DEVELOPING A SPATIAL DATA INFRASTRUCTURE FOR RWANDA:

Case Study of Land Administration Sector

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by

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Disclaimer

The work described in this dissertation was carried at the Centre for Environment, Agriculture and Development, University of KwaZulu-Natal, Pietermaritzburg, from November 2006 to July 2007, under the supervision of Dr Denis Rugege.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma at any other University. Where use has been made of the work of others, it is duly acknowledged in the text.

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Abstract

Governments all over the world are being challenged to develop Spatial Data Infrastructure (SDI), to improve the access and use of spatial data for decision support and sustainable development. Therefore, SDI is part of the basic infrastructure that needs to be efficiently implemented and managed in the interest of any nation. The aim of this study, therefore, is to assess the feasibility of SDI implementation in Rwanda, using the Land administration geospatial data sector as a case study, given time constraints of the research.

To achieve this, the concept of SDI is firstly explained in order to provide a common understanding of the concept. The new trends in the new Land Administration System of Rwanda, with emphasis on spatial data management are also presented. This information is generated from various written materials. Field work was also conducted by means of questionnaires, interviews and observation in attempt to assess Land Administration geospatial data, related assets and gaps with reference to SDI framework requirements. A situational analysis is carried out from the field work results.

The research sets the scene providing the major findings. The main spatial data providers are public and based on national level. Land use and cadastral related spatial data are the least developed, and Land Administration application data are quiet non-existent. Various users, mainly decision makers, exist but lack effective access to data. A number of challenges, such as a high duplication of data collection and maintenance, lack of appropriate ways of data sharing, a shortage of human resources in Geo-information, absence of policies and regulations, are also found in the Land Administration spatial data sector. Nevertheless, the new Land Administration System orientations and national priorities in terms of information technology, offer a favourable environment for the implementation of SDI. Having considered this, the research proceeds to propose a Land Administration SDI prototype with its main application of Spatial Data discovery Facility, and then highlights its benefits. The research ends with a conclusion and recommendations for future research.

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Last but not least, thanks to my beloved son Ivan COMFORT MANZI for his patience when he couldn't enjoy the full presence of his mother.

Abbreviations and acronyms

ANZLIC	Australian and New Zealand Land Information Council
CD-ROM	Read-Only Memory Compact Disc
CEAD	Centre for Environment, Agriculture and Development
CGDI	Canadian Geospatial Data Infrastructure
CGI	Common Gateway Interface
CGIS-NUR	Centre of Geographic Information System and Remote Sensing of the National University of Rwanda
DEM	Digital Elevation Model
DFGFI	Dian Fossey Gorilla Fund International
DFID	Department for International Development (United Kingdom)
EIS-AFRICA	Environmental Information System for Africa
ELECTROGAZ	Public institution for production, transport and distribution of electricity, water and gas
ESRI	Environmental System Research Institute
FAO	Food and Agriculture Organization of the United Nations
FGDC	Federal Geographic Data Committee
FIG	International Federation of Surveyors
GIS	Geographic Information System
GPS	Global Position System
HSRC	Human Sciences Research Council
ICT	Information and Communication Technology
ISNAR	International, Service for National Agriculture Research
IT	Information Technology
KFW	*Kreditanstalt für Wiederaufbau*
LA-SDDF	Land Administration Spatial Data Discovery Facility
LAS	Land Administration System
LIS	Land Information System
MINECOFIN	Ministry of Finance and Economic Planning
MINEDUC	Ministry of Education
MINICOM	Ministry of Commerce, Industry, Investment Promotion and Exports, Tourism and Cooperatives

MINITERE	Ministry of Land, Environment, Forestry, Water and Mine
MINITRACO	Ministry of Transport and Communication
MOLA	Meeting of Officials in Land Administration
NELSAP	Nile Basin Initiative
NISR	National Institute of Statistics of Rwanda
NLC	National Land Centre
NSDI	National Spatial Data Infrastructure
NSIF	National Spatial Data Infrastructure Framework
NUFFIC	Netherlands Organization for International Cooperation in Higher Education
NUR	National University of Rwanda
OGC	Open GIS Consortium
OGMR	Rwandan Office of Mine and Geology
PCGIAP	Permanent Committee on Geographic Information for Asia and the Pacific
PICG	International Programme of Gorilla Conservation
RDGG	Rwanda Development Gateway Group
RITA	Rwanda Information Technology Authority
SDI	Spatial Data Infrastructure
SIDA/ SAREC	Swedish International Development Cooperation Agency/Department for Research Cooperation
SKE	Spatial Knowledge Engineering
UK	United Kingdom
UNECA	United Nations Economic Commission for Africa
UN-ECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
US	United States
USAID	United State Agency for international Development
WCS	Wildlife Conservation Society

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Background

There is an increasing demand for use and access to spatial information in Rwanda as in other parts of the world, and consequently too the need for an efficient way to provide a better access to data. The country however, is still facing problems regarding spatial data availability, low accessibility, duplicity of collection, varying accuracies, absence of data sharing mechanisms, and others. An establishment of a Spatial Data Infrastructure (SDI) can bring sustainable solutions to all these issues.

