technology as a tool for integrated rural development planning

in Kenya. Geographic Information Systems are defined as systems designed to capture, store, retrieve, analyze and display data that are referenced to geographic locations.

The study will address the following specific objectives:

- 1) Identify the various components of integrated rural development planning.
- 2) Identify and organize the relevant data required for rural development planning using a GIS.
- 3) Describe the various analyses necessary to convert the data identified above into information that can assist planners and policy makers in policy formulation.
- 4) Demonstrate with examples how the GIS technology can be used in the planning process.

Rapid and more uniform development in the rural areas can be facilitated by efficient planning and management of both bio-physical and socio-economic resources. The central argument of this study is that, if the supporting structures, i.e. political and administrative structures are available, then geographic information systems technology provides an efficient tool for planning and managing bio-physical and socio-economic resources. This argument is based on the fact that the GIS technology provides an effective means for integrating and analyzing data from diverse sources upon which decisions regarding rural investment can be made.

It is assumed in this study that rural development can be, and is in fact being planned in Kenya, or at least

attempts to do so are being made. The study will attempt to match the planning policy as formulated by the government with the available technology. Evaluation of Government policies for rural development is not within the framework of this study.

1.3 Scope of The Problem

The study recognizes the broad and sophisticated nature of rural development planning. Rural planning activities include problem identification; data collection and analysis; solution generation; and project implementation and management. The issues dealt with range from economic planning, provision of services/facilities and environmental conservation. To pursue the objectives of rural development, good understanding of the various components of the spatial system and a means of dealing with them in a holistic manner are required. The potentials and the limitations of the bio-physical and socio-economic systems must be recognized, and all planning and decision making should take into account the mutual relations and inter-dependencies existing between and among these components. Rural development planning is a multi-disciplinary problem which demands an integrated approach. To this end, GIS technology will:

- 1) Provide a framework for multiple data integration, processing and analysis;
- 2) Enable planners and policy-makers, and to a certain degree members of the public, to gain access to data and

information more easily;

- 3) Help to bridge the communication gap existing between the various disciplines involved with development planning and implementation;
- 4) Facilitate cheaper and faster reproduction of spatially referenced information such as maps and statistical data relevant for planning and policy formulation; and
- 5) Cut down the time required to train planners by providing user-friendly systems which allow moderately trained planners to perform complicated data analyses.

For general administrative purposes Kenya is divided into eight provinces and forty-one districts (Map 1.1).

Each district is further divided into divisions, locations and sub-locations. The numbers and sizes of these sub-divisions are determined by either geographic, ethnic or economic characteristics. The study adopts a district as a planning unit for two reasons. Data collection and storage is done in terms of these administrative sub-divisions thereby making them appropriate planning units. Second, according to the present government policy, a district has been made the main unit of planning and administration for rural development.

Map 1.1

KENYA: ADMINISTRATIVE BOUNDARIES

Source: Government of Kenya (1989)

Produced on MIGS
Department of Geography
Carleton University

This research is not a case study. Data limitations and the need for teamwork in designing a true rural development planning project made it impossible to use the case study approach. However, for illustrative purposes, data from Taita-Taveta District will be used where possible. The choice of this area is based on my detailed knowledge of the area which is my home district. Another advantage of this area as a study case for rural development planning is its wide variety of bio-physical and socio-economic conditions typical of rural areas of Kenya including uneven distribution of population, natural resources and facilities, lack of industrial or other employment generating activities, and dependency on subsistence land-use activities.

Taita-Taveta district is bounded by the latitudes $2^{\circ} 45'$ and $4^{\circ} 05'$ South and longitudes $37^{\circ} 35'$ and $39^{\circ} 10'$ East. The district has a total area of approximately 16,975 sq. km. of which 16 sq. km. is covered by water (lakes Jipe and Chala), and 10,500 sq. km. (62 per cent) is occupied by National Parks. Administratively, the district is divided into four divisions and fourteen locations (Map 1.2). The estimated population in 1988 was 208,914 (Government of Kenya, 1989).

Map 1.2
TAITA: ADMINISTRATIVE BOUNDARIES

0 10 20 30
KILOMETRES

- 1 Werugha
- 2 Mbale
- 3 Ronge
- Divisional Boundary
- Locational

Source: Government of Kenya (1989)

Produced on MIGS
Department of Geography
Carleton University

1.4 Concepts of Geographic Information Systems

Geographic information systems are characterized by four functional components: data input, data management, data manipulation and analysis and data output. Computer-based GISs provide many advantages over manual systems including capacity to handle large volumes of data faster and more accurately, easy data access and update, and flexibility of output.

Information about geographic phenomena is made up of four major components (Aronoff, 1989): its geographic location, its attributes or characteristics, its spatial relationships to other objects and a temporal element. Simply stated, these components specify the location of the phenomenon, its identity or characteristics, how it relates to its spatial neighbours and the time period at which this condition or feature existed. Geographic information systems derive their power from their ability to integrate diverse data sets that previously could not be analyzed together. The ability of GISs to manipulate the spatial and attribute components together in answering queries, distinguishes them from thematic mapping packages which can only manipulate attribute data (Burrough, 1986). GIS packages thus combine powerful data storage and analysis facilities with the graphic display capabilities found in computer-aided design (CAD) systems (Klosterman, 1988). Incorporating the time element adds utility to data; however this also increases data complexity making it more difficult to handle. Consequently, the time factor has not

been addressed in detail in GIS development (Aronoff, 1989). But, given that data update is technically very easy in a GIS, temporal accuracy of information can still be maintained.

Efficiency and flexibility in data storage and access in GIS is facilitated by the database management concept. A database is a collection of information about things and their relationships to each other. These data are managed and manipulated by a set of programs referred to as database management systems (DBMS) (Litton, 1987). The advantages of database approach over purely digital filing include centralized data control, reduced redundancy, data independency, data integrity, query flexibility and shared data access (Date, 1987; Litton, 1987 and Aronoff, 1989).

1.5 Geographic Information Systems in Planning

The importance of maps and geographically referenced data for planning and routine managerial tasks has been recognized by many organizations. Geographic information systems have supported these applications by processing the necessary data efficiently and presenting the resulting information in easily discernible formats. Many GIS packages have been developed, some for specific applications such as the TIGER System for U.S census analysis and others for more general uses such as ARC/INFO, SPANS and PAMAP to name a few. Aronoff (1989) gives a summary of the range of applications to which GIS technology is being applied including agriculture and land-use planning, forest and wildlife management, geology, municipal and urban

planning, and environmental monitoring and management.

The application of information systems to urban and regional planning in developing countries has been a subject of interest at the United Nations Centre for Regional Development (UNCRD, 1986 and UNCRD, 1988). The subject has also been investigated by Nijkamp and Rietveld (1984); Giaoutzi and Nijkamp (1988); Yapa (1988), among others.

In general, the advent of computer-based information systems has made it much easier for planners to collect, process, analyze and distribute information. However, as Sazanami (1986) noted, implementation of computer-based systems in developing countries has been constrained by, among other things, lack of funds and technical know-how, poor communication infrastructure and lack of organizational structures to support their application. The use of geographic information systems is in general growing rapidly and it is believed this will extend to the developing countries. This rapid growth can be attributed mainly to two reasons. First, development within the GIS field is continuing rapidly with more general application systems being produced. The increasing availability of general application systems in the market is changing the process of GIS application from one of costly system design to one in which users select systems or a combination of systems that best meet their needs (Guptill, 1989). Second, the availability of powerful micro-computers and the subsequent development of micro-based GIS have greatly

contributed to the rapid growth of GIS applications. Klosterman (1988) reviews the prospects and challenges of micro-computer technology in regional planning. He identifies four features which make micro-computers suitable for developing countries. First, they are easy to maintain. Unlike mainframe computers, which require controlled environments such as air-conditioning, micros can operate in ordinary room conditions and can be serviced in developing countries. Second, micros are relatively easy to use. Third, microcomputers are highly adaptable and can be used with many software packages. Finally, microcomputers are relatively cheap and their costs are increasingly going down relative to the increasing speeds and memory capacities. Constraints such as power supply and high maintenance costs (servicing and spare parts) are still to be overcome.

1.6 Research Methodology

Geographic information systems are tools for solving specific problems. The efficiency with which they can do this depends on how well the system is matched with the problem. GIS project implementation thus involves defining the problem and selecting the best system for solving it. There are three possible approaches for GIS project implementation.

The first potential approach, and perhaps the most ideal, involves designing a GIS package to solve the identified problem. The advantage of this approach is that the functions and other technical specifications are tailored to suit the

identified problem. This approach is however expensive and time consuming, besides requiring expertise in software development. Alternatively, one can test the suitability of several GIS packages in solving the identified problem. Tomlinson and Boyle (1981) used this approach on behalf of the Saskatchewan Department of Tourism and Natural Resources to decide on which GIS to acquire for handling forest resource data. Among the characteristics tested in this approach are the technical capability, reliability, ease of use, data handling ability and cost-effectiveness. This is a very effective approach from a buyer's point of view, the only drawback being the difficulty of gaining unlimited access to many GIS packages prior to purchasing them.

The third possible approach, which will be used in this study, involves designing pilot projects to test the ability of the technology to meet specific user's operating needs using any GIS package. This approach tests the ability of the technology in general rather than testing the capability of any specific system. Pilot projects provide realistic information on data needs, production rates, memory and storage requirements, human interface functionality and user response to GIS products (Goodchild and Rizzo, 1987). The SPANS software from TYDAC Technologies was used in this study.

A standard GIS project implementation process consists of four main stages namely: problem definition or user needs assessment, data collection, database/model base development, and finally the physical project implementation (Dangermond et al., 1982 and Litton, 1987). These stages are summarized in Fig.1.1 below.

The process begins with a user requirements analysis (URA) which involves a detailed study of the needs of potential system users. A URA should identify the types and availability of data required to meet the defined objectives and the institutional organization existing to support the attainment of these goals (Guptill, 1988). The URA is a very important stage in project implementation since development of a successful GIS depends on how well the user requirements are defined.

Fig.1.1 GIS Project Implementation

Ideally a URA should be carried out in two complementary stages consisting of physical interaction between project implementers and the users (through meetings and interviews) and a review of documents outlining the functions and mandates of the key users of the system. For this study it was not possible to carry out the first task. User needs were therefore derived from Government Planning and Policy documents and from my personal experiences. The URA process is expected to produce details about end products characteristics such as information content, output format and frequency, and the expected accuracies.

After deciding on the types of information required, the next task is to determine and collect the data required for project implementation. In practice, both primary and secondary data collecting processes may be necessary. Secondary data collection involves data extraction from already existing data sources such as maps, aerial photographs, satellite images, reports and charts. In most cases data required for GIS projects can be obtained this way. Primary data collection becomes necessary to fill in gaps where required data are not available. No primary data were collected for this study.

The third stage involves database and model base creation. GIS applications require two separate databases i.e. the spatial database and the attribute database. Spatial data define the geographical location and can be obtained in either analog or digital form. Analog data from maps and aerial photographs must be 'captured' into the GIS by either digitizing or scanning. The TYDIG digitizing module from TYDAC was used to convert analog spatial data into digital form. Digital data can be obtained directly from digital data collecting devices such as satellite remote sensing or by importing digital maps from other GISs. No such data were available for the study area. The second part of the database contains the information which describes or classifies the spatial data. This is commonly referred to as attribute data. Most GISs manage their attribute data externally through an

interface with a database management system. Some systems, including SPANS, manage their attribute data internally. A GIS survey conducted in 1989 showed that over 75 per cent of the systems reviewed used external database managers (Parker, 1989). Attribute data are entered into the system either through the keyboard or imported as a digital file from other database systems. In this study attribute data were entered directly from the keyboard.

After the database has been created the next stage of database development is the creation of the model base which links the user and the database. This is done by translating user requirements or queries into equations capable of transforming the raw data in the database into useful information. These links might be conceptual relationships supported by previous studies or specific mathematical formulae that have been tested and proved.

The final stage of the project is the actual implementation of the database/model base using a specific GIS software and displaying the results. These results are then passed on to planners and policy makers for use in decision making. Results consist of maps and other graphics (histograms and pie-charts) and statistical reports. In this study the SPatial ANalysis System (SPANS) from TYDAC will be used for implementing the pilot database.

1.7 The SPANS System

SPANS is a raster-based GIS designed for a PC environment. The system accepts vector digital data from a digitizer (TYDIG module) which it converts to internal raster data based on the quadtree data structure. SPANS also accepts processed digital remote sensing imagery which is also converted into the internal quadtree structure. Several data interchanges are supported for both import and export of data to other systems such as Intergraph and Arc/Info GISs.

SPANS accepts attribute data in any form of an ASCII file. Attribute data can therefore be imported into the system from any commercial database system or a spread sheet. Direct attribute data entry can be done through any text editor. The system is provided with the Q Edit for this purpose.

The software runs on any IBM compatible with a 808286 chip or higher and a math co-processor. A minimum of 30Mb of memory are required and the IBM PC-DOS 3.0 version and up or the more powerful IBM OS-2 operating environment. A full range (raster and vector) graphics video card is required.

1.8 Research Organization

The rest of the study is organized into five chapters as follows. The next chapter discusses the issues and trends of rural development. The District Focus for Rural Development (DFRD) strategy for rural development planning in Kenya is also discussed. Chapter three introduces the concept of integrated spatial development planning. The second part

defines the rural development problem. The various sub-systems of rural development planning are presented in the final part of this chapter. Chapter four looks into the problem of database development. The chapter begins by discussing the database concept and the issues of data quality in general. The second half of the chapter identifies some of the data types needed in rural development planning and suggests a framework for organizing these data into a database. Spatial data analysis is the subject of the fifth chapter. This chapter discusses the processes and techniques available for solving some rural development-related problems using the GIS technology. Where data and system capability allow, examples are given using the SPANS system. Conclusions of the study are given in chapter six.

CHAPTER 2

RURAL DEVELOPMENT PLANNING

2.1 Introduction

During the last three decades development planning policies, particularly in the developing countries, have shifted from a growth-oriented paradigm to one based on growth with equity (Sundaram, 1988). Governments are attempting to institute programs aimed at spreading development benefits equitably throughout their national territories and in building the asset base in rural areas to ensure more effective use of resources and a more equitable distribution of the accruing benefits. Implementation of such policies and programmes has necessitated some changes in the structure and approach to planning.

First, it has become necessary to shift from a centralized to a decentralized approach to planning. Second, the need to adopt an integrated approach to planning is increasingly being advocated. Finally, governments and international aid agencies have recognized the need for local public participation in the planning process. For development projects to be successful, local people should have a major role in their planning and implementation. Planners can no longer ignore indigenous knowledge and regard local people as

incapable of devising strategies for their own development (Chambers, 1988; McCall, 1988; Mussa-Nda, 1988). This chapter discusses the issues and trends of rural development planning in general and specifically how they have evolved into the current planning process in Kenya.

2.2 Decentralization and Multilevel Planning

Central planning and administration were introduced in most developing countries on the grounds that they provided a rational and coherent framework for policy making for the effective use of scarce resources to promote rapid economic growth. However, many years of experience have indicated the contrary. Economic growth in most developing countries has remained sluggish, and where there was any growth, income disparities between the rich and the poor and among regions has widened, and the number of people living in absolute poverty has increased (Cheema and Rondinelli, 1983). Efforts to reverse this situation have led to the introduction of decentralization policies.

The term decentralization means different things to different people. Four major forms of decentralization are identified based on the extent to which authority to plan, decide and manage is transferred from the central government to other organizations. These forms of decentralization are: (a) de-concentration of functions to district offices within the same ministerial lines; (b) delegation of decision making authority for specific functions to semi-autonomous or

parastatal agencies; (c) devolution of central government functions to local governments; and (d) the transfer of functions from public to voluntary, private or non-governmental organizations (Minerbi, 1988; Cheema and Rondinelli, 1983). A greater degree of territorial (as opposed to functional) decentralization can be achieved in 'devolution' in which authority for a range of functions is transferred to local governments (Yapa, 1988). Conyers (1986) has argued that most or all of the existing examples of decentralization in Africa and Asia are quite limited and that they properly fall in the category of 'de-concentration'.

Despite the strong arguments put for decentralization (Cheema and Rondinelli, 1983 pp.14-17), the implementation of such policies and programmes in the developing countries has been hindered by several factors. First, little attention has been given to identifying the appropriate functions that can and should be decentralized, or to the obstacles to implementing decentralization policies and programmes. Second, local administrative organizations are often given powers to perform development planning and management functions without adequate financial resources and qualified personnel to carry out these tasks. Third, in the attempt to minimize political conflicts, governments tend to discourage the growth of community and non-governmental organizations needed to support and carry out decentralization policies. Finally, sometimes innovative programmes are created without linking them to

established organizations and sources of political and financial support.

The implications and challenges of decentralization for the planning process are discussed by Sundaram (1988). First, decentralization leads to a tremendous increase in the amount and type of data to be collected and analyzed. Comprehensive databases containing information on various socio-economic aspects of rural life have to be developed at different spatial and administrative levels. This will lead to an increase in data volumes which will require efficient and more complicated data processing methods. Second, multi-level planning requires coordination and a smooth flow of data and information in both vertical and horizontal directions. The expeditious flow of data is necessary to ensure consistency and complementarity in decision making at all levels. Third, competent personnel and administrative structures should exist to match the data levels. Fourth, for planners at different levels and from different regions to be able to communicate and act consistently, there should exist clear planning models and theories besides techniques and tools for handling large volumes of data. At present there seem to be insufficient data and no adequate models to analyze the causes of, and define the cures for, rural underdevelopment (Klosterman, 1988). Effective implementation of decentralization programmes requires a combination of central control and local autonomy.

This balance of power between central and local organizations can be attained through an integrated approach to planning.

2.3 Integrated Planning Approach

To some planners, integration means "Let's take a broader view, taking more factors into account in the planning process and the decision equation, try to satisfy a wider range of needs and values, and do all this in a way that works - that produces needed action, not just plans" (Lang, 1988:81).

Ahmad and Muller (1982) identify some of the objectives sought by integrated planning as follows: 1) to provide an equitable balance between different, sometimes conflicting interests and objectives; 2) to secure an efficient use of resources by increasing the rationality of the planning process; 3) to achieve socially-acceptable decisions by encouraging public participation in the decision making process; 4) to promote fuller consideration of alternatives by widening the number of factors considered; 5) to increase efficiency through a more coherent approach to policy making; and 6) to take into account uncertainty by providing for flexibility and continuity in the planning process.