SDI has been defined differently by various authors. What comes out of all definitions is the fact that SDI is the framework of elements that are needed by a community in order to make effective production, management, dissemination and use of spatial data (Groot and McLaughlin 2000; United Nation Economic Commission of Africa (UNECA) 2004; Federal Geographic Data Committee (FGDC) 2006; Geo Connection Programme 2006). Based on those definitions, and in the same line of UNECA (2004), the goal of SDI is to reduce duplication and costs of capturing spatial data, to make them more accessible to all users; to allow data sharing which is extremely important and to increase the benefits of using available data.

Basing on the early activities of United State's FGDC in the 1990s, the development of SDI has evolved as a central driving force in the management of spatial information over the last decade (FGDC, 2006). However, the current situation in Rwanda shows that more time is needed in order to meet the requirements of SDI framework as specified in the SDI implementation guide or Cookbook produced by the Global Spatial Infrastructure (GSDI); that is fundamental data, technology, policy and institutional arrangement, human resources and standards (GSDI, 2004). It is therefore imperative to take a step forward and start with an assessment of constraints in one sector which can play a role of a driver as is the case of Land Administration in this study.

As pointed out by the Rwandan Ministry of Land, Environment, Forestry, Water and Mine (MINITERE), the spatial data sector in the country is still dominated by the traditional system of data management characterised by hardcopy maps with their attributes organised in a separate documents files, manual data entry and updating (MINITERE, 2002). With time, the system will be unsuitable for handling a huge amount of spatial data available on a daily basis (Chou, 1997). Furthermore, such a system favours duplication of effort and financial means in data capturing and maintenance, given the standalone producers; therefore, it does not guarantee easy access to data and its availability. In concurrence with Dale and McLaughlin, (1999) data should be produced once and used by all users, given that no single agency can satisfy its spatial data on its own. Since spatial data is an expensive resource, it is important to foster efficient production, use and management of spatial data by means of SDI.

The establishment of a SDI and use of Geographic Information System (GIS) tool can offer significant solutions to the above problems. Thus, using SDI as a framework (Core spatial data Technology, policy and Institutional Framework, People, Standards and Metadata) (UNECA, 2004) and GIS as a tool facilitating data collection and storage, as well as facilitating in decision making (Chou, 1997), can play an important role in solving spatial data related issues.

Like other African countries, Rwanda has enthusiastically taken its first step towards the establishment of a National Spatial Data Infrastructure (NSDI). However, the country is facing a big gap in terms of requisite requirements for implementing a NSDI. Constraints related to technology, standards, policies, and human resources, poor partnership within institutions, core data and their custodians need to be addressed to allow an operational NSDI. It is sometimes necessary to go ahead and do things rather than wait for things to happen. This study does not pretend to design a NSDI of Rwanda, given the limitations faced by the Researcher in terms of time, funding and expertise. The research will be limited to the Land Administration field. The Researcher will conduct a preliminary assessment of the existing constraints and propose a SDI prototype for Land Administration. Then, the benefits of the prototype will be presented. While SDI plays a much broader role than supporting Land Administration, this could be considered as a key driver in SDI evolution in Rwanda.

Spatial data is the cornerstone of Land Administration components, which are land registration, land valuation, boundaries demarcation, zoning and land use planning related data (Dale and McLaughlin, 1999). Furthermore, it is stipulated in the new Rwandan Land Policy that a key component of an efficient LA is the management of land and property related data (MINITERE, 2004). Thus, the Land policy provides for an establishment of a Land Information Management institution as a strategic option.

However, the Rwandan Land Administration System has been characterised by the absence of land registry spatial data, especially in rural areas, and land use related data. Furthermore, the existing cadastre is only available in urban areas and is mostly paper and manual procedures based (MINITERE, 2004). As one of the pillars of the new Land Reform initiated in April 2006, the new Land Administration System (LAS) will be based on a modern cadastral system. Moreover, it has provided for the establishment of a National Land Centre (NLC) which will maintain the National Land registrar spatial database (MINITERE, 2004). According to the latter, the Centre will not only be in charge of collection, updating and maintaining Land Administration spatial data related, but will also ensure access and sharing to all stakeholders and different users.

The perspectives of the National Land Policy on the Land Centre encourage SDI development, and constitute our main motivation to conduct a study in this area. The Land Administration SDI prototype which will be proposed by the Researcher could be adapted by major land management organisations such as the NLC. This is in line with Bishop et al. (2000), who states that from the Bangkok experience, SDI and GIS have helped to improve the efficiency of Land Administration and urban management activities.

1.2 The problem statement

Land Administration is supposed to play a fundamental role in meeting the goals of the Rwandan development agenda which includes poverty reduction, economic growth, conflict prevention and management, and the fight against land degradation. However, the Rwandan Land Administration System, which is currently in its early stage of implementation, cannot achieve that mission, owing to various land issues such as the crucial spatial data management. To illustrate, one can point out problems such as land registry data that has gaps in towns and non-existing in rural areas, not updated, paper based data, low accessibility, different accuracy, varying standards (incompatible data), high cost of data. It is important to note the duplicity of data collection and maintenance of some geospatial data. This is the case of spatial database currently held by the National University, the Ministry of Infrastructure, the Ministry of Agriculture and Animal Resources, the MINITERE, the National Centre of Statistics, some Districts and Municipalities, and some non governmental organisations in Rwanda (Rurangwa, 2004).

Data accessibility is also critical, the use of available spatial data is sometimes restricted to a few institutions; therefore data sharing and other institutional arrangements are critical. The legal framework does not provide anything about information access. Article 34 of the National Constitution only stipulates the right of freedom of information (Parliament of Rwanda, 2003). Due to limited resources available to the country, and the need for collaboration and partnership in spatial data collection, access, dissemination, management and usage; it is imperative to promote an efficient and effective use of resources by developing a mechanism to improve access and sharing of existing data.

Rwanda has acknowledged a strong need for the establishment of a NSDI. However, due to limitations of resources, the country cannot start developing the whole NSDI, but would rather do it step by step. It is rightly argued that, to develop SDI in a perfect way, in cases of insufficiency of resources, some components can be developed initially (UNECA, 2004). It is also advisable to begin developing SDI in one of its major applications such as Land Administration (Bossler, 2002).

1.3 Research hypothesis

The establishment of SDI framework and use of GIS as a tool for collection and storage of Land Administration related spatial data in Rwanda, is facing various constraints related to technology, policy, standards, institutional arrangement and human resources.

1.4 Research objectives

1.4.1 Main objective

The overall objective is to examine the feasibility for the establishment of SDI in Rwanda with the case study of Land Administration geo-spatial data sector. The study will first assess gaps and assets related to that sector using the guideline of SDI requirements. Secondly, it will demonstrate the feasibility to implement a proposed Land Administration SDI prototype and the benefits it can generate.

1.4.2 Sub-objectives

1. To identify and describe components, drivers and best practices of SDI in Africa.
2. To describe interrelationships and interaction between Geographic Information System.
3. To identify various institutions providing fundamental spatial data for LA and their users.
4. To assess gaps and assets related to provided spatial data with focus on SDI requirements.
5. To propose a Land Administration SDI prototype and the benefits it can bring.

1.5 Research questions

1. What is SDI, what are its components, drivers and best practices in Africa?
2. What kind of relationships and interaction existing between GIS and SDI?
3. What are the institutions providing and or maintaining fundamental spatial datasets needed for Land Administration?
4. What sort of spatial datasets are produced and or maintained?
5. What are different users and how do they access data?
6. What kind of issues are related to data capturing, storing, updating, access, and sharing?
7. What are the current assets and gaps of SDI implementation policies and institutional aspects for Land Administration (policies, partnership, legal framework, funds, and human resources)?

8. What are the current assets and gaps of SDI implementation technological aspects for Land Administration (data, standards, GIS infrastructure, and internet and network connectivity)?
9. How can Land Administration SDI prototype be implemented and what benefits can be derived from it?

1.6 Conceptual framework

A review of SDI regional initiatives, early national initiatives and current SDI best practices in Africa was carried out for the purpose of this study. These include Australian and New Zealand Land Information Council (ANZLIC), Permanent Committee on Geographic Information for Asia and the Pacific (PCGIAP), UNECA, and Australian, United State of America, Nigeria and South African SDI. Moreover, SDI implementation Guideline and SDI Cookbook, products of respectively UNECA and GSDI were used. Finally, a review of other SDI literature was done. A general framework of SDI concept was extracted from these, which will guide the assessment in order to find out constraints and readiness. It will also inspire what proposed SDI prototype should look like (components, institutional arrangements and technological aspects). Figure 1-1 summarises SDI general framework components.