While it is relatively easy to recognize the need for and conceptualize integrated planning, it is very difficult to define, design and implement a model for it. Minerbi (1986) and Ahmad and Muller (1982) suggest some of the components necessary for developing and implementing integrated planning. First, the main subsystems involved and

their inter-dependencies need be identified. Comprehensive databases should then be developed for each of these subsystems in a manner allowing a free flow of data and information within the entire system as a whole.

The second prerequisite for integrated planning is communication. There must be an adequate and effective two-way communication among each sector concerned and across each level of planning involved. All actors must be able to submit their input and effectively obtain access to other inputs throughout each phase of project planning and implementation. This two-way data propagation requires adequate and reliable communication infrastructure and it ensures coordination and cooperation through free exchange of information, data and ideas. Extension of this communication to the public at large, will greatly facilitate popular participation.

Third, there should be a monitoring process so that policies, priorities, decisions and techniques applied can be examined and changed where necessary based on feedback experience or public desires. Finally, the planning approach should be flexible, to be able to take into account the dynamic nature of society. New social objectives, technological innovations and the need to cater for increasing number of people should be easily incorporated into the planning system. The need for responding to feedback from the public leads us to the third and final component of the new approach to planning i.e. local participation.

2.4 Local Participation

Participation is increasingly being accepted as a major input to development. This fact is reflected by the frequency of its reference in official policies and debates on development. Unfortunately, like most terminologies in the field of development, there seems to be a great deal of misunderstanding and confusion about its meaning and objectives and approaches to its promotion (Oakley and Marsden, 1984; McCall, 1988; Goulet, 1989). While most people agree that increased local participation is beneficial to rural development, few would agree on what the term "participation" means, and even fewer on the tactics to adopt in implementing the strategy.

Broadly, participation can be seen as a means for a widening and redistributing opportunities to take part in societal decision-making, in contributing to development and in benefiting from its fruits (Oakley and Marsden, 1984:18). Two extreme interpretations of this broad meaning of participation exist. On one end, participation is equated with "mobilisation". In this view, the people are mobilised to implement projects and activities which have been decided, usually but not necessarily, by external forces. This is contrasted with "empowerment" in which participation is regarded as "an active process in which the participants take initiatives and action that is stimulated by their own thinking and deliberation and over which they can exert

effective control" (Oakley and Marsden, 1984). Passive participation, where people are involved in actions that have been thought out or designed and controlled by others is not true participation.

Theorists and practitioners of development operate by various interpretations which exist in between these extremes. These are presented by Oakley and Marsden (1984) as a continuum, reflecting the divergent perspectives of the term. A somewhat mid-course position which, in my view, is both practical and capable of achieving the objective of popular participation, i.e. bring about some meaningful involvement in the development of the rural sector by those who depend on that sector for a livelihood, is adopted in this study. According to this view, participation is seen as a means "to sensitize people and thus, to increase the receptivity and ability of rural people to respond to development programmes, as well as to encourage local initiatives" (Lele, 1975). This should also include "people's involvement in decision making process, in implementing programmes... their sharing in the benefits of development programmes, and their involvement in efforts to evaluate such programmes" (Lisk, 1981).

2.5 Rural Development Planning in Kenya

The history of post-independence planning in Kenya began in 1964 with the formation of the Ministry of Planning and Economic Development whose responsibility was to "organize and promote economic and social development" (Obudho, et al.,

1988). A centralized approach to planning was adopted according to the principles set forth by the Sessional Paper No.1 of 1965, which emphasized the role of the state in directing the efficient use of the country's scarce resources to achieve rapid equitable economic, social and regional development (Government of Kenya, 1965). As illustrated by Ngethe (1987) and Obudho et al. (1988), the series of five-year national development plans which followed have been cognizant of two major problems, rural under-development and inter-regional disparities.

Until 1982 rural development planning had been carried out as part of national planning. Each government ministry through its representatives in the various administrative levels, planned and implemented its own projects in the rural areas directly from the headquarters. This centrally controlled planning tended to overlook the variations in community problems and priorities, the enormous diversity of geographic and climatic conditions existing in different regions, and failed to recognize and incorporate local initiative in the planning process. Consequently, most development programmes have not achieved their goals which has contributed to slow and non-uniform development. This vertical organizational structure fostered by sectoral and departmental autonomy contributed to many of the existing administrative and management problems including duplication of duties and functions, too much bureaucracy in the decision

making process, limited horizontal (inter-ministerial) coordination and inefficient project implementation and supervision (Obudho, et al., 1988).

The problems of centralized planning in Kenya have been complicated further by fiscal problems rooted in international economic stagnation. However, according to the report by the Working Party on Government Expenditure (Government of Kenya, 1982), internal management problems were the more serious factor contributing to underdevelopment. " While external events have undoubtedly slowed down the growth of both domestic revenues and foreign aid, they do not explain the persistent, almost irresistible growth of expenditures by ministries or the low productivity of those expenditures" (p.11).

The Working Party identified the following as the main contributory factors to the fiscal and management problems:

- 1) the strategy of providing a wide range of services to a rapidly growing population is extremely expensive and, to some extent it discourages participation and local input through self-help activities;
- 2) over-establishment within the Government structure coupled with inefficient deployment of personnel causes under-employment and inefficiency, besides the severe budgetary strains;
- 3) excessive Government investment in commercial and industrial activities absorbs a significant portion of the budget and diverts management talent from ensuring the efficiency of on-going operations and

normal Government administration to supervising doubtful new projects as well as rehabilitating ailing commercial activities; 4) inefficient planning, implementation and control of development projects. These problems arise mainly due to limited knowledge of the planning area by the planners at the headquarters; delays and distortion of policy; lack of inter-ministerial coordination at the district level; and failure to adhere to the pattern of development outlined in Development Plans in favour of unplanned projects inspired by a variety of forces including political considerations (p.14); 5) lack of adequate supervision and coordination of local authority activities and central government activities at the local level, resulting into either duplication of functions among the different administrations or total neglect of some functions within the district.

The Working Party concluded that rural development planning had become a complex process which could be more easily planned and managed at the district level. The committee recommended that " a district team, under the leadership of the District Commissioner and with the guidance of the District Development Committee, should be established as the major force and vehicle for the management and implementation of rural development" (Government of Kenya, 1982:53). The District Focus for Rural Development (DFRD) strategy is an attempt by the Government to implement these recommendations.

2.6 District Focus for Rural Development (DFRD)

The DFRD strategy works on the principle of a complementary relationship between the ministries (representing the sectoral approach to planning) and the districts where the various sectors are joined in common support of rural development activities (Government of Kenya, 1983). This strategy set out to accomplish three main goals namely: 1) to delegate the operational responsibility of rural development to the districts; 2) to increase productivity and effectiveness in the development process; and 3) to encourage local development through local participation in project identification, planning, implementation and management (Obudho, et al., 1988).

According to this strategy development projects are divided into two categories, district specific and multi-district or national projects. Multi-district projects will be handled at the ministerial level together with policy formulation, while planning and implementation of district specific projects shall be done at the district level.

Theoretically, planning, i.e. problem definition and solution generation, should begin at the location/sub-location levels. The Locational and Sub-locational Development Committees (LDC's and SLDC's) composed of chiefs, councillors, village heads, local ruling Party leaders and members of non-governmental organizations (mainly women's and youth groups) are responsible for discussing the community needs and

are responsible for discussing the community needs and identifying projects and activities for meeting these needs. These committees can also organize project implementation programmes through fund raising activities and voluntary labour. The effectiveness of these committees has been limited by absence of technical input from trained officers and the lack of financial resources for basic things like stationery and for organizing seminars and workshops (Government of Kenya, 1989).

After projects are discussed and agreed upon locally, they should then be forwarded to the Divisional Development Committee (DvDC), composed of divisional departmental heads of operating ministries, the community development assistant (CDA) and the divisional administration officer (DO) who acts as the chairman (Government of Kenya, 1982b). The DvDC reviews, selects and prioritizes projects and programs from the list forwarded to them by the LDCs. The selected projects are then submitted to the District Development Committee (DDC) for further screening and implementation.

The DDC is the main decision making level and carries the overall responsibility for rural development project planning, implementation and management. It is composed of the District Commissioner (Chairman), District Development Officer (Secretary), District Departmental Heads, Members of Parliament, District ruling Party leaders, Chairmen and Clerks of local authorities, Chairmen of DvDC's, representatives of

development related parastatals and invited members of development related NGO's. This committee is responsible for monitoring the spatial distribution of government services, identifying in detail local development resources that are unexploited, and determining the local projects which can promote agricultural production, small-scale and cottage industry, cooperatives, community development and extension programmes, social service programmes, housing and urban development (Obudho et al., 1988). The DDC also identifies long term local development needs upon which the District Development Plan will be based (Government of Kenya, 1982). The strategy is designed to operate according to the Mall Project Cycle (Bethke, 1985) as shown below.

Fig. 2.1 Mall Project Cycle
(From Bethke, 1985)

Within the DDC a technical sub-committee referred to as the Executive Committee, has been established. This consists of the District Commissioner, the District Development Officer, Department Heads from operating ministries, Clerks

of local Authorities and representatives of development related parastatals. The tasks of the executive committee include technical preparation of plans, and project implementation and management on behalf of the DDC. Departmental heads are expected to provide technical guidance in designing projects relating to their fields, while allowing members from other disciplines to contribute in the final plan in order to achieve an integrated solution. The executive committee is also responsible for reviewing all the project proposals for the district, screening out those found to be inconsistent with the District Development Plan, assigning priority to accepted projects and finally preparing cost estimates for the projects marked for implementation for each financial year. These estimates are then submitted to the ministerial committees for use in budget preparation (Government of Kenya, 1982b).

2.7 Rural Development Policy

The projected population of Kenya by year 2000 is 35 million people of which 9 to 10 million will be urban dwellers (Government of Kenya, 1986). To sustain this population and attain even a modest improvement in the current standards of living, drastic measures need to be taken in improving the economy, employment creation and in expanding food production. The framework for accomplishing these goals is laid down in the Sessional Paper No.1 of 1986 entitled "Economic Management

for Renewed Growth" (Government of Kenya, 1986). The strategies proposed by this framework include:

- 1) accelerated economic growth to average 5.6 per cent a year at the end of this century;
- 2) expansion of agriculture as a means for stimulating economic growth and job creation;
- 3) the great majority of new jobs should be created on farms and in small-scale industries in rural and urban areas not in the cities or large industries; and
- 4) directing more investment resources to the development of a prosperous agricultural sector, establishment of rural market centres and towns, and to the support of the informal sector.

To achieve these objectives, balanced rural-urban development is required. The cornerstone of rural-urban balance is a productive agriculture and livestock economy that provides food, income and employment for rural families. Growth in agriculture also creates the potential for new industries and services in small cities and towns of the rural areas. It is becoming increasingly difficult to achieve the three goals of rural development (increased food production, more farm income and employment generation) in the face of rapidly growing population, rapid urbanization and a virtually fixed supply of land (Government of Kenya, 1986:13). There seem to be conflicts between the long term economic growth and food production as maize, wheat, and the raising of animals

for milk and meat begin to encroach on land needed to produce export crops that are essential to continued economic growth, increasing farm incomes and generation of foreign exchange. Such conflicts can be avoided through sound management of agriculture. Three broad approaches are proposed (Government of Kenya, 1986).

First, inputs such as fertilizers must be made widely available in convenient packages and at convenient locations for small-scale farmers. This requires the establishment of efficient marketing and delivery systems. Second, farmers must be made aware of improved farming practices by more effective extension services and induced to practise improved husbandry through price and other incentives. Third, it is necessary to introduce new, higher yielding varieties of maize and other grains to sustain growth and provide food security. Kenya's research capacity must focus on the development of new varieties, most particularly of maize and other grains, for introduction within this decade. Successful implementation of this approach could allow the achievement of food security with rising farm incomes and employment without compromising the growth of agricultural exports.

To ensure that this potential is realized, a second component of development strategy must address the growth of small-scale manufacturing, commerce and other services in the rural areas, which will provide the bulk of rural off-farm employment. Such development must be rooted in the economic

resources and needs of the country. Among other things, accelerated industrialization in Kenya requires three basic things: i) a large and rapidly growing domestic market to absorb industrial goods; ii) an efficient low-cost, high productivity manufacturing sector; and iii) the products of these industries must be capable of competing in world markets in order to exploit the external market.

A third component of rural-urban balance concerns the establishment of a pattern of settlement centres throughout the entire country. Provision of transport networks is crucial for the reinforcement of the marketing and other links between farms and market centres that will spring up naturally as agriculture prospers. Water supplies and electricity are essential for the growth of such centres, and adequate housing to cater for the expanding population.

Finally, provision of basic needs, including adequate nutrition, shelter and clothing; convenient and clean water; good health; and education, are essential both for the maintenance of dignity of all people, and to enable them to participate productively in a growing economy (Government of Kenya, 1986).

2.8 Conclusion

The need for decentralized planning in Kenya cannot be over-emphasized. While the DFRD strategy is by no means an antidote to poor planning and management, in my opinion it proposes the right solution and has both the structure and

capacity of implementing such solutions. However, a review of the decentralization process in Kenya (Ngethe, 1987; Obudho, et al., 1988) reveals some recurrent problems which have hampered its successful implementation. Unless these problems are overcome, as Mackenzie and Taylor (1987) noted, the objectives, and hence the benefits of DFRD strategy may never be realized. Five conditions which are likely to affect positively the successful implementation of the strategy are identified as follows.

First, there needs to be more decentralization of power and human resources to the district and lower administrative levels. Technically qualified personnel should be posted to specific locations, with greater mandates and financial resources so as to increase the effectiveness of the locational and sub-locational committees in policy making and project implementation. Although this can be seen as a mere de-concentration of functions, it is a first step towards the other end of the continuum of decentralization i.e. devolution. Premature devolution may exacerbate inter-regional and interpersonal disparities.

Second, decentralization should be supported by more local participation, particularly by the non-elite citizens in development committees. Besides Harambee, formation of local organizations such as women's groups should be encouraged and given a greater mandate to plan and implement self-help projects. The practice of guarding against political

conflict by discouraging the growth and active participation of community-based and non-governmental organizations should be abandoned. Governments should encourage the creation and strengthening of the local organizations likely to take charge of the implementation of local initiatives (Mussa-Nda, 1988).

Third, the control over financial resources should be decentralized to the district level as much as is possible. Centralized financial/budgetary control dilutes the powers of the DDC considerably, besides inhibiting the efficiency in district level project implementation (Obudho, et al., 1988).

Fourth, effective mechanisms need to be developed to link or integrate existing local organizational forms and activities with the DDC, in matters of policy and project implementation. There is a need for more efficient planning and coordination of development projects undertaken by the central Government, local governments, non-governmental organizations and local self-help activities (harambee). Application of GIS technology has a great potential for contributing to the solution of such organizational problems by increasing integration and information accessibility.

Finally, there is a need for more efficient use of resources including manpower, data and information. The solution to these problems lie in proper communication, expeditious flow of data and information and effective coordination.

It is these issues, particularly the last two, the study attempts to deal with through spatially integrated planning and management using the geographic information systems technology. The concepts of this strategy will be discussed in the next chapter.

CHAPTER 3

INTEGRATED SPATIAL DEVELOPMENT PLANNING

3.1 Introduction

Industrialization and rapid economic growth can be much more easily attained by concentrating investments in large metropolitan areas, but promotion of social equity requires de-concentration of some types of investments in order to make towns and intermediate cities more attractive to investors and to serve the population more effectively. Self-sustaining economic growth is unlikely to occur without a well articulated spatial system composed of dispersed and interlinked central places, performing both specialized and diversified production, distribution, consumption and exchange functions.

Development theorists have argued for a long time over whether primate cities are catalysts or cancers to rural development, and there are convincing arguments for both sides. Urban and rural sectors are intimately related, and an integrated urban-rural development is, in my opinion, the most effective way of ameliorating some of the intransigent problems of rural development.

Rondinelli (1983) sees the development of intermediate or secondary cities as providing five major benefits. First,

they relieve pressures on the larger cities in terms of housing, transport, employment and provision of services problems. Second, development of well distributed secondary cities, reduces regional inequalities by dispersing the urban benefits, which have been accepted as 'better' standards of living. Third, secondary cities are seen as the means of stimulating rural economies through the provision of services, facilities and markets for agricultural products, as well as being able to absorb surplus labour should agricultural production become more efficient. Fourth, secondary cities provide increased regionally decentralized administrative capacity. Finally, it helps in reducing urban poverty by increasing productivity in intermediate cities.

Rather than attempting to restrain the growth of large cities, development strategies should encourage the growth of existing towns to provide employment, services, and facilities to the agricultural hinterlands. At the same time agricultural productivity must continue to expand to meet the increasing demand for food from the urban population and to enable the rural communities to afford town-based services and facilities. This chapter discusses an approach for achieving these two goals and how it can be applied to the rural planning policy in Kenya.

3.2 The Concept

Integrated spatial development planning strategy is founded on the functional integration concept of spatial

development which aims at harmonizing urban and rural functions as a means of stimulating a somewhat equitably distributed development. According to this concept, development of an integrated system of growth centres of different sizes and functional characteristics can play an important role in facilitating more widespread regional development (Rondinelli, 1985). The strategy seeks to achieve higher levels of food production, expand employment and achieve higher income levels, through agricultural rather than industrial development.

"If greater productivity and higher incomes are to be achieved, some critical mass of services must be made available in rural areas, including appropriate agricultural technology, research and extension services, high yielding seed varieties, adequate credit and other inputs. Greater opportunities for non-agricultural employment must accompany increased agricultural production. Agricultural processing and distribution activities must be established, and industries must be created to provide low-cost inputs and equipment for farmers. Finally, if rural development is to go beyond simply increasing farm output, attention must be given to providing for basic human needs" (Rondinelli, 1985:5).

The ultimate goal is to integrate urban and rural communities into a system of settlements through which a wide range of mutually beneficial economic, social and physical interaction can occur. Applications of this concept to planning in Kenya has been investigated by several scholars (Obudho, 1983; Obudho and Taylor, 1979; Taylor, 1974).

The integrated spatial development planning approach is based on the central place and service centre concept which

is built upon the following assumptions derived by Roy and Patil (1977):

- 1) people are distributed in variously sized settlements in space;
- 2) these people have bio-physical as well as socio-economic needs;
- 3) people utilize physical and human resources i.e goods and services to satisfy their needs;
- 4) people form settlements in space in the form of homesteads, villages, towns or cities and continue to stay together as long as resources are adequate to meet their needs; and
- 5) they go to other places in search of goods and services that are not available in their own settlements.

Well articulated integrated spatial systems (those with a well developed hierarchy of central places i.e. settlements of different sizes with different combinations of central functions) according to Rondinelli (1985) are capable of:

- a) maximizing the usage of natural resources; b) strengthening markets for agricultural goods and other rural resources;
- c) distributing more widely services such as health, education and extension services, and other inputs needed for increased agricultural production; d) creating new rural employment opportunities, especially in agro-processing, agribusiness, small-scale and cottage industries that use local resources as the primary inputs for production; and e) slowing the rate and altering the pattern of rural to urban migration.

3.3 The Planning Process

The planning approach proposed draws largely from the functional coordination strategy adopted by the World Bank, the rural modernization strategy pursued by some United Nation's Development Agencies, the U.S.A.I.D's new directions development strategy (Rondinelli and Ruddle, 1978) and the urban functions in rural development (UFRD) strategy described by Rondinelli (1985). The approach proceeds in six stages as follows. First the issues of rural development planning are defined and the various subsystems involved identified. A resource profile consisting of an inventory of spatially referenced bio-physical and socio-economic characteristics of the planning area is then prepared. Next these data are analyzed so as to provide information regarding the economic base of the area, its level of development in absolute and relative terms, and the strengths and weaknesses of the existing economic and physical linkages within the region. Fourth, the information derived is used to formulate policies necessary to ameliorate the identified problems and weaknesses. The fifth stage is the translation of policy into projects which are then implemented. Finally, the strategy should provide a means for managing and monitoring the projects after they are implemented.

Two major goals of rural development are identified. First, rural development should seek to increase rural productivity to attain food self-sufficiency and to increase

rural incomes through a diversified rural economy. Second, rural development should aim at reducing the inter- regional and rural-urban disparities in standards of living. The underlying assumptions of the approach adopted are twofold.

First, it is assumed low agricultural productivity largely contributes to rural poverty and that increased productivity depends on, inter alia, increasing access of farmers, particularly small scale, to production inputs, technology, financial resources, and markets. This can be achieved through mobilization and efficient use of the limited resources, mainly land and capital. Land in this context is taken to include the physical (soil, water and climate) and the biological (flora and fauna) components. Availability of basic social services (health and education) is another necessary condition for increasing productivity.

Second, it is assumed that the current spatial systems are neither horizontally nor vertically integrated, and this greatly inhibits the creation and growth of a national spatial economy. A self-sustaining growth requires functionally and spatially integrated production, distribution and consumption systems. Such systems can be obtained by developing mutually benefiting physical and economic linkages between and among rural and urban settlements.

Based on these assumptions and the identified goals, four main issues of rural development are derived as summarized in Fig.3.1 below.

Fig.3.1 Components of Rural Development Planning

3.4 Land-use Planning

The purpose of land-use planning is to guide decisions on land-use in such a way that the resources of the environment are put to the most beneficial use for the society (C.R.D, 1979). Effective land-use planning requires a complete and accurate inventory of a number of aspects of land including ownership, current uses, soil types, vegetation types and other socio-economic characteristics of the area. Land-use planning involves three distinct processes referred to as land capability determination, land suitability analysis

and land-use allocation. Land tenure and land ownership can also be considered as land-use planning issues.

3.4.1 Land Capability Determination

Land capability refers to the inherent potential of an area to produce goods and services of various kinds under specified types and intensities of economic and technological inputs (C.R.D., 1979). Capability classes define a broad range of general land uses such as agriculture, forestry, grazing, wildlife conservation, and are determined by the number and extent of soil and site properties known to impose limitations on a range of different uses (McRae and Burnham, 1981).

Some of the land characteristics used in determining capability classes are: 1) topographic characteristics such as elevation, slope and sun aspect; 2) texture and structure of the surface soil; 3) minimum effective soil depth; 4) rainfall and moisture availability, including surface and sub-surface water systems; and 5) prevalent vegetation types. The main purpose of land capability classification is to categorize land according to its most appropriate use so as to provide guidance against putting land to uses which increase its susceptibility to or rate of degradation.

3.4.2 Land Suitability Determination

After land has been categorized according to its capability, the next step in land-use planning is to identify land units according to specific land-use suitability classes.

The Food and Agriculture Organization (FAO) defined land suitability as the ability or fitness of a land unit in its present condition to produce specific goods and services (McRae and Burnham, 1981). Land can also be classified according to its potential suitability i.e. its suitability at some future date after some necessary improvement has been effected. Suitability classes are determined as follows.

First a specific land use is identified, for example, tea growing. The ecological requirements for this use such as optimum altitude, rainfall, soil pH, drainage and depth are then defined. Land units are then searched to determine how best they meet these conditions and are classified accordingly. The five FAO suitability classes namely S1 (highly suitable), S2 (moderately suitable) S3 (marginally suitable), N1 (provisionally not suitable) and N2 (permanently not suitable) have been adopted in Kenya (Muchena and Van de Pouw, 1981). Class S1 is used for land units which are found to have optimum conditions for a selected land-use type. All other land units are given classes according to the numbers and extent of their deficiencies. These classes are subdivided further into subclasses, indicating the main type(s) of limitation(s) and suitability units which show minor management requirements within a subclass (McRae and Burnham, 1981).

A land suitability classification produces a series of maps indicating how different land-uses would perform on

different land units. From this and other information, the potential productivity (Yield/Ha) of each land unit under different uses can be estimated.

3.4.3 Land Allocation

Decisions on land allocation should take into account both the land capability/suitability and the needs of the society. A suitability classification system can categorize a land unit as highly suitable (class S1) for forestry, but marginally suitable (class S3) for arable farming. This does not necessarily mean that the most appropriate use for that land unit is for forestry. The land-use allocated to this land unit after considering all alternative uses and the needs of the society could be arable farming.

3.4.4 Land Ownership

Land ownership and distribution is another important aspect of land planning. In most of the developing world the intense competition for arable land is a primary cause of poverty. As a World Bank report noted "... within the rural sector, at the core of the poverty problem are families who either own and cultivate very small holdings or own no land at all " (World Bank, 1978:38). This problem can be addressed through land reform policies (land tenure, land redistribution, sub-division control, re-settlement and land improvement). The aim of these reforms is to produce tenure

patterns that are consistent with the goals of economic and social development.

Attainment of land reform objectives will greatly benefit from an easily accessible, complete and up-to-date cadastral system. Existing cadastral systems are characterized by problems of accessibility, duplication, aggregation and confidentiality. These problems can be overcome by a multi-purpose cadastre i.e. a computer-based land information system, which incorporates information on land registration (cadastral surveys) and planning and management issues (NRC, 1980).

The incorporation of rural land ownership information in a geographic information system in Kenya is complicated by two main factors. First, most land ownership units in the rural areas comprise small, irregular and sometimes dispersed land parcels. To include such information in a database requires the establishment of very large and complex databases. Unlike the regular shaped land parcels found in urban areas, each of the uniquely shaped rural land parcels has to be digitized from a very large scale base map for an acceptable degree of accuracy to be attained.

This problem is further complicated by the fact that most property boundaries in the rural areas are marked using crude survey methods (the general boundaries under the Registered Land Act (RLA), Chapter 300 of The Laws of Kenya), making it

impossible to represent them accurately in a geographic information system.

3.5 Resource Management

Land resources include soil and water, forests, minerals and wildlife. The main aim of resource management is to ensure an economical and sustainable harvesting. Five aspects of environmental management are considered as follows.

3.5.1 Soil and Water Management

Management of soil and water resources can be taken to include the control of quantity, quality and losses of these resources. The water management problem is concerned with four things: (i) meeting the increasing demand for reliable clean water supplies, (ii) controlling water pollution from agricultural practices such as use of fertilizers and pesticides, (iii) ground water management, and (iv) maintenance of water quality for aquatic life harvesting.

The two main aspects of soil management are soil protection and maintenance of soil productivity. The most widely used method for predicting soil losses due to erosion is the universal soil equation (USLE) (Morgan, 1986):

$$A = R \times K \times L \times S \times C \times P$$

where A = the soil loss in kg/m²,

R = the rainfall erosivity factor,

K = the soil erodibility factor,

L = the slope length factor,

S = the slope gradient factor,

C = the cropping management factor, and

P = the erosion control practice factor.

The USLE was developed as a method to predict average annual soil losses from erosion. Morgan (1986) describes the

various methods used for determining the parameters used in the USLE. By trying different combinations of these parameters planners (extension staff) can advise farmers on different cropping and management practices that will reduce soil erosion. As suggested by Wischmeier (1976), the USLE may be used to:

- (1) predict average annual soil loss from a field slope with specific land use conditions;
- (2) guide the selection of cropping and management systems, and conservation practices for specific soils and slopes;
- (3) predict the change in soil loss that would result from a change in cropping or conservation practices;
- (4) determine how conservation practices may be applied or altered to allow more intensive cultivation;
- (5) estimate soil losses from land use areas other than agricultural; and
- (6) provide soil loss estimates for conservationists to use for determining conservation needs.

Soil erosion is controlled either by providing a protective cover to the soil or by mechanically controlling the speed of erosive factors (water and wind).

Soil quality management relies on the existence of an inventory of physical and chemical properties of the soil. From these data the nutrient contents of different soils can be analyzed. Information from such analyses is passed on to farmers in the form of appropriate types and quantities of

fertilizers to use for specific crop productions on specified soils.

3.5.2 Forest and Vegetation Management

Forests protect soils and water catchments, supply timber for fuel and other uses such as shelter, furniture and paper, and are also sources of medicinal drugs and food. The objectives of the forest department are to plant and protect man-made and natural forests in all government lands, promote agro-forestry, and to regulate forest harvests to ensure their sustainable use (Government of Kenya, 1989). Planners and forest managers require information regarding spatial locations and extent (areas) of forests, prevalent tree species, ages and heights of trees contained in different forests.

3.5.3 Mineral Resources

Mineral resources include gem stones and industrial minerals. They provide revenue which can be used to supplement the community's finances for socio-economic services. The Government Mineral Resources Department is concerned with mineral exploration, geological mapping and the control of mineral prospecting and extraction. Planners require information about the localities of different mineral types, available quantities, and value, ownership and the state of extraction.

Planners and policy makers may want to know: where different mineral resources are located; who owns this land

and who has the extraction rights; the extent of extraction; or how much revenue the region earns from the minerals - from sales, licensing or lease ?

3.5.4 Wildlife Resources Management

Wildlife resources are a major source of foreign exchange in Kenya mainly through tourism. The Department of Wildlife Conservation is charged with the responsibility of managing and protecting the arid and semi-arid lands and the wildlife resources residing in these lands. In order to carry out this task, the department requires bio-physical information such as soil characteristics, vegetation type/cover, and the availability of surface and sub-surface water resources. For administrative purposes, the Department of Tourism requires information regarding the spatial locations, extent, and classes of protected wildlife conservation areas, species types and numbers residing in different areas and their biological characteristics (browsers or grazers). Information on the distribution and patterns of visitors to these resources can also assist planners and park managers in planning for and improving the existing amenities. Wildlife resources can also be beneficial to the society as a source of protein to supplement livestock production.

3.6 Settlement Systems

Regions develop into systems of settlements differentiated by size (areal or population), production activities or by the number and types of facilities and

services located in them. While natural factors such as agricultural potential, topography, and availability of water contribute to the location and growth of such centres, allocation of economic resources significantly determines the rate of development and the degree of disparity among settlements.

The third rural development planning issue is concerned with the distribution of socio-economic services and facilities within settlements. These services include health, education, extension, credit, market and employment facilities.

3.6.1 Medical and Health Services

The goal of Ministry of Health is to promote better health of the population through provision of curative, preventive and promotive health services (Government of Kenya, 1989). Curative services are provided through government hospitals, health centres and dispensaries, and by private and non-governmental organizations. The distribution and the types of facilities available in these institutions are important planning inputs. Preventive and promotive health services are rendered to the public through Public and Environmental Health Departments, which provide services in health education, Maternal-Child Health/Family Planning (MCH/FP) and Food and Nutrition. Environmental Health department also deals with the control of disease causing

vectors (mosquitoes, aquatic snails, etc.) and immunization programmes.

The health status of a population can be assessed using a number of indicators including the crude death rate, infant mortality rate, life expectancy at birth and the number of medical staff and facilities available per unit of population (Government of Kenya, 1989b).

3.6.2 Extension Services

The role of extension service is to disseminate new agricultural technology and skills to small and medium scale farmers in the rural areas. Extension services should combine information about markets and opportunities, data on farmers' needs and desires, and research recommendations with information on policy objectives for agricultural development (Rondinelli and Ruddle, 1978). Most agricultural extension programmes face enormous operational problems, which are rooted in institutional, organizational and communication difficulties caused by inadequate interpersonal communication. These operational problems are being addressed through personnel decentralization and adoption of new information exchange strategies such as the training and visiting (T&V) strategy (Government of Kenya, 1986). In implementing this strategy, extension staff are allocated specific farmers throughout a season, to whom they provide both in-class and field training.

3.6.3 Education and Training

Elimination of illiteracy was one of the Government goals at independence. For schools to be able to provide quality education, they need adequate facilities such as classrooms, laboratories and libraries, besides teachers. Monitoring and managing educational institutions demands the existence of up-to-date information on the spatial distribution of types (primary, secondary and post-secondary), categories (government aided, government assisted or private), and the distribution of teachers.

3.7 Spatial Linkages

A region is not merely a system of functionally diversified settlements but also a network of social, economic, and physical interactions. The processes of interaction are shaped by linkages among settlements through which rural people obtain access to town based services and facilities, markets for their products and receive many of the inputs needed to increase agricultural productivity. Urban people gain access to farm produce to meet their food demands and to the raw material they require for their industries. Regional planners and policy makers are therefore concerned with the effectiveness of these interactions and the degree to which settlements are linked in ways that provide a maximum access to people living in all parts of the region.

Analysis of spatial linkages can provide information with which planners and policy makers can determine the degree to

which settlements within the region are integrated, the extent to which people living in various parts of the region have access to town based facilities, and the location of the main service centres within different settlements (Rondinelli, 1985).

3.7.1 Transport and Communication Linkages

The availability of communication networks is essential for rural development. Roads are perhaps the most crucial public investment in rural development projects. Feeder roads into the agricultural areas facilitate input supplies and the marketing of produce. Good transportation linkages reduce travel time, lower shipping costs, widen marketing, commuting and migration opportunities, allow greater access to non-agricultural employment, improve communications and extend areas of service delivery. In addition to the direct economic gains, less easily measured social benefits resulting from communication infrastructure include access to amenities in other centres which reduces isolation, improved living conditions, and making the area more attractive to qualified teachers, doctors and other professional personnel.

3.7.2 Water Supply Systems

The Ministry of Water Development is responsible for supplying fresh water to the population. In its efforts to meet this responsibility, the ministry is involved with planning, designing and implementing water supply projects. Availability of water within easy reach of the people will

not only improve their welfare but also release their time and energy for other productive activities. The goal of the Government, according to the National Master Water Plan (1974), is to ensure the availability of potable water to within 4 km of every household by the year 2000 (Government of Kenya, 1989b:23). This is to be achieved through the establishment of water supply projects, sinking of boreholes, construction of catchment dams and provision of the necessary conveyance infrastructure in the form of pipes and furrows. Several water supply projects have been implemented through self-help projects by local communities. The Ministry of Water Development should support these local efforts by providing technical assistance in the design, construction, water treatment and provision of management services.

Besides domestic water supply, the Ministry is also responsible for protecting water catchment areas, prospecting and drilling boreholes in the arid and semi-arid areas and the management of irrigation schemes in conjunction with the Ministry of Agriculture and the National Irrigation Board (NIB). Efficient performance of these tasks require complex information such as modelling the effect of destroying a forest on the water catchment, determination of ground aquifer capacities, discharge and re-charge rates, forecasting the benefits or losses to be incurred by introducing an irrigation scheme, etc. Chemical tests on soils are also needed to determine the risks of salinization or alkanization.

3.7.3 Energy Supply

Energy is an essential input for both social and economic development. It is required for both domestic consumption and production purposes. There is a need to determine the current and expected energy demands, available energy sources (wood fuel, petroleum and electricity). The Ministry of Energy Resources is involved in research for new and renewable energy resources such as solar and wind.

In most urban areas, energy is supplied by central electric power grids and petroleum fuels. Rural communities depend on a variety of traditional energy sources, mainly fuel wood and charcoal. The national demand for fuel wood is projected to grow at the rate of 3.0 per cent and that of charcoal at 4.7 per cent per year in the period 1985-2000 (Government of Kenya, 1986:59). The needed expansion of wood-fuel supplies can be satisfied through agro-forestry, re-forestation and afforestation programmes, and the use of charcoal based on waste products from coffee, maize and sugar.

A number of alternative energy sources are available in rural areas e.g. wind and water power, solar energy and bio-gas. In purely economic terms, these alternatives are too expensive for either individuals or communities. Moreover, these nontraditional energy sources can only serve small, isolated population clusters and individual farmsteads, hence do not offer extensive solutions to the energy requirements of rural development.

Rural electrification seems to be the most viable option. Implementation of rural electrification is an expensive venture, and is economical where there is a reasonably high demand, including non-domestic. At the moment, the Government has embarked on a programme for supplying electricity to the rural areas through the Rural Electrification Programme (REP). The goal of REP is to supply all primary schools with electricity in order to promote industrial education. Rural residents living along or near the grid lines will be supplied with electricity at a nominal installation charge of about \$100.

3.7.4 Economic Linkages

The fourth major set of spatial linkages of interest to planners and policy makers are the economic linkages. Planners are interested in knowing the pattern of flows of agricultural products from rural areas to demand centres. They would like to know which areas provide raw materials for manufacturing activities and where farmers obtain the agricultural inputs such as fertilizers, farm implements, improved seeds and credit. Such information can assist them in improving accessibility and in planning rural industrialization programmes.