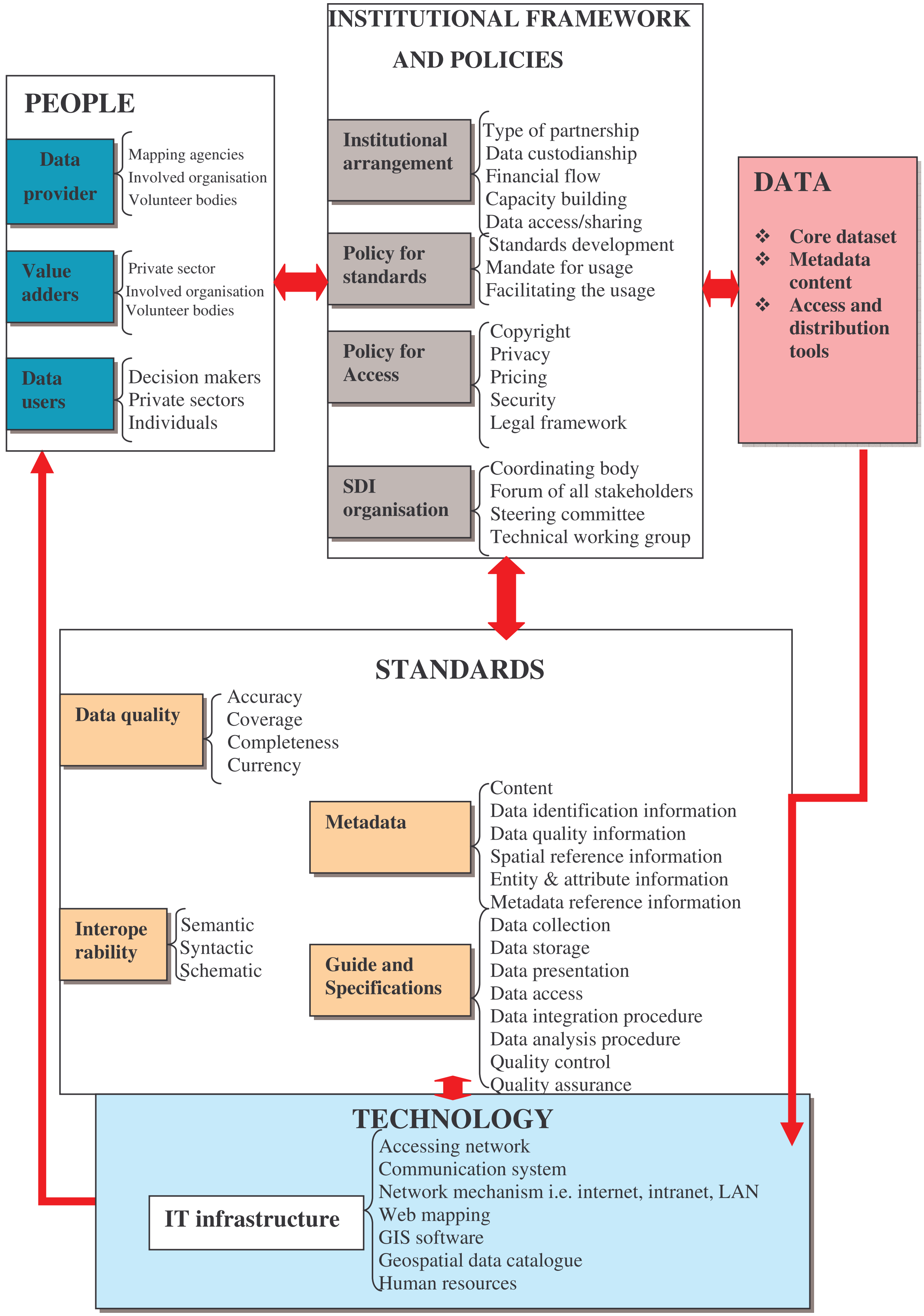


Figure 1-1: SDI conceptual framework adapted (UNECA, 2004, GSDI, 2004, Groot and McLaughlin, 2000)

The conceptual framework was used as a guide to assess Land Administration spatial data environment. It includes five main components which are spatial data, people, policies and institutional framework, standards and technology (UNECA, 2004; GSDI, 2004; Groot and McLaughlin, 2000). As described by these authors, Figure 1.1 shows three categories with respect to the people component. These are data providers composed mainly of data custodians, value adders or different organisations or institutions that develop their application data, and different users.