3.8 Conclusion

The issues and the questions raised here are by no means exhaustive or necessarily the most important ones. The

objective was to illustrate the nature of the rural development planning problem.

In the discussion the political factor in development has not been stressed as much as the spatial or physical factors. This does not by any means trivialize the issue. The fact that the somewhat latent political factor plays a great role in both policy formulation and project implementation is acknowledged. In fact in many cases, as some scholars (Gore, 1984; Unwin, 1989) have argued, socio-political relationships play an equal, if not greater, role in rural development. It is, however, not possible to incorporate this important factor in a physically oriented planning model.

CHAPTER 4

DATABASE DEVELOPMENT

4.1 Introduction

Having seen the range of issues that may interest rural development planners, the next logical step is to determine the kinds of data capable of providing answers to these questions. In this chapter the database development process is discussed. The first part discusses the theoretical aspects of database development including the issue of data quality. The second part identifies the data needed for an integrated rural development planning project and provides a framework for organizing these data into a database.

The database development process serves three important purposes besides project implementation. First, the process of creating the database encourages planners to make a thorough inventory of existing data from censuses, special studies, project analyses, feasibility studies and other reports about the region. Second, the data gathered through this exercise can be compiled into a regional statistical compendium that can provide planners, government officials, private investors and community groups with information about the region that previously had been scattered in inaccessible or little-known reports. Finally, the database provides a

baseline for the analysis of conditions within that region that can be used later in assessing changes that result from regional development projects and programmes (Rondinelli, 1985).

4.2 Database Concepts

A database can be described as an organised collection of related sets of data managed in such a way as to enable the users or application programs to view the complete collection, or a logical subset of the collection, as a single unit (Oxborrow, 1986). Basically a database is a computerized filing system i.e. a system whose overall purpose is to maintain information and to make that information available on demand. Besides compactness, speed and ease of access, database systems offer several other advantages over purely electronic filing systems. These are identified by (Date, 1986; Litton, 1987; Aronoff, 1989) as:

- a) data redundancy can be reduced either through elimination or control;
- b) data inconsistencies can be avoided by eliminating redundancy;
- c) data sharing ability for existing and new applications is enhanced;
- d) standards can be more easily enforced with centralized data control;
- e) security restrictions can be enforced with little interference with data accessibility by giving selective access (retrieve, modify or update) to different users;

f) data integrity (accuracy, correctness, validity, consistency and completeness) can be more easily ensured in a database system; and

g) applications can be made data independent, i.e. immune to changes in physical data storage or logical data structure.

Not all database systems offer all these advantages; in fact some of these advantages such as data integrity and data independency are very difficult to achieve. The main disadvantages of the database approach include: a) large initial cost outlay and the large storage overheads (Lodwick and Feuchtwanger, 1987), b) added complexity, and c) increased theoretical risk of loss or corruption associated with centralized control (Aronoff, 1989).

Chambers (1989) identified some of the major factors that influence the design of a GIS database as: the data needs of the applications that will be developed; availability and format of existing data; update and maintenance procedures; size of the database; hardware platform/configuration; number and sophistication of users; organizational structure of the users; and the available budget and management support.

4.3 Data Collection and Data Capture

Data needed for project implementation may already exist in archives or have to be collected. Archival data sources include digital satellite images, aerial photographs, cadastre, maps and charts at different scales and projections, and statistical and other textual reports. If the required

data are not available, primary data collection has to be carried out. Data collection techniques include terrestrial surveys, photogrammetry, remote sensing and census-type surveys.

Table 4.1
GIS Data Forms

	Analog	Digital
Graphic	Map sheet Photograph	Digital map file Satellite image
Textual	Field sheet Paper file	Data logger cartridge Database segment

Source: Lodwick and Feuchtwanger (1987) p.104

After data have been collected and compiled, the next step is to enter them into a GIS, a process referred to as data capturing. There are several techniques for data capturing. These are summarized in the table below.

Table 4.2
Data Capturing Techniques

Analog	Digital Transfer
Graphic Digitizing tablet Drum Scanner	Magnetic disk & tape Electronic transmission
Textual Keyboard Character & voice recognition	"

Source: Lodwick and Feuchtwanger (1987) p.104

4.4 Database Creation

The process of database development can best be visualized using the four levels of data abstraction described

by Peuquet (1984). These can be represented in a simplified form in the figure below.

Fig 4.1 Levels of Data Abstraction

4.4.1 Conceptual Modelling

A conceptual model represents a simplification of the real world system stated in terms of elementary concepts that can eventually be transformed into a physical database. This model is independent of any particular database system and its main purpose is to bridge the gap between the real life system (very general) and the final database (very specific). Conceptually modelling of information without any consideration of computer coding is referred to as infological or schematic modelling (Tsichritzis and Lochovsky, 1982). The most commonly used infological model is the Entity-Relation-Model (ERM) (Feuchtwanger, 1985). An ERM breaks down reality into a series of entities (attributes) and the relationships between and among them. This process can be used to organize data regardless of the structure or model to be applied. Some data models have standard procedures to follow in order to minimize redundancy, for example the normalization process used in relational data models (Litton, 1987; Oxborrow, 1986).

Reality as represented in a database can be organized and viewed in a variety of ways depending on the types of problems or issues that are important to the planners and the amount and type of data available. This study views a region as an integrated spatial system consisting of four interacting entities namely; bio-physical resources, socio-economic resources, and rural and urban functions as shown in the figure below.

Fig.4.2 Integrated Resource Concept of a Region

Using this concept, regional development is seen as a process where natural and physical resources must be procured and transformed into goods and services, which are then delivered to internal and external markets.

4.4.2 Datalogical Modelling

For computer implementation, the conceptual model needs to be transformed into a form compatible to system-specific data structures. In order to obtain access to data from one or more files contained in a database easily, it is necessary

to have some kind of structure or organization within the database system (Burrough, 1986). The modelling of data in terms of data structures and computer specifics is referred to as datalogical or semantic modelling (Tsichritzis and Lochovsky, 1982). A datalogical model defines the same things as the conceptual model but is consistent with a specific data structure.

Given any infological model, there are several alternative database approaches that can be used to organize and store these data. The three most commonly used approaches are termed hierarchical, network and relational datalogical models, and are based on tree-type, plex-type and tabular-type data structures respectively (Feuchtwanger, 1985). The relational model is increasingly becoming popular notably due to its conceptual simplicity and the ease with which users can interact and query data from this type of structure which supports the powerful structured query language (SQL) (Litton, 1987, Westwood, Undated). Most GISs have their own models for managing and processing spatial data (ARC/INFO's ARC or SPANS quadtree), and use the more common DBMS for managing attribute data such as the INFO relational DBMS in ARC/INFO or the network-type DBMS used by the Intergraph system (Lodwick and Feuchtwanger, 1987).

4.5 Data Quality

Geographic information systems permit a wide range of operations to be applied to both attribute and spatial data

in the production of tabular and graphic output. This ability give GISs the potential to increase dramatically the magnitude of errors in the database. There have been so few studies on the whole problem of residual variation and how errors arise, or are created and propagated in geographical information processing, and what the effects of these errors might be on the results of the studies made (Burrough, 1986:103). "Urgent action is needed to minimize the potential worst case consequences and also to provide a methodology for coping with the effects of processing uncertain data" (Openshaw, 1989:263). Aronoff (1989) points out that "Knowing the quality of data is critical to judging the applications for which they are appropriate" (p.133).

Although much has been written about the need to recognize and improve data quality for GISs (Chrisman 1982, 1984 and 1987; Burrough, 1986; Bailey, 1988; Aronoff, 1989; Goodchild and Gopal, 1989), there still remains a general lack of information on procedures to ensure accuracy and precision at different stages of data base development (Campbell and Mortenson, 1989) and its subsequent use. At present there are no standard techniques for tracking, assessing or controlling errors in spatial data analysis. GIS results are reported without any indication of the accuracy of the products. "While the goal of eliminating errors from output products may at present prove to be infeasible, decision makers should at minimum be provided with a means of assessing the accuracy of

the information upon which their decisions are made" (Veregin, 1989:3).

The immediate objective of data quality analysis is therefore not to eliminate errors, but to identify and manage them. The problem of error management can be best illustrated by the hierarchical concept of problem solving as described by Veregin (1989) (Fig.4.3 below).

Fig.4.3 A hierarchy of needs for modelling error in GIS operations (from Veregin, 1989 p.4)

The assumption is that problems at the lower level of the hierarchy must be solved before those at higher levels are considered. Data quality analysis in this study will not go beyond the first level i.e. error source identification which is concerned with identifying and classifying sources of error in spatial data.

4.5.1 Components of Error

Seven major components of error are identified. The first four errors pertain to individual data elements and can be

objectively evaluated using statistical analyses. The last three errors on the other hand pertain to the entire data set as a whole. They are not generally capable of being tested objectively, instead they are evaluated by subjective judgement or by reporting information about the data (Aronoff, 1989).

1. Positional Accuracy

This is the expected deviance in the geographic location of an object in the data set (e.g. on a map) from its true ground position. Positional accuracy has two components, bias due to inconsistency of the observer; and precision i.e. the degree of exactness with which the quantity is expressed (Lodwick and Feuchtwanger, 1987). The significance of positional accuracy depends on the type of spatial data being analyzed. For example, it is almost insignificant when dealing with natural resource data such as vegetation or soil types maps, but very critical in cadastral or engineering data. The precision component of positional accuracy is also dependent on the reporting scale.

2. Attribute Accuracy

This refers to the accuracy of the thematic values or the classification system used. Assessment of accuracy for continuous attribute variables is similar to that of positional accuracy assessment. Discrete variables accuracy assessment is done via classification systems. As Aronoff (1989) points out, this is a complex and somewhat

controversial procedure due to the many influencing factors including the number, shape and size of the individual areas and the way test points are selected and how mixed up classes are dealt with. Classification accuracy assessment has received considerable attention in the field of remote sensing.

3. Logical Consistency

Logical consistency refers to how well logical relations among data elements are maintained e.g. how consistent boundaries marking the same feature are in different data layers. Logical inconsistencies are a major source of slivers (false polygons created by wrongly intersecting lines or surfaces) during overlay operations. They can be treated internally by the software e.g. rubber-sheeting and edge matching, or by pre-capture data processing such as boundary reconciliation.

4. Resolution

The resolution of a data set is the smallest discernible unit or the smallest unit represented. For positional data, spatial resolution can be given as the measure of distance, while the minimum mapping unit is used for thematic maps. Decision on the level of resolution is determined by the expected use of the map, legibility, source data accuracy, and drafting expenses (Aronoff, 1989).

5. Completeness

There are three aspects of completeness, namely completeness of coverage, classification and verification (Aronoff, 1989). The completeness of coverage refers to the proportion of data available for the area of interest. Completeness of classification on the other hand, is an assessment of how well the chosen classification is able to represent the data. Completeness of verification refers to the amount and distribution of field measurements or other independent sources of information that were used to develop the data.

6. Time

Time is a critical factor in using many types of geographic data. This aspect of data quality is commonly reported as the date of data acquisition. In GIS analyses, time is frequently overlooked when multiple data sets collected independently are used together (Aronoff, 1989).

7. Lineage

The lineage of a data set is made up of its history, the source data and the processing steps used to produce it. Each data source and processing method introduces a level of error into the information that is ultimately produced. Knowledge of the lineage can be an important consideration in choosing a data set for a specific application (Aronoff, 1989).

4.5.2 Sources of Error

There is some error associated with all geographical data and more errors are added at every step in the process of generating and using geographic information. The most easily recognized source of error is the data collection stage. Welsh et al. (1987) and Vitek et al. (1984) differentiated between inherent and operational errors.

Inherent errors refer to the uncertainties present within the source materials such as delineation of transitional boundaries of vegetation. It is very difficult if not impossible to recognise and control inherent errors. Burrough (1986) attributed the major source of unseen errors to natural spatial variation in the original data.

Operational errors represent uncertainties that are introduced during data input and machine processing within the GIS. According to Chrisman (1982), the largest potential errors in digital map processing occur during the digitization process. Error-reducing procedures have however not been well documented (Campbell and Martinson, 1989). Ottawa (1987) stated that operator experience in digitizing reduces errors associated with this procedure. Jenks (1981) after reviewing several studies stressed the effects of fatigue on digitization accuracy. Maffini, et al. (1989) after experimenting on the effects of scale and time taken in digitizing found that the level of accuracy goes down with

decreasing scale of the source map and time taken per digitizing job.

The major sources of errors are listed in the table below.

Table 4.3
Common Sources of Error Encountered in Using a GIS

Stage	Sources of Errors
Data collection	- errors in field data collection - errors in existing maps used as source data - errors in the analysis of data
Data input	- inaccuracies in digitizing caused by operator and equipment, - inaccuracies inherent in the geographic feature
Data storage	- insufficient numerical precision - insufficient spatial precision
Data manipulation	- inappropriate class intervals boundary - error propagation due multiple overlays, - slivers caused by problems in polygon overlay procedures
Data output	- scaling inaccuracies - errors caused by inaccuracy of the output device - errors caused by instability of the medium
Use of results	- the information may be incorrectly understood - the information may be inappropriately used

Source: Aronoff, 1989 p.142

4.6 Data Requirements

One of the greatest obstacles to comprehensive planning has been the availability of data. This is, however, changing with the development of efficient mass data collecting techniques such as remote sensing and satellite positioning. Four data-related problems, however, still remain to be resolved. First there is a general problem of data

utilization. Plenty of data are collected with little attention given to data processing and analysis. Some government organizations are more interested in conducting or financing surveys than in using their results (Sazanami, 1986). Whether this practice results from lack of technological capabilities for analysis or from lack of policy is not easy to tell.

The second problem concerns data fragmentation. Different organizations collect and maintain their own data for their specific needs which results in duplication of data collection efforts and limited utility of information due to inaccessibility. Duplication occurs because users are not aware of what data other users may already have or are planning to collect. Sometimes the data classification systems are not compatible, hence the need for double coverage. Inaccessibility arises when users cannot obtain information for a variety reasons. In a few cases the information may not be available, in most, unreasonably lengthy searches due to poorly structured and managed data are the causes of inaccessibility (NRC, 1980).

Third, while technologies such as remote sensing provide easy, accurate and fast data collecting methods, extensive use of these technologies is inhibited by the high costs involved in obtaining such data. Another cost-related problem is the high cost of converting data, most of which are in analog formats, to machine readable forms. The cost of data capture

is held to be about 70 per cent of the total cost of GIS project implementation.

Finally, the problem of integrating data from different sources (fields or areas) will continue for a long time. Different countries and different disciplines collect and store data in different formats. The issue of data standards, with regard to accuracy and format, is receiving considerable attention within GIS circles (DCDSTF, 1988).

4.6.1 Data Availability

A study conducted by the United Nations Environment Programme (UNEP) in Kenya (Bulski, 1986) indicates that enormous amounts of data concerning topography, hydrology, geology and climatology exist in different governmental and non-governmental organizations. The Kenya Soil Survey (KSS) has also conducted many studies on soils, rainfall distribution, land uses and erosion susceptibility for various soil types all over the country. The Ministry of Agriculture has surveyed and mapped the entire country into Agro-ecological zones (AEZs) at the district level (Jaetzold and Schimdt, 1983). The AEZs indicate the land suitability for the major crops and their expected yields at different management levels. The Kenya Rangelands Ecological Monitoring Unit (KREMU) has carried out land use /land cover surveys for various districts using remote sensing techniques (Agatsiva and Mwendwa, 1982). These surveys are intended to provide planners and decision makers with knowledge on the abundance

and extent of the various land use types at different administrative units (i.e. divisions and locations). The Central Bureau of Statistics (CBS) collects and stores socio-economic data on which the National and District development plans are based. This information is updated yearly and published as annual statistical abstracts. The main role of a GIS is to integrate all these data and analyze them holistically, hence provide planners and policy makers with a more effective basis for decision making.

The types of data required for rural development planning include climatic and physical characteristics, environmental and natural resource data, agricultural productivity, population and human settlement patterns, and the distribution of socio-economic services and facilities, including physical infrastructure. Each of these categories is described further as it would appear in a database. Where data are available, complete database segments for these will be contained in the pilot database. For brevity, the complete database segments will not be included in the text. New data sets are continuously derived from the basic (primary) data through data manipulations and analyses.

4.6.2 Physical Characteristics Data

The main physical characteristics required for land-use planning are soils, climate and topographic characteristics.

1. Soil Information

Many of the soil properties which are important in land evaluation are normally collected during routine soil surveys. In Kenya, soil surveys have been conducted at four different levels. The Exploratory Soil Surveys cover the entire country in two scales. These coverage have been published as: (a) An outline of the major soil types in Kenya, 1:3M (Muchena et al., 1982) and (b) The Exploratory Soil Map and the Agro-climatic zone Map of Kenya, 1:1M (Sombroek et al, 1980). The next series are the Reconnaissance Soil Surveys at scales ranging from 1:100,000 to 1: 250,000 e.g. Soils and Vegetation of the Tsavo Area (van Wijnngaarden and van Engelen, 1985). The last two categories, semi-detailed and detailed soil surveys are large-scale surveys involving irrigation projects (Kanake, 1982) or individual farms (Shitaka, 1983). Other soil-related surveys include series on site evaluations, land suitability analysis, land utilization types, and soil resource management (Mwichebe, 1986).

Analysis of soil data can be used for classifying land according to productivity, erodibility, irrigation potential, ease of cultivation and potential to flood risks. This information is required in the determination of land capability/suitability classes and for management and conservation purposes.

Physical Properties of Soil

S_GROUP	S_NAME	S_DEPTH(cm)	DRAINAGE	S_TEXTURE
234 Pn	Feralsol	30	Well_D	Loamy-clay

Source: Jaetzold and Schimdt (1983)

Chemical Soil Properties

MAPPING UNIT	S_ph	CEC (me/100g)	ELEC. Cond (mmho/cm)	ESP
YP3	8.2	45.5	0.3	2
YA4	11.1	33.0	10.0	97.0

Source: Kanake (1982)

Chemical properties of soil provide information useful for various applications, including soil fertility determination, land suitability classification, soil management, pollution monitoring and feasibility studies for irrigation systems.