In the context of policies and institutional framework components, appropriate policies are required to facilitate data production and sharing. In this respect, policies for standards, copyright, privacy, pricing, capacity building and institutional arrangement are required to facilitate participation of organisations in SDI initiatives. The legal framework encompasses the approved copyright and privacy laws and other relevant laws. Institutional arrangements with respect to data custodianship, financial flow, type of partnership; are needed to facilitate partnership by removing institutional barriers. An appropriate organization for SDI is required to coordinate and follow SDI activities. The SDI coordinating body should be able to mandate relevant SDI approvals to other participants.

Spatial data is a central component of a SDI. Fundamental or core datasets, the one used for many different purposes and many different application; must be clearly defined.

Metadata, interoperability, data quality and guide and specification are important requirements that need to be standardised with respect to the standard component. Interoperability is an important subject that needs to be emphasized in the context of the standards component. It is the ability of the system to provide information sharing (Groot and McLaughlin, 2000). There should be no heterogeneity between data custodians, value adders, and users system. In this respect, there are three sources of heterogeneity that should be brought into consideration during standardisation. These are semantic, syntactic, and schematic heterogeneities. As explained by Groot and McLaughlin (2000), semantic heterogeneity is relevant for differences in definition, structure and coordinate systems of data layers. Syntactic heterogeneity relates to differences in software, hardware, data base management systems, and data format which are used by the data provider and analyser. Schematic heterogeneity relates to differences in data model, data coding, and topology.

Metadata, which is data about available and accessible data layers is another important component of standards. In order to make metadata easily readable and understandable by different users, there should be a standard that provides a common terminology and definition for the documentation of geospatial data. Guides and specifications must describe how to do a task in a standard way and provide the procedures standards. Having quality standards and producing data based on them is very important within an SDI. Without standards, it becomes impossible to integrate datasets or to exchange data between organizations.

The technology component is the foundation of SDI. Data sharing relies on efficient computing and communication technologies through access network. For additional explanations to the SDI components, see 2.2.2.

1.7 Structure of the thesis

Chapter 1. General introduction

This chapter deals with the background to the research topic, objectives and questions that will guide this research.

Chapter 2. General understanding of SDI

It provides a common understanding of the SDI framework. Emphasis is placed on SDI concepts and components, its drivers, SDI initiatives in African countries, and examines the interaction between GIS-SDI.

Chapter 3. Brief overview of Land administration system in Rwanda

This chapter describes briefly the new land administration system of Rwanda with emphasis on geospatial information management.

Chapter 4. Research methodology

It will provide materials and methods used for data collection, analysis and interpretation of results.

Chapter 5. Towards an establishment of an SDI in Rwanda: Land Administration related spatial data challenges.

This chapter will concentrate on findings of the research. The current challenges on spatial data for land administration will be examined with respect to SDI perspective.

Chapter 6. Proposed Land Administration SDI prototype

The chapter will propose a SDI prototype which can be implemented for Land Administration. It will finally present benefits of a SDI, which can be in data collection, storing, access, and sharing.

Chapter 7. Conclusion and recommendations

The conclusions will be formulated with respect to the predefined research objectives and questions.

CHAPTER 2: GENERAL UNDERSTANDING OF SDI

2.1 Introduction

Information in general, and spatial information in particular, is vital to make sound decisions at local, regional and global levels. However, any kind of information especially geographic information, is an expensive resource. This is the reason why many initiatives are being taken to improve access and exchange of available data, promote its reuse, and minimise duplicity of effort of collection and maintenance. These initiatives have resulted in the conception of a working framework which is known as SDI.

This chapter is a response to the first and the second objectives and the issues raised by the first research question. It aims to address the need for a common understanding of the nature of SDI. It will review the concept of SDI, its components, explore some of the key drivers influencing SDI development and SDI initiatives in Africa, and finally demonstrates the relationship between GIS concept and SDI.

2.2 SDI: definition, components and drivers

2.2.1 Definition

Various definitions of SDI have been formulated according to different regional, country and individual approaches (see Table 2-1, p. 13). The fact that there are so many definitions and views, is an indicator that there is no universal understanding what SDI entails (UNECA, 2004). This is rooted in the fact that SDI has been defined following the motivations leading to the SDI establishment and these are different from one country to another.