General indications about internal soil drainage and site wetness can be inferred from topographic maps, aerial photographs or satellite images. For most purposes, such indirectly obtained information is sufficient for evaluating land. Direct drainage measurements are rarely used except where they are of major importance such as in irrigation studies or where observations are relatively easy to make as of springs and floods (McRae and Burnham, 1981).

Some of the useful information on internal drainage characteristics include depth to water table, presence of springs and subsurface rivers. This information can be used

for various applications including land capability determination, aquifer capacity estimation, selection of bore hole sites, feasibility studies for irrigation and in monitoring changes in ground water table.

2. Climatic Data

Climatic data are usually available from meteorological agencies as maps and/or records of temperature, precipitation, and wind speed and direction.

Agro-Ecological Zones

ZONE	ALTITUDE (m)	TEMPERATURE °C	A_RAIN (mm)	L_RAIN (mm)	S_RAIN (mm)
Uncl.	0-300	24-30	Under 200	<100	<100
LH2	1800-1900	15-18	1200-140	530	500

Source: Jaetzold and Schimdt (1983)

These data can be used to determine mean (daily, monthly and annual) values for rainfall, temperature and evaporation. Soil moisture deficits i.e. the difference between precipitation and evapo-transpiration can also be determined from these data. Combination of climate and soil data will provide information useful for land capability/suitability determination.

3. Topographic Information

Altitude, slope (angle and length), aspect and position in the landscape are useful attributes in land capability determination. Topographic factors influence land capability through their effect on soil qualities such as erosion hazard,

ease of cultivation or mechanized farm operations. These characteristics are commonly incorporated into land evaluation systems by reference to critical values of slope angle or altitude (McRae and Burnham, 1981) which can be derived from contours on the topographic maps. Topographic factors are used for determining land capability classes, erosion/flood risk and control measures, and the various physical accessibility indices.

4.6.3 Natural Resource Data

Natural resources can be grouped into three broad categories namely: forests, minerals and wild life resources.

1. Forests

Data on forest resources can be organised in terms of individual forests highlighting both economic and environmental characteristics. More detailed forest data can be organized in terms of the spatial distribution of trees, particularly if aerial or satellite images are used as a source map.

Forest Data					
NAME	AREA (Ha)	CLASS (G/NG)	DOMINANT SPECIES and HEIGHTS (m)		
			Sp_1	Sp_2	Sp_3 etc.
Ngangao	55	G	Fir (20)	Cypress (25)	Wattle (15)

Source: Agatsiva and Mwendwa (1982)

data, areas which are inadequately served can be identified, and using population, topographic and infrastructure availability data, the most appropriate sites to locate new facilities or expand existing ones can be determined.

Distribution of Health Facilities

LOCATION	HOSPITALS	HEALTH CENTRES	DISPENSARIES	P/CLINICS
----------	-----------	----------------	--------------	-----------

Accessibility of Health Services

FACILITY	ATTENDANCE(p.m)		DOCS.PER	NURS.PER	BEDS PER
	out/p	in/p	1000	1000	1000

3. Educational Facilities

Educational facilities and services include physical infrastructure (number of schools, classroom spaces and status of auxiliary facilities such as laboratories, workshops and libraries, and services such as numbers and categories of teachers. Data on academic performances also provide useful planning information.

Distribution of Primary Education Facilities

DIVISION	NUMBER OF SCHOOLS	ENROLMENT		NUMBER OF TEACHERS	
		BOYS	GIRLS	TRAINED	UNTRAINED

2. Minerals

The best way to organize mineral resource data is according to the mining sites, highlighting information regarding type, value, ownership and extent of extraction.

Mining Sites

SITE	MINERAL	AREA	QUANTITY(Kgs)	Ext. of EXTRACTION

3. Wildlife Resources

Wildlife resources reside in different categories of Government- protected land reserves. Data required for the management and administration of wildlife resources could be organised in terms of parks as shown below, or according to spatial distribution of animal species.

Wildlife Management Data

NAME	AREA (Ha)	CLASS	CENSUS DATA		
			sp_A	sp_B	sp_C
Tsavo E					
Tsavo W					

Information on facilities available in different parks can be organised using point data and associated attribute files for use by park managers and tourism organizations.

4.6.4 Agricultural Productivity

Agriculture can be categorized into food crop, cash crop and livestock production. For the purposes of planning and management, three main kinds of information are required. First, it is necessary to know the ecological requirements for

each land-use. Second, planners would want to know the economic and/or the social value of the potential land-use categories. Finally, knowledge of the present distribution and extent of the various land-uses is also useful for land planning and management. In many cases, the first two types of information have been collected and documented (Acland, 1987; Jaetzold and Schimdt, 1983) including details on management practices (fertilizers and chemical requirements) for different varieties under specific ecological conditions. Data on current land-uses has to be collected regularly.

1. Food Production

Crop Requirements Data

CROP	S_TEXTURE	S_pH	S_DRAINAGE	RAINFALL (mm)	ALTITUDE (m)	TEMPERATURE (° C)
Maize(m)	L-M	5.5-8.0	WELL_D	750	1000-1700	25
Millet	M	5.0-8.0	WELL_D	625	< 1200	18

Source: Acland (1987)

The table above shows how the ecological requirements of different crops can be summarized. Information such as calorific and protein contents of different crops can also be included in this table for use in estimating food demands.

Farm Management Data Crop Beans

MAPPING UNIT	FERTILIZER TYPE	APPLICATION AMT.(kg)	COST(sh)	OTHER A(kg)	INPUTS B(lt) C(hr)	ESTIMATED YIELD(kg)
LM4	P ₂ O ₅	38	-	-	10 -	567

Source: Jaetzold and Schimdt (1983)

The information provided by the two tables above can be used by farmers and extension staff in determining land suitability and in estimating the land productivity (expected yields).

Calorie/Protein Demand Characteristics

Location	Population (in adult units)	Calories (KCl)	Total Demand	
			Proteins (Kg)	Energy (KCl)

From these data planners can determine the approximate food requirements for each planning zone using established per capita calorie/protein intakes. Information on food demand is a useful criterion for land-use allocation.

Land Allocation Data Land-use

LOCATION	AREA (Ha)	OPTIMUM DATE FOR PLANTING	HARVESTING	EXPECTED YIELD (kgs)
----------	--------------	------------------------------	------------	-------------------------

From ground survey techniques or using aerial and satellite image interpretations, the actual amount of land under each land-use can be determined. Combining this information with data on average yields, the expected yield can be determined. A comparison of the projected food demands and expected or predicted yields will enable planners to estimate deficiencies and surpluses, and thus plan for them in advance.

2. Cash Crop Production

Besides food production, agriculture is also the main source of rural income which is required for purchasing goods and services such as clothes, education and medical services. Information regarding the quantity, quality and location of cash crop production, particularly perishables such as horticultural products, will assist planners and policy makers in determining where to locate processing and preservation facilities, establish priorities for infrastructure investment such as roads, water supply systems and rural electrification.

Cash Crop Production Data Crop Name

LOCATION	AREA (Ha)	YIELD (kg/ha)	COST (sh/kg)	INCOME (Shs)

Most of these data would provide more accurate planning information if organized at higher resolution such as the parcel level.

3. Livestock Production

Livestock production is a major economic activity in the rural areas. In the high potential areas, intensive dairy farming is practised, while large scale communal or private ranches dominate the arid and semi-arid areas. Information on carrying capacity and productivity is essential for planning and management purposes.

Carrying Capacity Data

MAPPING UNIT	AREA (Ha)	RAINFALL (mm)	VEG_TYPE	C.CAPACITY (L.U)
--------------	--------------	------------------	----------	---------------------

Livestock Production

LOCATION	CATTLE (1 L.U)	GOATS (0.5L)	PIGS (0.6)	POULTRY ()	TOTAL INCOME (shs)
----------	-------------------	-----------------	---------------	----------------	-----------------------

Perishable livestock products, such as milk and eggs, require quick access to market or processing centres. Knowledge of the prime production centres will assist planners and prospective customers in planning marketing or processing strategies.

Livestock Production Data

LOCATION	MILK(lts) @ p sh/lt	EGGS @ q sh	HONEY(lts) @ r sh/lt	INCOME (shs)
----------	------------------------	----------------	-------------------------	-----------------

Livestock production data can also be organized in terms of individual ranches in the predominant ranching areas. Such data should highlight the sizes, detailed population (including age), and the available infrastructure such as boreholes, cattle dips, etc.

Distribution of Ranches

NAME	AREA (Ha)	POPULATION By AGE	GPS CALVES MID_AGE MKT_AGE	FACILITIES BOREHOLES CLINICS DIPS
------	--------------	-------------------	-------------------------------	--------------------------------------

4.6.5 Socio-Economic Data

Data on socio-economic characteristics and facilities can be organised in terms of administrative units or according to central places (settlement centres). Although most socio-economic data are collected according to administrative units, detailed analysis of the availability and adequacy of services and facilities can be done in terms of settlement centres.

Socio-economic data include demographic characteristics (population size, density distribution, growth), health, education, market centres (size, type, distribution, functions and activities), employment characteristics (type, distribution and size of employment opportunities and the labour force).

1. Demographic Data

Demographic data classified according to age cohorts is very useful in planning for future facility/service requirements, for example in projecting the number of school places or future labour force.

Population by Sex at Selected Age Groups

LOCATION	0 to 5		6 to 13		14 to 17		15 to 59		+60	
	(M)	(F)	(M)	(F)	(M)	(F)	(M)	(F)	(M)	(F)

2. Health Facilities

The purpose of these data are to enable planners and policy makers determine the levels of available medical and health services in absolute and relative terms. From these

data, areas which are inadequately served can be identified, and using population, topographic and infrastructure availability data, the most appropriate sites to locate new facilities or expand existing ones can be determined.

Distribution of Health Facilities

LOCATION	HOSPITALS	HEALTH CENTRES	DISPENSARIES	P/CLINICS
----------	-----------	----------------	--------------	-----------

Accessibility of Health Services

FACILITY	ATTENDANCE(p.m)		DOCS.PER	NURS.PER	BEDS PER
	out/p	in/p	1000	1000	1000

3. Educational Facilities

Educational facilities and services include physical infrastructure (number of schools, classroom spaces and status of auxiliary facilities such as laboratories, workshops and libraries, and services such as numbers and categories of teachers. Data on academic performances also provide useful planning information.

Distribution of Primary Education Facilities

DIVISION	NUMBER OF SCHOOLS	ENROLMENT		NUMBER OF TEACHERS	
		BOYS	GIRLS	TRAINED	UNTRAINED

Distribution of Secondary Schools

LOCATION	NUMBER	BOYS	GIRLS
Kimorigo	2	260	223
Chala	1	42	53

These data could be expressed in more detail using point type data using the name of the school as follows.

Secondary Schools Facilities/Services Availability

SCHOOL ENROLMENT CATEGORY	NUMBER OF TEACHERS	LAB./STUDENT
BOYS GIRLS (A,B,C)	TRAINED UNTRAINED	RATIO

4.6.6 Infrastructure and Linkages

The most appropriate method of analyzing the availability and sufficiency of infrastructure facilities and the linkages among them is by use of point and line data. Proximity and linkage strengths can be determined using network analysis models such as the gravity model.

1. Availability of Services

Distribution of Infrastructure Facilities

TOWN	ELECTRICITY	WATER	SEWERAGE	TELEPHONE
------	-------------	-------	----------	-----------

Distribution of Socio-Economic Services

LOCATION	BANKS	POST OFF.	POLICE POST	FACTORIES
----------	-------	-----------	-------------	-----------

These facilities/services can be inventoried according to classes for example water; piped water for each household (class 1), piped water from a communal collecting point (class 2), water from a borehole (class 3) and so on.

2. Economic Characteristics

Employment Characteristics

LOCATION	AGRIC.	ADMIN.	COMMERCIAL	INDUSTRY	SELF_EMPLOYED
----------	--------	--------	------------	----------	---------------

3. Transportation Facilities

Transportation infrastructure, particularly road linkages are key factors for rural development. Information regarding roads lengths, their classes, current condition, traffic volumes (passengers and goods), etc. form useful planning data.

Transportation Infrastructure

ROAD_NAME	CLASS	LENGTH	TYPE	CONDITION	DATE of REPAIR
Voi-Mtt	A23	18 km	Paved	Good	12-09-90
Mtt-Wund	C104	15.5	"	Fair	03-12-88

Source: Government of Kenya (1989)

4.6.7 Land Ownership Data

Land ownership or cadastral data can be organised according to the mode of registration i.e. as either fixed survey or general boundary plot. This broad classification, approximately fits in the rural-urban categorization.

1. Urban or Fixed Survey Plots

Name of Centre
Class

PLOT_No.	AREA(Ha)	TENURE	L_USE	OWNER	VALUE(sh)
----------	----------	--------	-------	-------	-----------

2. Rural or General Boundary Plots

Administrative Area
Registration Block

PLOT No.	AREA (Ha)	OWNER	TENURE	L_Use_CLASS
L_VALUE				

4.7 Conclusion

Almost without exception, data change with time. One of the advantages of the database approach is the ease with which data sets can be up-dated. However, this is an expensive task and in most cases the old data are not to be discarded. To make data up-date efficient, the initial database must be designed such that data update can take place with minimum interference with the entire database. The goal of database design is to create files that are "easy to maintain, update, modify and protect" (Chambers, 1989). Data items should be grouped according to how frequently they change such that up-dates can be done in terms of database segments rather than in a random manner.

As it has been pointed out, quality control of spatial databases is still in its infancy. At the present, little can

be done about this problem apart from increasing the awareness of project implementors and database developers about the sources of errors and exercising more caution during data capture and the entire analysis process. So far the only way to minimize data capture errors is through experience, use of good source data and avoiding fatigue or rushed jobs.

CHAPTER 5

DATA ANALYSIS TECHNIQUES

5.1 Introduction

The main objective of regional analysis is to give planners and policy makers an insight into the potentials and obstacles to increasing regional development. "Regional planners are interested in identifying marginal or peripheral areas that do not have sufficient numbers of central places to serve their residents, where access to functions is weak or non-existent, and where linkages among settlements are poorly developed" (Rondinelli, 1985:177). This information can then be combined with detailed sectoral economic and technical studies to produce regional investment strategies and identify specific projects relevant for specific areas. This chapter attempts to illustrate how such an insight can be obtained by applying the analytical capabilities of a GIS.

A GIS does not however replace the human function of value judgement in planning (Aronoff, 1989). Planners and policy makers must define the needs and values of the organization or society from which they develop the models for the analyses. The role of GIS in this process is to make planning and decision making more manageable for human beings by reducing the amount of data they have to interpret in order

to make decisions. Since computers are able to effectively deal with many more factors than human brains and process much information at the same time, this should lead to more comprehensive decisions, provided that good data are available and the objectives well selected. It is important that the operators understand and follow the analysis processes in order to be able to interpret the results correctly.

5.2 The Spatial Analysis Process

The analysis process begins with a user having a specific problem or query regarding some spatial phenomenon. There exists a database containing comprehensive data relevant to the user's query. All that is required is the operator to establish a link with the database that will generate information relevant to the user's problem. These links are provided by functions that convert data from one or more input sources into relevant output information. This process is summarized by the figure below.

This approach is adopted here as follows. First a potential planning problem is identified. The goals and objectives are then outlined and possible analysis processes and techniques capable of producing useful information concerning the problem discussed. Where possible the application will be demonstrated. The four main issues of rural development planning identified earlier will be used as a framework for these analyses.

Fig.5.1 The Analysis Process

5.3 Land-Use Analysis

Taita-Taveta district has two distinct zones; namely the highlands and the lowlands. The highlands, which form less than 30 per cent of the total land area, have a high potential for agriculture and produce most of the food requirements for the district. Horticultural crops, coffee and milk, most of which are marketed, are also produced in the highlands. Land scarcity is a major constraint to development in these areas. Intensive competition for high potential land by people and between land-uses has led to uneconomic sub-division of the available agricultural land. The resulting pressure on land has greatly contributed to low productivity, low returns and food shortages (Government of Kenya, 1989). One way of

addressing these problems is by adopting intensive farming methods in order to increase agricultural production per unit area.

In the lowlands, agriculture is constrained by inadequate water. Land is currently used for production of drought resistant crops and livestock rearing. The greater part of this land is occupied by national parks. It is difficult to practice irrigation in some parts (Voi and Mwatate) due to limited ground water potential, while in the Taveta area there is room for increasing production by fully exploiting the irrigation potential.

The GIS technology can assist planners and policy makers in carrying out the processes of land capability/suitability determination, land-use allocation, and in exploring alternative land-uses. Using the overlay and modelling operations planners can map and analyze the various factors that determine the "most appropriate land-use allocation". Determination of minimum economic units of land can assist planners in regulating land sub-divisions. Spatial analyses can also be used to select areas with potential for irrigation in the lowlands by estimating the volumes of available ground water resources. Some of the analytical operations and techniques for such processes are described below.

5.3.1 Interpolations

Interpolation is the procedure of predicting unknown values using the known values at neighbouring locations. The

neighbouring points may be regularly or irregularly spaced, and may come from a socio-economic survey or from accurate scientific measurement (levelling, trigonometric heighting or the direct output of a photogrammetric stereo plotter). Interpolation operations assume that the phenomenon being predicted (e.g. terrain elevation) is closely approximated by the mathematical function being used. The unknown values are then calculated according to this function. Two major interpolation techniques available in SPANS are contouring and potential mapping.

Contours are used to connect sets of points having the same numeric value or characteristics. Contours can be used to depict a wide range of spatially distributed characteristics including relief, climatic data and socio-economic information. In vector-based systems contours are depicted as lines while raster-based systems produce bands (raster images) between the isolines (vector lines) separating two consecutive classes. Burrough (1986) discusses some of the methods available for interpolating spatial data (Chapter 8). In the SPANS system point data are converted into contours using triangulated irregular networks (TIN) which join neighbouring points together creating irregular networks or Delauney triangles. Values within these triangles can then be determined either through linear or non-linear interpolation functions.

Potential mapping is a form of contouring which produces more smoothed out or averaged surfaces from point data. It starts with the assumption that the attribute values of any point are related to the attribute values of the points around it and that this effect is lessened the further away the data points are from the point being calculated (TYDAC, 1989).

The two modules, contouring and potential mapping do the same things. Contouring is more suitable for mapping scientifically measured data such as elevation and climate (rainfall and temperature) which are smooth and continuous, while potential mapping is favourable for mapping socio-economic data which are normally discrete and noisy (many inconsistencies) such as mapping income distributions or disease incidence. Several options are provided in the SPANS potential mapping module for smoothing out (eliminating) such noises or anomalies. A high resolution smoothing function can be selected to pick out and highlight local details or peculiarities in the data.

The SPANS contouring and potential mapping modules can be used to determine several quantities. The three most commonly used are the heights, slope and aspect. The height option simply produces a map showing all points with the same value (elevation, rainfall, temperature, income level, etc.). The two rainfall maps below (Map 5.1 & Map 5.2) were produced using the SPANS potmap and contour modules from the same data. The smoothing effect in the potmap example is very noticeable. The grey areas in both maps represent areas where data were not available.

Map 5.1

Annual Rainfall (Contour)

Map 5.2

Annual Rainfall (Potmap)

The slope function calculates and presents the rate of change of an attribute per linear change (gradient or rise/run) and gives the value as a percentage. Slope values can be used in many applications including land capability analysis, soil erosion measuring and in civil engineering designs. Map 5.3 is an example of a slope map produced from the slope option of the contour module.

The third option computes aspect. Aspect represents the direction of slope with respect to north measured as the azimuth of the normal to the slope. Aspect values give an indication of the time and period of exposure to sunlight. These values can be used by agriculturalists for seasonal land-use allocation for crops which are sensitive to the amount of sunshine, by recreation planners in locating recreation facilities or in feasibility studies for solar energy exploitation. Map 5.4 below is an example of an aspect map. In this map slopes are classified as north, east, south or west if the azimuth of the normal to the slope lies between 315-45, 45-135, 135-225 and 225-315 degrees respectively.

In all three operations, the user can query the maps to obtain the exact (cell) values of elevation, slope and aspect at the cursor. This method of querying provides more reliable values than those obtained via the classification legend using the 'Query At Cursor/Quadtree Class' command.

Map 5.3

Slope Map

Map 5.4

Aspect Map

Three other quantities can be determined using the SPANS contour/potmap modules namely: angle of incidence, and the X- and Y-derivatives. The angle of incidence calculates the angle between the sun's zenith angle (0° when the sun is overhead and 90° when the sun is at the horizon) and the normal (perpendicular) to the slope. This value is also likely to find some applications in solar energy research and implementation. The X- and Y-derivative calculates the change in slope between the point of observation in the X (East) or Y (North) directions. These quantities may have some useful applications in civil engineering (roads, sewerage and irrigation systems). The next three interpolation-based functions inter-visibility, illumination, and the perspective view, are not available in the SPANS system.

Inter-visibility functions or view-shed modelling determine the area that can be seen from a fixed point, i.e. the direct line-of-sight from specified target locations. Inter-visibility functions can be used to map the area visible from a scenic lookout, map the area that can be detected by a radar antenna, or assess how a road will be hidden from view for road design applications. This is a valuable function for such diverse applications as landscape and recreation planning, military planning and communications (Aronoff, 1989).

Illumination functions portray the effect of shining a light onto a three-dimensional surface. The three sets of

factors that control this function are the nature and position of the illumination source, topography and the reflectance of the surface, and the position and direction from which the model is viewed. Illumination operations are used in aiding human perception of spatial data by using three-dimensional surfaces. These surfaces need not represent elevation. Any data that behaves more or less as continuous surface can be used. Illumination functions can also be used to assess natural conditions such as how growing conditions will be affected by the quantity and direction of sunlight or determine the rate of vegetation regeneration as influenced by solar illumination conditions. The illumination function combines the aspect and incidence functions in a three dimensional model.

A surface portrayed from a viewing position other than vertical is termed a perspective view. Perspective views are also referred to as digital terrain models (DTMs) or digital elevation models (DEMs). They are useful in showing the three-dimensional context of features on a surface, such as a natural landscape. Whereas the vertical view tends to flatten the perceived relief, a perspective view exaggerates relief to emphasize surface features. These powerful presentation tools can also be used to highlight differences in socio-economic characteristics as was demonstrated by Taylor (1979) where he used a 3-D model to display average farm incomes in Muranga District. Perspective views could not be demonstrated

because the version of SPANS used cannot produce three dimensional models.

5.3.2 Overlay Operations

Most GIS software packages support arithmetic and logical overlay operations. Arithmetic overlays include operations such as addition, subtraction, division and multiplication of each value in the data layer by the value of the corresponding location in a second data layer. A logical overlay involves finding those areas where a specified set of conditions occur (or do not occur) together using Boolean algebra operations (AND/OR/NOT/XOR). Overlay operations have many applications in analysis involving site selections such as land suitability classifications.

The SPANS software supports four types of overlay operations. These are: direct two maps overlays (impose, stamp and join); matrix overlays (two maps); the indexing overlay (up to 15 maps); and overlay operations using user-defined functions during modelling. In the direct overlays the user has very little control of the outcome. The matrix and indexing overlays allow the user to control the output by defining the overlay criteria using the input maps. These are examples of mathematical overlays.

With the index overlay operation up to 15 maps can be combined according to user-specified conditions. The input maps are selected using the 'Overlays/Indexing/Make Template' command which creates a blank template to be used for specifying the overlay conditions. Table 5.1 below is a part of such a template after the overlay conditions were specified. These conditions were used to create the map showing suitable areas for maize cultivation (Map 5.5).

The five maps used are: alt1 = altitude, temp1 = temperature, rainpot = rainfall, dral = soil drainage and sph1 = soil pH. The first column in Table 5.1 represents the attribute classes from the map legend. The values in the second column are class numbers and the third column represents the user-defined intra-class weighting criteria, referred to as the legend rank. The ranking in this column specifies the order of importance i.e. how the classes within the map are to be prioritized. The higher the value, the greater the importance. Negative values can be used to show un-desirability, where the greater the value in magnitude the more undesirable the class is. Inter-class priority is defined by the class weight shown as a percentage. These values, found in the title row of each map (30.000 and 5.000 in Table 5.1), are also fixed by the user.

Table 5.1
Indexing Overlay Input File

```
:new mapid & title : maize   Suitability For Maize Cultivation
```

```
: no of Input Maps : 5
```

```
: Input Maps (Id Max Colour)
```

```
alt1 10   templ    9   rainpot    5   dral 6   sph1 5
```

```
:
```

```
: Format = Weight   Map ID   Title
```

```
30.000    alt1    :    alt1
```

```
:          -      0:    0
```

```
:0         -      1:    1
```

```
:0-300     -      2:    1
```

```
:1800-190  -      3:    1
```

```
:1370-168  -      4:    4
```

```
:1220-152  -      5:    6
```

```
:920-1220  -      6:    9
```

```
:790-980   -      7:    6
```

```
:300-600   -      8:    4
```

```
:600-790   -      9:    1
```

```
:200-350   -     10:    1
```

```
5.000     templ    :    templ
```

```
:          -      0:    0
```

```
:0         -      1:    1
```

```
:24-30     -      2:    1
```

```
:15-18     -      3:    2
```

```
:18-20     -      4:    6
```

```
:18-21     -      5:    7
```

The classes for the new map are calculated at each quad cell through the 'Overlays/Indexing/Build Quadtrees' command as follows:

$$\text{cell value} = (\text{weight of map1} \times \text{rank of legend} + \text{weight of map2} \times \text{rank of map2} + \dots) / \text{total weight}$$

This is done for each cell within the map to produce an indexing scale which will range between the lowest negative value assigned to the highest positive ranking assigned.

5.3.3 Area Analysis

The 'Area Analysis/Single Map' command determines and reports areas from a map according to map classes. For example the area of each suitability class in Map 5.5 can be obtained using this command. Alternatively, the 'Area Analysis/Two-Map X-Tab' command which computes class areas in one map and reports the results according to the units (boundaries) of another map can be used. For example planners may want to determine the potential (in terms of area) for each administrative division to produce maize. This is done by reporting the area results of Map 5.5 using administrative boundaries (Map 5.6). The results are summarized by the report shown below (Table 5.2). Assuming that the planners know or can determine the yield of each suitability class in tonnes/hectare, the expected yield from each division can be estimated.

Table 5.2

Area Analysis: Cross-Tabulation

Row : maize - Areas Suitable for Maize Cultivation
 Col : admdiv - TAITA DISTRICT - DIVISIONAL BOUNDARIES

Window: 00 - Universe

Contingency Coefficient 0.4719
 Tschuprow's T 0.2348
 Cramer's V 0.3091

Area (km sq)

Total %

Row %

Col %

		TVT	MTT	VOI	WUND	Total
In	5	32.1	91.6	70.3	87.9	281.9
		0.19	0.54	0.41	0.51	1.65
		11.40	32.50	24.93	31.17	
		0.81	3.30	0.75	9.25	
.						
.						
In	1	245.8	60.3	1755.3	0.0	2061.4
		1.44	0.35	10.29	0.00	12.08
		11.93	2.93	85.15	0.00	
		6.16	2.17	18.77	0.00	
Total		3989.5	2775.4	9350.8	945.9	17065.5
		23.38	16.26	54.79	5.57	

Map 5.5 Maize Cultivation Suitability Map

Map 5.6 DIVISIONAL BOUNDARIES

5.3.4 Modelling

Modelling functions combine spatial and non-spatial attribute data in the database to answer questions about real world issues using models. These models may be represented in words, mathematical equations, or as a set of spatial relations displayed as a map. The advantage of using models is that they can be tested and manipulated more conveniently and less expensively than the conditions they mimic (Aronoff, 1989). Models can be used to test alternative scenarios or to predict the causes and/or the consequences of proposed actions or possible occurrences. The information obtained can assist planners in selecting the best alternative or in designing the necessary precaution or control measure.

There are three types of modelling applications in SPANS referred to as area based modelling, point modelling and attribute modelling. All modelling equations are written in a file called "Equation.inp" in the universe (directory) and are accessed via their unique identifiers. A typical equation takes the following form:

```

E eqid Title For Equation
: First comment
a1 = [var1];
a2 = [var2];
.
: Second comment
an = [varn];
val = f(a1, a2, ..., an)
val

```

Where, E identifies the beginning of every new equation and eqid is a unique identifier of each equation.

5.3.5 Area-based modelling

Area-based modelling use data from existing maps to create new maps based on user-specified mathematical concepts to simulate real life situations. The equations are accessed using the 'Modelling/Unique Conditions' or 'Modelling/Quad By Quad' commands. These commands compute at each cell (quad) the value of the modelling equation and produce a map containing as many "unique" valued quads (cells) as the equation produces. The user is required to provide a classification scheme to classify (generalize) the new map.

There are many possible situations one can use this function. Theoretically, as long as a relationship can be expressed mathematically and the maps and/or attribute tables are available in the database, a modelling application is possible. The map below (Map 5.7) shows the ratio of temperature to precipitation obtained from a simple modelling equation shown below.

```
E evapo Evapo-transpiration Rate
t = [dtemp];
p = [anrainpo];
e = t/p;
e
```

5.3.6 Point Based Modelling

Point modelling is a way of creating new point data based on some specified criteria. Two commands are used in point modelling, Points/In Quadtree and Points/Density Sample. Both commands use the "result" function which appends

a column or columns of attributes from the modelling equation to a point file.

The 'Modelling/Points/In Quadtree' command uses a function known as "select" to create subsets of point files by performing conditional searches on existing maps. The user defines the selecting criteria using a conditional statement of the general form:

```
(select if<condition 1> and <condition 2>, etc., Omit)
```

The selected attributes are then stored in newly created point file using the result function. This operation is a form of a logical overlay. Other attributes can also be added to the created point file from existing quadtree maps, specified columns of attribute tables, or directly from modelling expressions.

```
result ([map ID] or [table, 3] or <expression>)
```

For example planners may be interested in finding all highly productive farms which are not easily accessible i.e. all farms with output more than 1000 kgs., and are more than 4 km from the main road. The equation for this would be:

```
E frm_1000 Inaccessible Productive Farms
(select if [road] >=4 and [farm] >=1000 and [base], omit)
```

This equation will search the road and farm maps within the base area for the conditions specified. From the point file generated, a new map can be created to show the location of the farms meeting the user's conditions.

The 'Modelling/Points/Density Sample' command generates gridded point files based on a density sample defined by the

user. Attributes can then be appended to these grid points using the result function. The new point files can be used for other applications such as contouring or exported as ASCII files for use with other software packages outside SPANS.

The equation below was used to create 20 km square grids in the base map area and append altitude, rainfall and temperature values from the maps [elev], [anrainpo] and [temp] to the resulting point file.

```
E elev1 Grid Creation
{20 if [base], 0};
result (20, [elevs], [anrainpo], [temp])
```

The altitude map (Map 5.8) below is a contour output from the elevation column of the point file created by the equation above. Point grids can also be created for only certain specified portions of a map. The equation below will create 10 square metre grids on only those areas where the crown closure (CC) density is 1-30% (identified as Class 1).

```
E grid_30 Grid For CC 1-30%
x = (0.01 if [closure] == 1, 0);
result (x, [height,1], [road,1])
```

Map 5.7

Temperature, Rainfall Ratio

Map 5.8

Altitude Zones (Contour)

5.4 Resource Analysis

The main purpose of resource analysis is to provide guidelines for more efficient extraction and management of natural resources. Environmental Impact Assessment (EIA) studies can also be included under resource analysis. The five resources of interest to a rural development planner are soil, water, forests, minerals and wildlife resources. The information required for planning and managing purposes can be broadly categorized as the location of the resource (where are the resources ?), the extent or size of the resource (what is the area, volume or population ?), its quality (the various classes or categories), and the various competing uses for the resources. Resource analyses can be performed using overlays, modelling and measurement functions.

5.4.1 Forest Resources

The Department of Forestry aims at demonstrating to the local people how trees can be integrated into farming systems (agro-forestry) as a means for promoting self-sufficiency in fuelwood requirements and to promote soil and water conservation practices. It is also concerned with protecting and re-vegetating all Government lands for environmental conservation and future economic utilization of the forest resources on a sustainable yield basis (Government of Kenya, 1989).

Planning and managing forest resources comprise analyses ranging from simple area calculations to complex

modelling of the effect of destroying a forest on the water catchment. Estimation of timber volumes, harvest times or selection of which trees to interplant with which crops are some of the possible applications.

5.4.2 Mineral Resources

Taita District has a very high potential in mineral resources, some of which are being exploited and others are yet to be identified and exploited (Government of Kenya, 1989). The most significant constraint in the mining sector pertains to lack of proper information on all the deposits in the district. Mining activities occur in a very disorganized way. Proper survey and organized prospecting need to be instituted. Marketing of the minerals needs to be organized in such a way that the local people can benefit from these resources.

The GIS technology can be used for maintaining a complete and up to date inventory of all mineral deposits in the district. In mineral prospecting studies, the modelling functions can be used to predict the likelihood of getting specific minerals based on geological, topographic and vegetation characteristics.

5.4.3 Wildlife Resources

About 62 per cent of the land in Taita District is occupied by National Parks. The wildlife resources found in these parks are a major source of the country's foreign exchange earnings. In 1988, the country earned over 300

million Kenya pounds from tourism (Government of Kenya, 1989b). Proper inventorying of these resources can be done using the GIS technology. Species can be mapped according to their spatial distribution, population, migration habits and population changes. Such information can be used for protecting the endangered species or for investigating the possibility of harvesting some species to supplement protein demands. This information could also assist planners in dealing with conflict between human beings and wildlife, which is a major problem in the areas around the national parks. Inventorying the facilities available in different parks and monitoring the distribution of visitors is another management task which could benefit from GIS application.

The main operations required for resource management are the 'Area/Analysis' and 'Modelling/Attribute' commands.

5.4.4 Attribute Based Modelling

Attribute modelling is a method of creating statistical reports relating the attributes of one map to reporting units of another using in-built functions (range, mean, weighted centroid, max./min. values, etc.) available in SPANS. To use these functions the user inputs equations of the general form:

function [attribute map] by [reporting map]

This equation takes the selected function, applies it to the attribute map/table and reports the results according to the chosen output map. For example a forest manager may want to determine the mean height of different tree species. The

equation below will be used to compute and report this information:

mean [height,1] by [species]

The equation above takes the tree height values from the first column of an attribute table "height", computes the mean according to each species and report the results in a tabular form.

Area based modelling can also be used for more complex assessments such as the economic value, volume or the costs of harvesting and transportation. To illustrate this, a modelling equation from the SPANS manual is used. The equation below calculates the dollar value (val) for harvesting aspen trees from different land parcels based on the volume of aspen in the field (vol), the cost of harvesting (hc) and transporting the wood (tc) and the going dollar value for aspen wood on the market. The equation is written as follows:

```

E nvalue Aspen Value Model $/Ha
: k1 = Cost/Cu.M/Km.
  k1 = 0.05;
: k2 = Value of 1 Cu.M
  k2 = 15;
: k3 = The harvest cost of 1 tree yielding 1Cu.M
: k3 = 3;
: a = Loading cost/Cu.M
  a = 2;
  b = [roads,1];
  c = [mill,1];
: hmax = Maximum height of trees
  hmax = 30;
: Sp = Tree species
  sp = [species];
  sm = [drainage,1];
  Ascfc = [capable,1];
  scfc = [capable,3];
  hgt = [height,1];
  h2 = pow(hgt,2);
  vol = h2/2 * Ascfc * (Sp==7);
  hc = pow((hmax - hgt),0.5) * scfc * sm * (Sp==7) * k3;
  tc = (a + (3 * b + c) * k1);
  val = vol * (k2 - hc - tc);
  val

```


This equation combines many factors including distance from the forest to the main road [road,1], distance from the main road to the saw mill [mill,1], ecological site factor (Ascf and scf), etc., to produce a map showing the costs of harvesting aspen trees from different areas.

5.4.5 Soil and Water Conservation

Soil and water conservation is a major concern in the district. Excessive cultivation of land in the highlands and rapid deforestation are greatly contributing to this problem. Several conservation measures are being undertaken including digging of bench terraces, contour bunds and trenches, check weirs and gabion walls and cut-off drains (Government of Kenya, 1989). Analytical capabilities of GIS can be used to assist conservationists in determining the sizes and strengths of such physical barriers, according to topographic, causal and land-use factors. Using the universal soil loss equation, different cropping and erosion conservation practices can be tested and the most appropriate ones applied.