The PCGIAP defines SDI, referred to as GIS infrastructure, as comprising datasets, policies, institutional arrangements, standards and technical framework, which enable users to access spatial and related information (PCGIAP, 2003). According to SDI Cookbook, SDI is mainly a collection of five components which are core spatial data, policies, standards, technologies and institutional arrangement that facilitate the access to geographically-related information (GSDI, 2004).

The ANZLIC (2006) defines the SDI as a set of technologies, policies, institutional arrangement, standards, clearing house network and core data.

As stipulated in the Executive Order 12906, amended, the United States National SDI is defined as an umbrella of technologies, policies and people needed to promote spatial data access; within all levels of government, private and academic institutions stakeholders (FGDC, 2006). The definition of Canadian Geospatial Data Infrastructure (CGDI) is mainly based on all assets that ensure the harmony and a web based access of spatial data. These are technology, standards, access systems and other protocols (GeoConnection Programme, 2006). The South African Spatial Data Infrastructure is considered as a technical and policy framework facilitating collection, management, maintenance, integration, distribution and utilisation of spatial data (UNECA, 2004). Groot and McLaughlin (2000) refer to the main components (networked geospatial database, institutional organisation, technological, human and economic resources) that interact to facilitate spatial data sharing, access and use, in their definition. The table 2-1 gives a sample of SDI definitions.

Table 2-1: A sample of SDI definitions (Chan et al. 2001, adapted and UNECA, 2004)

Sources	**Definition of SDI**
Australia New Zealand Land Information Council	A national spatial data infrastructure comprises four core components, institutional framework, technical standards, fundamental datasets and clearinghouse network.
Global spatial Data Infrastructure Conference 1997	Global Spatial Data Infrastructure (GSDI) should generally encompass the policies, organisational remit, data, technology, standards, delivery mechanisms, financial and human resources necessary to ensure that those working at global and regional scale are not impeded in meeting their objectives.
Federal Geographic Data Committee	National SDI is an umbrella of policies, standards and procedures under which organisations and technologies interact to foster efficient use, management and production of spatial data.
Other references ➢ Tompson (1995) ➢ Groot (2000) ➢ Executive Order of US President (1994) ➢ McLaughlin and Nichols (1992)	➢ Victoria's Geospatial Information. Strategic plan of the State Government of Victoria. Australia (Land Victoria, 1999) ➢ Groot and McLaughlin (2000). ➢ Commonwealth Spatial Data Committee (1998)

Basing analogy on the infrastructure services such as roads, or telecommunication network, geo-information infrastructure promotes a reliable environment which facilitates access to geographic data for all users and providers.

A key element of all the above definitions is a scope of components which are covered by an SDI. Spatial data is a central element of any SDI definition. Nevertheless, SDI is not only about spatial data, but also technologies, policies, standards, human resources and related activities necessary to acquire, process, distribute, use, and maintain spatial data. Therefore, SDI can be understood as an umbrella under which all the above components interact to foster a more efficient use, management and production of spatial data.

In practical terms, if any SDI is operational, spatial data would be available on the internet via a spatial data discovery facility or clearinghouse, for users and producers. For example any device (laptop or desktop computer) connected to internet could access a GIS client application on a geo-portal, which could allow the user to create customised maps from diverse data derived from distributed databases.

Other types of operations could be conducted on the data layers that would depend on the types of functionalities which were built into the system. By linking separate spatial databases, SDI creates an integrated network which allows easy accessibility, availability and use of data; which is not possible through individual non-linked databases. Once SDI is built, data do not need to be centralised for its purpose it can be kept in as many locations as there are data custodians, and accessed over a distributed computer network

2.2.2 SDI Components

One can extract the core components of SDI by referring to early regional and national SDI initiatives such as the European Umbrella Organisation for Geographic Information (EUROGI), the Australian and New Zealand SDI (ANZLIC, 2006), Asia and Pacific SDI ((PCGIAP, 2003), the United State NSDI (FGDC, 2006). The core components are spatial data, policy, people, standards, and technical aspect, as summarised below.

2.2.2.1 Spatial Data

The central pillar of SDI is the spatial data. The simplest definition of "spatial data" is all information about location which can be referenced on the earth surface (Bossler, 2002). Spatial data can be referenced by means of latitude and longitude; national coordinate grid, postal code, electoral or administrative areas (Groot and McLaughlin, 2000). The terms spatial data, spatial related data, geospatial data, spatial information or geographic information are used quiet often interchangeably. For the purpose of this study, they are used in the same way.