Applications of GIS technology in soil and water management is at a very advanced stage. The Integrated Land and Watershed Management Information System (ILWIS) discussed by Valenzuela and de Brouwer (1988) is one example. This system was designed to produce actual and estimated future erosion scenarios depending on land suitability factors, crop types, farming practices and erosion susceptibility, among

others. Other applications include assessment of soil moisture deficit (van Lanen and Bouma, 1988) and modelling of salt leaching by simulation to estimate the amount of water needed for a desired level of desalinization or to give an estimate of the extent of leaching accomplished by a given quantity of water (Anlauf, et al., 1988).

5.4.6 Spread Function

The spread function is a powerful operation that can be used to analyze a wide range of phenomena such as defining drainage basins or flood plains by spreading from a point and allowing movement only to adjacent cells with specified elevation or evaluating transport time or cost over a complex surface (Aronoff, 1989). The spread function combines the characteristics of proximity and network functions. This application can be used for predicting the likelihood and the extent of destruction of a flood using rainfall and terrain data.

The ANSWERS (Areal Non-point Source Watershed Environment Response Simulation) system described by de Roo (1988) is an example of the application of the spread function. This system is used for modelling run off and soil erosion by simulating the behaviour of a predominantly agricultural watershed immediately after a rainfall. The primary application of this model is in planning and evaluating various strategies for controlling surface run-offs and sediment transport from intensively cropped areas.

This model can also be used for predicting the speed and extent of spread of a flood.

5.5 Settlement Systems Analysis

There are three district hospitals, 22 rural health centres and dispensaries and 11 non-governmental organizations offering out-patient medical services in Taita District. These facilities are not adequate for the growing population in the district. Worse still, the distribution of these facilities is not even and most of them lack the essential equipment and personnel necessary for them to be able to render the required services (Government of Kenya, 1989). The same problems confront the education sector. Some of the main constraints to the provision of these vital services are: a) long distances to health/education facilities, b) inadequate facilities and infrastructure in most of these institutions, c) inadequate qualified personnel, d) bad terrain which limits expansion or accessibility, e) inadequate information on diseases, and f) low income levels making it difficult for some people to use existing services/facilities.

In most cases information about the levels of these services is scanty and/or inaccessible. Use of a GIS can reduce these problems by enabling the distribution of these services to be inventoried, analyzed and presented spatially. Integrating this information with demographic and other socio-economic information will enable planners to assess

the level of sufficiency and project future demands for the services. Spatially displayed data on socio-economic characteristics could also allow researchers and policy makers to recognize some important patterns and relationships such as geographical concentrations of disease occurrences and water quality, the relationship between pass rate and distance to school and many others.

Some of the functions available for dealing with such problems include attribute query functions which allow the user to compare the classes or conditions from different maps interactively, measurement and classification operations, and point-/line-in-polygon analysis.

5.5.1 Attribute Query Functions

Attribute query functions retrieve records from the attribute data base according to conditions specified by the user. Query functions range from simple retrievals such as finding the class assigned to a selected polygon to complex queries that involve selective searches of specified attributes in one or more data layers and the generation of reports that summarize the results. The complexity of the query function is very much dependent on the data structure used. A well structured database will allow the user to perform queries in an ad hoc manner, using very basic (English-like) commands, and will perform the queries at a relatively high speed. The structured query language (SQL) is

one of the popular query languages supported by relational database management systems (Westwood and Brinkman, Undated).

In SPANS, data querying is done interactively using the 'Display - Query' command. Three options are available. The first option 'Display/Query At Cursor/ Quadtree Class' is used for "viewing" several maps at the same time. Up to ten maps can be stacked on top of the other and the attribute class on each map displayed simultaneously at any point. The geographical (latitude and longitude) and projection (e.g UTM) coordinates at the cursor (point being queried) are displayed together with the attribute classes (Fig.5.2).

Fig.5.2 Querying Quadtree Classes

The second option 'Display/Query At Cursor/Distance' computes and displays the distance between cursor locations on a map cumulatively as the cursor is moved. The third option 'Display/Query At Cursor/Modelling' calculates the results of a modelling equation instantly at a specified location selected with the cursor and displays the results on the screen. These operations are not strictly query operations, they are in fact display operations. The "select"

function described above is more of a query operation than these.

5.5.2 Modelling

Modelling operations can be used to compute and map numerical socio-economic indicators. This can either be done directly with the Modelling commands and user-defined equations or by the in-built 'Area Analysis/Attribute/Function' command. Examples of information which can be derived this way include economic indicators such as income, inflation, unemployment and agriculture/industrial production indices, health indicators such as birth rates, number of hospital beds/1000, life expectancy and disease occurrences.

5.5.3 Proximity Measurements

Proximity is a measure of the distance between features. Mostly this is measured in units of length, but other units such as travel time or noise levels can be used. Four parameters must be specified in order to measure proximity (Aronoff, 1989):

- a) the target locations (e.g. a road, a hospital, a park);
- b) unit of measure (e.g. distance in metres, travel time in minutes, noise levels in decibels or pollution levels in parts per million);
- c) a function to calculate proximity (e.g. straight line distance, travel time); and
- d) the area to be analyzed.

In SPANS analysis can only be performed on areal data. For proximity type of analysis, point data has to be transformed into areal data by either the 'Point/Circle' the 'Point/To Voronoi' commands.

Creation of Thiessen's polygons or voronoi diagrams (Burrough, 1986) is a technique for determining proximity by defining areas of influence around sets of points based on the shortest straight line distances. The polygons are constructed in such a way that the polygon boundaries are equidistant from the neighbouring points so that each location within a polygon is closer to its contained point than to any other point. Thiessen's polygons can be used in the analysis of climatic data and in the determination of zones of influence for socio-economic facilities such as schools and medical services, where the shortest distance is the main accessibility factor.

Map 5.9 below is an example of a voronoi map produced with SPANS. Let us suppose that in this map the black dots represent the centres for some kind of service such as schools, health centres or milk cooling centres. The 'Area Analysis' report (Table 5.3) indicates the potential area each of these centres would serve, assuming that physical access is the only factor to consider. Combining this information with other demographic and topographic characteristics, planners can determine where to locate new services or which of the existing ones need be expanded.

Table 5.3
Single Map Area Analysis

Map : townfvor - townsvor

Window : 00 - Universe

Class Legend	Area (%)	Cum Area	Area (km sq)
1.KILOMETA	5.34	5.34	914.0
2.KITOBO	0.26	5.62	47.3
3.ELDORO	0.38	6.00	65.1
4.KIMORIGO	0.24	6.25	41.8
.			
.			
30.NDOME	3.00	90.81	513.7
31.GHAZI	9.19	100.00	1571.3
<hr/>			
Total of 31 classes	100.00		17105.0

The 'Point To/Circle' command creates a series of concentric circles around a point using user-defined radii. For example to determine the number of households living within 1, 5 and 10 km away from a facility, a buffer map such as Map 5.10 below is created and then overlaid to a map containing distribution of households and an appropriate counting function such as the neighbourhood or point-in-polygon analysis applied. Map 5.10 is an enlargement of the central area of the same point map used to create Map 5.9.

Map 5.9

Urban (Service) Centres

Map 5.10

Proximity To Service Centres

5.5.4 Neighbourhood Operations

Neighbourhood operations such as "search" evaluate the characteristics of the area surrounding a specified location, e.g. counting the number of people living within a 5 km radius to hospital. These functions require the specification of at least three basic parameters: one or more target locations, a specification of the neighbourhood around each target, and a function to be performed on the element within the neighbourhood. If for example we wanted to find the number of people living within 5 km from a hospital the process will proceed as follows:

Target = Hospital
Neighbourhood = 5 Km radius
Function = No. of People

Using the 'Point To/Circle' command, a 5 km radius circle is drawn around the hospital. This map is then overlaid on the population density map as shown below.

Fig.5.3 Neighbourhood Calculation

$$\text{No. of People} = A1 \cdot D1 + A2 \cdot D2 + A3 \cdot D3$$

Where A_i = intersecting area at i , and

D_i = population density at i .

5.5.5 Polygon Analyses

Line-in-polygon and point-in-polygon analyses are specialized search functions which allow users to identify point or line with specified characteristics within a polygon(s) e.g. find all boarding schools in the district or determine the total length of class A roads in the district. This operation could not be carried out using SPANS.

5.6 Spatial Linkage Analysis

Among other things, development in Taita-Taveta District depends on the establishment of basic infrastructure to link effectively the agricultural sector and the towns (central places). There is a need to develop new roads in the agricultural areas as well as maintain the already existing ones. The lack of basic infrastructure is a major constraint to transportation and marketing of produce in the urban centres. The state of roads to these centres and to factories is either poor or completely missing (Government of Kenya, 1989). Lack of processing/preserving facilities has constrained the growth of horticulture and dairy industries.

In planning for infrastructure development, three basic questions need be asked: What spatial linkages are available (from where to where)?, What flows along these linkages (goods, services and people), and How effective are these linkages (load, number of linkages and economic benefits). Planners and policy makers are interested in knowing the pattern of flow of agricultural products, farm inputs and

other commodities and the movement of human beings to service and employment centres. From this information they can determine the key networks and decide where new linkages are required or expansions are necessary.

GISs have been used in planning and managing transportation systems, particularly in urban areas. Shortest path algorithms are used for laying out optimal bus lines and for efficient routing of service vehicles. In the rural context, these capabilities can be used in determining the location of processing and preservation facilities for perishable (dairy and horticultural) products, in assigning routes to produce collection and veterinary services trucks. Network analyses can be used to establish proximal areas around service centres such as schools, markets or health centres on the basis of minimum travel time or distance thresholds (Yapa, 1988).

5.6.1 Water Supply Systems

There are ample water sources in the highlands including permanent streams, rivers and springs. In the lowlands, water is scarcely available from seasonal rivers, dams, boreholes and shallow wells (Government of Kenya, 1989). The main towns and some market centres have been provided with water. Efforts are being made to provide water to most centres and communities who have to travel for long distances in search for water by sinking bore holes and constructing dams.

GIS technology can be used in designing and managing the infrastructure required for delivering water. By superimposing settlement distributions on maps of water supply (sewerage, electricity or telephone) systems, planners can compare infrastructure capacity with the demand for the resources. By converting zoning maps into maps of potential demand and incorporate them into analysis models, possible overloads can be identified. Planners can then play 'what ifs' by substituting different zoning proposals and development scenarios. Feasibility studies for irrigation systems can also benefit from the modelling capabilities of a GIS.

5.6.2 Energy Supply

Energy is a vital component for development. Woodfuel, biogas and electricity are the commonly used sources of energy in Taita District. Woodfuel (firewood and charcoal), form more than 90 per cent of the total energy consumption (Government of Kenya, 1989). Wood cutting has consistently conflicted with afforestation programmes. Unless the demand for wood is reduced, the District will require over 217,000 tonnes of wood per annum by the end of 1993. The use of biogas, which is currently very low, should be encouraged. In the highlands this can be done by encouraging intensive dairy farming methods (zero-grazing), to increase the amount of animal wastes trapped.

Electricity is mainly used in the major towns. It would be beneficial to extend its use to most towns and centres in order to promote small-scale rural industrialization. Other sources of energy mainly solar and wind, need to be developed. Solar energy has been introduced in some secondary schools and it seems to be doing quite well (Government of Kenya, 1989). The use of these forms of energy should be promoted since they do not conflict with afforestation efforts. Promotion of electricity in the rural areas is being undertaken through the Rural Electrification Programme.

Spatial analysis could be used in planning and prioritizing energy development programmes. Such programmes range from deciding which areas to electrify first, planning afforestation programmes, determining areas where use of biogas is feasible, assessing the feasibility of exploiting wind energy from wind records or for selecting sites for buildings designed to use solar energy using aspect and incidence measurements.

5.6.3 Measurement Functions

Spatial measurements include determination of distances between points, length of lines, perimeters and areas of polygons, and the sizes of group cells with the same class. Being a raster-based system, SPANS has limited capabilities for linear or vector-type measurements. Attributes such as polygon perimeters or road lengths cannot be determined. Distance estimates can however be obtained using the

'Display/Query At Cursor/Distance' command. This command calculates the distance between cursor locations on the map.

The 'Arc To/Corridor' command is used for converting lines or vectors to areas by generating buffers or corridors along them at user specified distances before the maps are used for analysis.

5.6.4 Network Analysis

A network is a set of inter-connected line features that form a pattern such as roads, rivers, irrigation canals, electricity supply lines or telephone lines. A GIS can be used to perform three principal types of network analyses: prediction of network load, for example in predicting the amount of water and sediment in a river system to monitor erosion and flood risk; route optimization, used in emergency or supply vehicles routing; and in resource allocation e.g. zoning of an area into easily serviced portions (Aronoff, 1989). Irrigation feasibility studies can be carried out using network analysis operations. Planners can determine the most efficient canal route or the volume of water at any specific point.

5.7 Conclusion

Demonstration of the analytical capabilities was constrained by three main factors. The first constraint was lack of data. Second, most of the mathematical models required for modelling-type operations were not readily available. Furthermore, to use some of these models, such as

the universal soil equation, several constants have to be determined through calibration. Finally, the process was also constrained by some system limitations. The inability of SPANS to incorporate point and linear data in the analyses reduces its capability to deal with proximity and network type of analyses, which are very useful for assessing the adequacy of services/facilities and the presence/strengths of spatial linkages. Linkage analysis can be performed much more easily using topologically structured vector data as opposed to raster data.

Regional planning involves large volumes of data. Some memory limitation problems were experienced. Although theoretically one can overlay up to fifteen maps (using index overlays), in practice this may not be possible unless the maps are very simple. Theoretically, contouring applications allow a maximum of 1,500 points. The system could not, however, handle 1000 points. The study area could only be covered by 776 points produced by a 20 by 20 km grid. A data set with such a distribution may not be good enough for most practical analyses.

However, from the few examples given, and the evidence from the other studies discussed, it is evident that the GIS technology, in general, can be applied to most of the rural development issues identified.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Observations and Conclusions

The main aim of this study was to investigate the applicability of GIS technology to integrated rural development planning by developing and implementing an experimental database. The first three of the four stated objectives of the study were achieved. The fourth, and perhaps the most important objective, could not be satisfactorily attained due to data limitations. It was difficult to obtain most of the data at the desired format and level of aggregation. Most of the data available were in highly aggregate forms (national or regional level) while the study required data broken down to the administrative location or lower levels. This problem was further complicated by the inability to obtain models or parameters needed to implement some readily available models such as the soil erosion model. Due to these limitations, only a few examples were used to demonstrate the applications. Finally, it is very difficult to demonstrate the power of a digital database on paper.

The study has, however, shown that the multi-faceted problem of rural development planning which requires, among other things, large volumes of data and complex analyses

spanning a wide range of disciplines stands to benefit greatly from the integration and analysis features of GIS. The overlay and modelling operations available in SPANS were found to have many potential applications in land-use planning and resource management.

It was also observed that the ability to analyze linear and point data (proximity and network analyses) is very important in rural development planning. Analysis of availability and adequacy of services and spatial linkages, which were identified as major components of rural development, require these functions.

Rural or regional planning demands large data storage and computational facilities. Despite the growth in micro-computer power, from the experience obtained in this study, it can be concluded that micro-based GIS may not be suitable for regional planning application due to memory limitations. The use of more powerful operating systems such as the IBM's OS2 or the AT&T's UNIX system may provide a solution to these memory related problems.

Finally, the study concludes that, while the potential for rural development planning to benefit from the GIS technology is high, several conditions must be satisfied before these benefits are realized. First, the choice of the system is very critical. This is a very tricky problem for an application as broad as rural development planning. Grid-based (raster) systems are known to be very efficient for natural

resource data, which cover a significant proportion of rural development planning. At the same time, spatial linkages and related analysis, also key to rural development planning, demand vector-based systems. At the moment, very few systems, if any, would be powerful for both applications. Second, comprehensive data bases must be developed before any meaningful outputs can be obtained. Third, analysis models must be developed and a multi-disciplinary planning team must be involved in the planning. No single planner with the most powerful GIS can deal with the complex rural development planning problem.

6.2 Prospects for Implementation

In implementing any new technology three basic questions are always asked. First, is the technology applicable ? Second, do the benefits of the technology outweigh the costs? Third, are there adequate structures and facilities such as power supply, maintenance personnel and spare parts to support the technology ? The fact that computers can do almost everything makes it quite easy to answer the first question. However, the same factor makes it almost impossible to answer the second question. It is not easy to estimate, for the purpose of carrying out a cost-benefit analysis, the benefits which will arise from the computerisation of any organisation. This is because it is not possible to foresee all the new applications which will be made possible by the introduction of the new technology. The answer to this question is therefore more or less a matter of opinion.

Computers in general have become a commonplace technology. They are being widely used in business and industry, even in third world countries. GIS applications should not be an exception. There are three organizations in Kenya using this technology at the moment, and a fourth one is in the process of acquiring one. The Global Environmental Monitoring System (GEMS) at the UNEP headquarters in Nairobi, the ECA's Regional Centre for Surveying and Remote Sensing (RCSRS) facility also based in Nairobi and the Kenya's Department for Resource Surveys and Remote Sensing (formerly KREMU) are the current operational GIS facilities. The Department of Survey in the Ministry of Lands, which is responsible for all topographic and cadastral mapping, is in the process of installing a GIS at its mapping branch in the Nairobi headquarters. It is therefore valid to conclude that GIS technology is beginning to grow in Kenya, and if the case for their suitability and applicability to rural development planning can be proved, there is undoubtedly an adequate and steadily growing support for the technology.

Finally, in my view the Executive Committee of the DDC forms the desired multi-disciplinary planning team. This committee is composed of highly trained officers from all sectors involved in rural development. These officers can easily adopt and effectively utilize the technology without enormous amounts of training. All that is required is an operator to link the team with the technology.

6.3 Recommendations

The study recommends the use of GIS technology for rural development planning for the following reasons. First, the technology may enable planners and policy makers to make use of data which they could otherwise not be able to do due to volume and analytical limitations. For example, the incorporation of weather prediction information in the analysis of land capability/suitability may help agricultural extension staff advise farmers on most appropriate land-use practice on a season by season basis rather than using obsolete information found in publications.

Second, the technology provides an ideal framework for data integration. Data integration in GIS will provide an incentive to different organizations to standardize data collection methods, thereby increasing data availability while lowering data collection and storage costs by reducing duplication.