(i) Fundamental datasets: SDI models identify some datasets deemed fundamental (Warnest, 2005). Fundamental geospatial datasets are essential for the successful implementation of SDI. Other terms that are used interchangeably to describe these datasets include reference, core, base, foundation or framework data (UNECA, 2004). According to the Environmental Information System for Africa (EIS-AFRICA) and Human Sciences Research Council (HSRC) (2006); fundamental dataset are defined as the foundation on which other spatial data and applications are built. They are used as the basis that enables one to spatially represent phenomena, objects or themes important for various realisations and multiple users, at local, national, sub-regional or regional jurisdiction level. Groot and McLaughlin (2000) distinguish fundamental data referred to as "framework data", into the foundation data. Following, is their classification, in Figure 2-1.

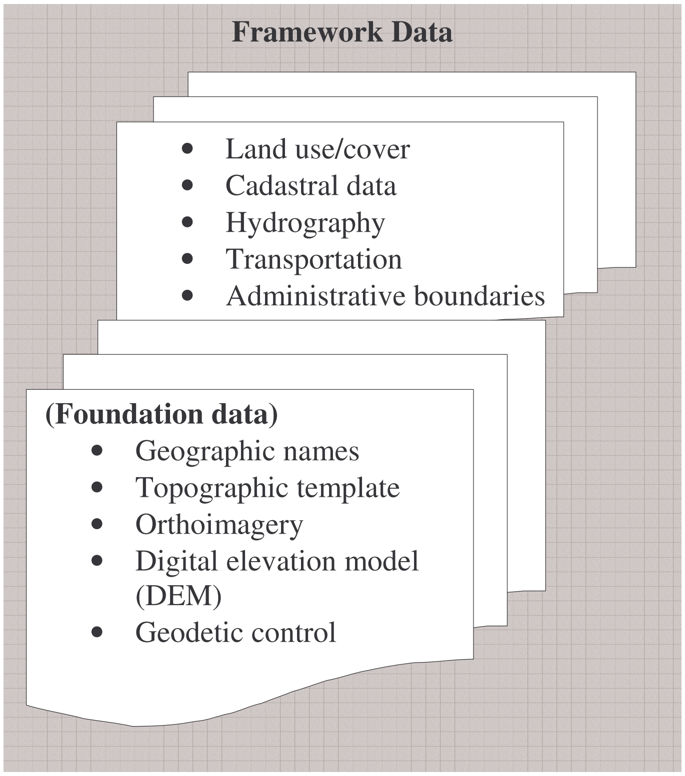


Figure 2-1: Fundamental datasets (Groot and MacLaughlin 2000).

In designing appropriate and sustainable fundamental geospatial datasets, the relevance of data to the economic, social and political setting and current policy of each country, is an important consideration. Therefore, fundamental data are not necessarily uniform for each country. For example the Canadian Geospatial database includes topographic maps, air photos, satellite images, nautical and aeronautical charts, census and electoral areas, forestry, soil, marine and biodiversity inventories (GeoConnection Programme, 2006). Thus, the layers of fundamental geospatial data (as presented in Table 2-2), have been identified for African countries.

Table 2-2: Major components of fundamental spatial datasets for Africa (EIS-AFRICA and HSRC, 2006, adapted)

Data Theme	**Data set**		
Geodetic Control Network	Geodetic control points Height datum	Geoid model	
Imagery	Aerial photography	Satellite imagery	
Hypsography	Digital elevation model Spot heights	Bathymetry	
Hydrography	Coastline Waterways (stream, rivers, canals, etc)	Surface water features (lakes, ponds, etc)	
Boundaries	Governmental/ Administrative units Populated places	Census enumeration areas	
Geographic names	Places names	Feature names	
Land management units/ areas	Land parcels/ Cadastre Land tenure	Street address Postal/zip code zones	Land use planning zones
Transportation	Roads Road centrelines	Railways Airports and ports	Bridges and tunnels
Utilities and services	Power	Telecommunications	
Natural environment	Land cover Soils and land suitability Geology Vegetation	Ecological zones Climate (rainfall, temperature) River catchments	Natural hazards zones Conservation areas Fauna
Socio-economic	Demography	Basic services (schools, health, water, etc)	

The above datasets are not necessarily adapted in their integrity, each country decides on the major datasets according to their needs. For instance, in Nigeria's National Geo-policy, the core data identified include geodetic control database, topographic database, digital imagery and image maps, administrative boundaries data, cadastral database, transportation data, hydrographical data, land use/ land cover data, geological and demographic database (UNECA, 2004).

(ii) Fundamental datasets accuracies: the table below presents the accuracy ranges for four geographic levels when using base maps of a particular scale.