Finally, the GIS technology may streamline the organizational problems arising from lack of coordination and piecemeal decision making by different organizations without considerations of complementing or conflicting activities from other sectors. The inter-dependency of the various subsystems comprising rural development planning, and the society at large, cannot be over-emphasized. These inter-dependencies and inter-relationships can be exploited through effective inter-disciplinary communication linkages, which a GIS provides.

To support the growth of GIS industry, more training and research are required. Training in GIS applications should be introduced in educational curricula at both university and college levels. Research in the design of efficient databases and the evaluation and control of errors in spatial databases are areas requiring immediate attention.

REFERENCES

- Acland, J.D (1987) East African Crops. Longman.
- Agatsiva, J. L and H. Mwendwa (1982) Land Use Mapping in Kenya Using Remote Sensing Techniques. KREMU Technical Report No. 72. Nairobi.
- Ahmad, Yusuf J. and Frank G. Muller (1982) Integrated Physical, Socio-economic and Environmental Planning.
- Anlauf, R. et al. (1988) Regional Modelling of Salt Leaching. In "Land Qualities in Space and Time", Buoma, J and A.K Bregt (eds) Proceedings of a Symposium organized by the International Society of Soil Science (ISSS), Wageningen, The Netherlands, 22-26 August 1988.
- Aronoff, Stan (1989) Geographic Information Systems: A Management Perspective. WDL Publications, Ottawa, Canada. 294p.
- Bailey, R.G (1988) Problems With Using Overlay Mapping for Planning and Their Implications for Geographic Information Systems, Environmental Management, Vol.12, No.1, pp.11-17.
- Blais, J.A.R (ed) Lecture Notes in Digital Mapping and Land Information. The University of Calgary, 1987.
- Blakemore, M. (1983) Generalization and Error in Spatial Databases, Proceedings, Sixth Annual Symposium on Automated Cartography, Ottawa, pp.313-322.
- Brookes, H.P. et al, (1982) Information Systems Design. Prentice Hall of Australia.
- Brouwer, Floor. (1987) Integrated Environmental Modelling: Design and Tools. Martinus Nijhoff Publishers, Dordrecht.
- Bulski, Wojciech (1986) Data Sources, Standards and Quality Control for a GEMS-GRID Kenyan Case Study. UNEP, Nairobi.
- Buoma, J and A.K Bregt (eds) Land Qualities in Space and Time. Proceedings of a Symposium organized by the International Society of Soil Science (ISSS), Wageningen, The Netherlands, 22-26 August 1988.
- Burrough, P.A (1986) Principles of Geographic Information Systems for Land Resource Management. Oxford University Press, Oxford U.K 193p.

Burnham, C.P and S.G McRae (1981) Land Evaluation. Clarendon Press, Oxford.

Chambers, Don (1989) Overview of GIS Database Design. Arc News Vol.11, No.2

Chambers, R (1988) Rural Development: Putting the Last First. Longman, U.K.

Cheema, Shabbir G and Dennis A. Rondinelli (eds) Decentralization and Development: Policies Implementation in developing Countries. Sage Publications Inc., UNCRD 1983.

Chrisman, N.R (1982) A Theory of Cartographic Error and Its Measurement in Digital Databases, Proceedings, Fifth International Symposium on Computer-Assisted Cartography, Crystal City, pp.159-168.

_____ (1984) The Role of Quality Information in The Long-term Functioning of a Geographic Information System, Cartographica, Vol.21, No.2, pp.79-87.

_____ (1987) Efficient Digitizing Through The Combination of Appropriate Hardware and Software for Error Detection and Editing, International Journal of Geographic Information Systems, Vol.1, No.3, pp.265-277.

Conyers, D (1986) Decentralization and Development: A Framework for Analysis. Community Development Journal 21, pp.88-100

C.R.D, (1979) Methodology Study and Development of a Database for Rural Land Evaluation in Ontario. University of Guelph, Publication No.93.

Date, C.J (1986) An Introduction to Database Systems. Fourth edition (reprinted in 1988). Addison-Wesley Publishing Company. Reading, Massachusetts.

Dangermond, J. et al, (1982) Description of Techniques for Automation of Natural Resource Inventories. Environment Systems Research Institute, Redlands California.

DCDSTF, (1988) The Proposed Standard for Digital Cartographic Data, The American Cartographer, Vol.15, No.1, pp.129-135.

de Roo, A.P.J (1988) Modelling Water Erosion Hazard As A Land Quality. In "Land Qualities in Space and Time", Buoma, J and A.K Bregt (eds) Proceedings of a Symposium organized by the International Society of Soil Science (ISSS), Wageningen, The Netherlands, 22-26 August 1988.

Dickinson, Holly J. and Hugh W. Calkins (1988) The Economic Evaluation of Implementing Geographic Information Systems.

International Journal of Geographical Information Systems.
Vol.2, No.4 pp 307-327.

Feuchtwanger, Martin (1985) An Investigation of Efficient Computer Techniques for Storage and Retrieval of Land-Related Information. Msc. Thesis, The University of Calgary. USCE Report No. 20010. 88p.

Gecola, Rome H. (1988) Information Systems For Rural Development. Information Systems for Government and Business: Trends, Issues and Policies, pp 423-431. UNCRD, Nagoya Japan.

Giaoutzi, M and P. Nijkamp (eds) Informatics and Regional Development. Gower Publishing Company. pp 259-344.

Goodchild, M and S.Gopal (eds) The Accuracy of Spatial Databases. Taylor and Francis, London 1989.

Goodchild, M.F and B.R Rizzo (1987) Performance Evaluation and Workload Estimation For Geographic Information Systems. International Journal of Geographical Information Systems.vol.1, No.1, pp 67-76.

Gore, Charles (1984) Regions in Question: Space, Development Theory and Regional Policy. Methuen, New York.

Goulet, Denis (1989) Participation in Development : New Avenues. World Development, Vol.17, No.2, pp.165-178.

Government of Kenya (1965) Sessional Paper No. 1 ." African Socialism and its Application To Planning in Kenya ". Government Printers, Nairobi.

_____ (1982) Development Plan 1983-88. Government Printer, Nairobi.

_____ (1982b) Report and Recommendations of The Working Party on Government Expenditure. The Ndegwa Commission. Government Printer, Nairobi.

_____ (1983) District Focus for Rural Development. Office of The President, Nairobi.

_____ (1986) Sessional Paper No.1 " Economic Management for Renewed Growth ". Government Printer, Nairobi,

_____ (1989) Taita-Taveta District Development Plan, 1989-1994. Government Printer, Nairobi.

_____ (1989b) Development Plan 1989-94. Government Printer, Nairobi.

Guptill, S.C. (ed) (1988) A Process for Evaluating Geographic Information Systems. Technology Exchange Working Group. Technical Report 1. USGS.

Guptill, S.C (1989) Evaluating Geographic Information Systems Technology. Photogrammetric Engineering and Remote Sensing. vol. 55, No.11, pp 1583-1587

Jaetzold, R and H. Schimdt (1983) Farm Management Handbook of Kenya, vol.II, Natural Conditions and Farm Management Information. Ministry of Agriculture, Rossdorf.

Jenks, G.F. (1981) Lines, Computers, and Human Frailties, Annals of The Association of American Geographers, Vol.71, No.1, pp.1-10.

Kanake, P.J.K (1982) Semi-detailed soil survey of Kimorigo/Kamleza Irrigation Schemes - Taveta (Taita-Taveta District)

Klosterman, Richard E (1988) Micro-computer Technology and Regional Planning: Prospects and Challenges for The Developing World. Information Systems for Government and Business: Trends, Issues and Challenges. UNCRD, Nagoya Japan.

Lang, R (1988) Planning for Integrated Development, in "Integrated Rural Planning and Development" F. W Dykeman (ed).

Lele, Uma (1975) The Design of Rural Development. Baltimore, John Hopkins Universty Press

Lisk, F.A.N (1981) Popular Participation in Basic Needs Oriented Development Planning, in Labour and Society (Geneva), Vol.No.1

Litton, G.M (1987) An Introduction To Database Management: A Practical Approach, Wm C Brown Publishers

Lodwick, G.D and M Feuchtwanger (1987) Land-Related Information System, Lecture Notes, The University of Calgary, UCSE Report No.10010.

Mackenzie, F and D.R.F Taylor (1987) "District Focus as a Strategy for Rural Development in Kenya". Canadian Journal of Development Studies. vol.8, No.2 pp

Maffini, G. et al. (1989) Observations and Comments on the Generation and Treatment of Error in Digital GIS Data, in "Accuracy of Spatial Databases" Goodchild, M and S. Gopal (eds.), Taylor and Francis, London.

Marble, D.F, et al., (eds) Proceedings of the First International Symposium on Spatial Data Handling. Zurich 1984

Marble, D.F, et al., (1984) Basic Readings in Geographic Information Systems. SPAD Systems Ltd, Williamsville, New York.

Marble, D.F and S.E Amundson (1988) Microcomputer-based Geographic Information Systems and their Role in Urban and Regional Planning. Environment and Planning B: Planning and Design, volume 15, pp.305-324.

Mason, T.J, et al. (1975) Atlas of Cancer Mortality for U.S. Counties: 1950-1969, DHEW. Publ.No.(NIH) 75-780. U.S. Govt. Printing Office, Washington, D.C.

McCall, Michael (1988) The Implications of Eastern African Rural Social Structure for Local Level Development: The Case for Participatory Development Based on Indigenous Knowledge Systems. Regional Development Dialogue. vol.9 No.2 pp 41-69.

McRae, Stephen D (1989) GIS Design and The Questions Users Should be Asking. Proceedings of GIS/LIS '89, Orlando, Florida Nov. 26-30
pp. 528-537

Minerbi, Luciano (1986) Notes on Integrated Area Development, Communication and Information Systems. Information Systems for Urban and Regional Planning: Asian and Pacific Perspectives. UNCRD, Nagoya Japan.

Morgan, R.P.C. (1986) Soil Erosion and Conservation. Longman, U.K

Muchena, F.N et al, (1982) An Outline of the Major Soils in Kenya (with a generalized soil map at scale 1:3M). Kenya soil Survey, Nairobi.

Mussa-Nda, N (1988) Rural Development Challenge For the 1990's: A Great Role for Local Development Strategies. Regional Development Dialogue, vol.9, No.2 pp. 1-10.

Mwichebe, S (1986) The Present Land-Use of The Narok Area (Narok District), Kenya Soil Survey, Miscellaneous Report No.M31

Nijkamp, Peter and Piet Rietveld (eds) Information Systems for Integrated Regional Planning. Elsevier Science Publishers, North Holland. 1984.

Ngethe, N (1987) "African Rural Reconstruction and the Role of a Local Strategy: The Case of Kenya ". Paper presented at a seminar of Eastern Africa Rural Development Experience: strategies in Local Development. 30th June to 3rd July, Nairobi.

NRC (1980) Need for A Multipurpose Cadastre: Panel on a Multipurpose Cadastre, Committee on Geodesy, Assembly of Mathematical and Physical Science, National Research Council. National Academy Press. Washington, DC.

Oakley, P and D Marsden (1984) Approaches to Participation in Rural Development. ILO, Geneva.

Obudho, R.A et al (1988) The District Focus Policy for Rural Development in Kenya: An Empirical Approach of Bottom-up Concept. African Development Policy. UNCRD pp 158-188.

Obudho, R. A (1983) Urbanization in Kenya. University Press of America.

Obudho, R.A and D.R.F. Taylor (eds.) (1979) The Spatial Structure of Development: A Study of Kenya. A Westview Replica Edition.

Openshaw, S (1989) Learning to Live With Errors in Spatial Databases. In "Accuracy of Spatial Databases" Goodchild, M and S. Gopal (eds.), Taylor and Francis, London.

Otawa, T. (1987) Accuracy of Digitizing: Overlooked Factor in GIS Operations, Proceedings, GIS'87, San Francisco, pp.295-299.

Oxborrow, Elizabeth (1986) Databases and Data Systems: Concepts and Issues. Chartwell-Bratt

Parker, H.D (1989) GIS Software 1989: A Survey and Commentary Photogrammetric Engineering and Remote Sensing Vol.55, No.11, pp. 1589-1591

Peuquet, D and J. O'Callaghan (1983) Design and Implementation of Computer Based Geographic Information Systems. New York, Amherst.

Peuquet, D.J (1984) " A Conceptual Framework and Comparison of Spatial Data Models". Cartographica. vol. 21, No.4, pp 66-113.

Rondinelli, D.A (1985) Applied Methods of Regional Analysis: The Spatial Dimensions of Development Policy. Westview, Boulder

Rondinelli, D.A (1983) *Secondary Cities in Developing Countries: Policies for Diffusing Urbanization*, Sage, Beverly Hills.

Rondinelli, D.A and H Evans (1983) "Integrated Regional Development Planning: Linking Urban Centres and Rural Areas in Bolivia," World Development, vol.11, No.1, pp. 31-54

Rondinelli, D.A et al. (1983) *Decentralization in Developing Countries: A Review of Recent Experience*. World Bank Staff Working Papers 581, The World Bank, Washington D.C

Rondinelli, D.A and K Ruddle (1978) *Urbanization and Rural Development: A Spatial Policy for Equitable Growth*. Praeger, New York.

Rose, Wolf-Dieter (1988) *Remarks on the Economics of Computer - assisted Cartography and Geographical Information Systems. Proceedings of Euro Carto seven*, Enschede. The Netherlands, 20-22 September, pp 87-95.

Roy, P and B.R Patil (1977) *Manual for Block Level Planning*. The Macmillan Company, New Delhi.

Ruddle, K and D Rondinelli (1983) *Transforming Natural resources for Human Development: A Resource System Approach to Development Policy*. United Nations University Press, Tokyo.

Sazanami, H (1986) *Assessing the Context for Information Systems for Urban and Regional Planning in Developing Countries. Information Systems for Urban and Regional Planning: Asian and Pacific Perspectives*. UNCRD, Nagoya Japan.

Shitakha, F.M. (1983) *Detailed soil survey of the Coffee Research Station Ruiru (Kiambu District)*. Kenya Soil Survey, Nairobi.

Sundaram, K.V (1988) *Changing Data and Information Needs for Agricultural Planning: The Challenges for Developing Countries. Information Systems for Government and Business: Trends, Issues and Challenges*. UNCRD, Nagoya Japan.

Smith, T.R et al. (1987) *Requirements and Principles for The Implementation of Large-scale Geographic Information System. International Journal of Geographic Information Systems*. Vol.1, No.1 pp 13-31.

Sombroek, W.G et al, (1982) *The Exploratory Soil map and Agro-climatic Zone Map of Kenya, 1980, Scale 1:1M* Kenya Soil Survey, Nairobi.

Taylor, D.R.F (1974) The Role of the Smaller Urban Place in Development: The Case of Kenya, in Urbanization, National Development, and Regional Planning in Africa. Edited by Salah El-Shakhs and Robert Obudho, Praeger Publishers, New York.

Taylor, D.R.F (1979) Spatial Apects of The Development Process. In "The Spatial Structure of Development: A Study of Kenya", Obudho, R.A and D.R.F. Taylor (eds.) A Westview Replica Edition.

Tomlinson, R.F and A.R Boyle (1981) The State of Development of Systems for Handling Natural Resource Inventory Data. Cartographica. vol. 18, No.4 , pp 65-95.

Tsichritzis, D.C and F.H Lochovsky (1982) Data Models. Englewood Cliffs, New Jersey.

UNCRD, (1986) Information Systems for Urban and Regional Planning: Asian and Pacific Perspectives. UNCRD, Nagoya Japan.

UNCRD, (1988) The Challenges for Developing Countries. Information Systems for Government and Business: Trends, Issues and Challenges. UNCRD, Nagoya Japan.

Unwin, T (1989) Urban-Rural Interaction in Developing Countries: A Theoretical Perspective. In " The Geography of Urban-Rural Interactions in Developing Countries. Robert B. Potter and Tim Unwin (Eds.) Routledge, London.

Valenzuela, C.R and H. de Brouwer (1988) Future Land Use Modelling Using The Integrated Land and Watershed Management Information Sytems (ILWIS).

In "Land Qualities in Space and Time", Buoma, J and A.K Bregt (eds) Proceedings of a Symposium organized by the International Society of Soil Science (ISSS), Wageningen, The Netherlands, 22-26 August 1988.

van Lanen, H.A.J and J.Buoma (1988) Assessment of Soil Moisture Deficit and Soil Aeration By Quantitative as Opposed to Qualitative Methods.

In "Land Qualities in Space and Time", Buoma, J and A.K Bregt (eds) Proceedings of a Symposium organized by the International Society of Soil Science (ISSS), Wageningen, The Netherlands, 22-26 August 1988.

van Wijngaarden and van Engele (eds) (1985) Soil and vegetation of the Tsavo area; (quarter degree sheets 175, 176, 183, 184, 190, 191, 196 and 197); scale 1:250,000; in cooperation with WOTRO, The Nertherlands.

Veregin, H (1989) Error modelling for the Map Overlay Operation. In "Accuracy of Spatial Databases" Goodchild, M and S. Gopal (eds.), Taylor and Francis, London.

TYDAC (1989) SPANS User Manuals, TYDAC Technologies Inc.

Vitek, J.D et al. (1984) Accuracy in Geographic Information Systems: An Assessment of Inherent and Operational Errors, Proceedings, PECORA IX, pp.296-302.

Walsh, S.J et al. (1987) Recognition and Assessment of Error in Geographic Information Systems, Photogrammetric Engineering and Remote Sensing, Vol.53, No.10, pp.1423-1430.

Westood, K and J Brinkman (undated) Toward The Successful of Relational and Quadtree Structures in a Geographic Information System, GeoVision Corporation.

Wischmeier, W.H (1976) Use and Misuse of the Universal Soil Loss Equation. J.Soil and Water Conservation, 26, pp.189-193.

World Bank (1978) World Development Report 1978. Washington.

Yapa, L.S (1988) Computer-Aided Regional Planning: A Study in a Rural Sri Lankan Experience. Environment and Planning B: Planning and Design vol. 15 pp 285-304

_____ (1989) Low-Cost Map Overlay Analysis Using Computer-Aided Design. Environment and Planning B: Planning and Design vol.16 pp 377-391

END

06-03-92

FIN