Table 2-3: Data accuracies for four geographical levels (EIS-AFRICA and HSRC, 2006)

Geographical level	**Scale level**	**Scale range**	**Average scale**	**Accuracy range**	**Average accuracy**
Global (Africa)	Small scale	1:500,000 1:2,000,000	1:1,000,000	100m-400m	200m
Regional	Medium scale	1:100,000 1:500,000	1:250,000	20m-100m	50m
National	Large scale	1:25,000 1:100,000	1:50,000	5m-20m	10m
Local	Very large scale	1:5,000 1:25,000	1:10,000	1m-5m	2m

According to EIS-AFRICA and HSRC (2006), it is important to take into account the accuracy levels of data when creating fundamental spatial dataset. Varying accuracy can negatively affect data sharing and integration.

(iii) Spatial data format: from SDI perspectives, spatial data may exist in different formats. Some are in their form of computer representation or GIS format classified by De By et al. (2004) as:

- Vector data where geographic features are stored as geometric figures using points, lines, and polygons or triangulated irregular networks.
- Raster data with geographic space divided into regular or irregular cells, which together make up the complete study space. This category includes

- Digital photography: geographic data are captured as photo images and stored as pixels. An example is digital orthophotos.
- Imagery: spatial data are captured by multi-band sensors and stored as pixel. An example can be SPOT image.
- Grids are elevation data collected in a square or rectangular pattern.
- Triangulated irregular networks or elevation data collected in irregular patterns, normally at locations where significant changes in location occur.

Datasets can be organized and held in digital tables which are not necessary GIS format, such as Excel worksheets. Apart from digital formats, other spatial data exists as reports, hardcopy tables, and hardcopy maps (EIS-AFRICA and HSRC, 2006).

2.2.2.2 People

This component includes custodians of spatial data, value-added reseller, users and administrators (Warnest et al., 2002). In SDI Africa implementation guideline, the data custodian is considered as an agency or organization to which the responsibility of development and maintenance of the fundamental dataset is assigned (UNECA, 2004). That responsibility is ideally allocated to an agency which is dependent on this data for its operations, and which will prioritize the development and updating of this data.

Sometimes, the responsibility of the custodian agency is extended to other duties like transfer and sharing of the information, standards setting, insuring the quality of information and to apply market conditions provided that this does not significantly disrupt accessibility (FAO Africover Eastern Africa, 2003). Custodianship is considered as the heart of spatial information management (Warnest, 2005). It plays the sound role of eliminating unnecessary duplication in spatial data management and promotes partnership with national, regional and local providers and users of spatial data (Rajabifard, 2001).

Value-adders play an intermediate role between custodians and users. They use fundamental datasets to develop and supply application data to users (Groot and McLaughlin, 2000). Users can be corporate, small or large business groups or individuals, public or private. Administrators are adequate human and technical resources to collect, maintain, manipulate and distribute geo-information (Warnest et al., 2002). They work for custodians' institutions or value adders agencies.

2.2.2.3 Policies and institutional framework

Since the whole scope of SDI is to facilitate better accessibility and exchange of data between different producers and users of spatial data, a well-organised infrastructure for co-ordination and co-operation between different stakeholders is necessary. The framework is to cover issues like institutional arrangements (leadership, custodianship, funding and capacity building), different policies and legislation of an SDI.

(i) Leadership: to manage all issues it is convenient to form some kind of organizational body. The organization structure comprises the following elements as suggested by UNECA (2004):

- **A Ministry in Charge**: it is advisable that the SDI be under a ministry in charge of development of sectors of geo-information, surveying, mapping and remote sensing. The ministry in charge must provide a strong support at policy level, and ensure that the concept of SDI is understood in the high organs of decision making like government and parliament.
- **A Lead Agency**: this will be an institution which is in charge of geospatial data management. This organ will host a geospatial data service centre. As explained by Groot and McLaughlin (2000), the geospatial data service is a facility which acts as a broker between data users and the providers of the applications data. It will play the role of coordinating the actions related to administrative functions, resources management, and technical aspects. Here are some examples of leadership of SDI initiatives. The Dutch Council for Real Estate Information (RAVI) in Netherlands, the ANZLIC in Australia and New Zealand, the National Spatial Information Framework (NSIF)/Department of Land Affairs in South Africa, the Egyptian Survey Authority (ESA) in Egypt, the National Space Research and Development Agency (NARSDA) in Nigeria.
- **A forum of data producers and data users** reinforces the concept of participation essential for the involvement of all the stakeholders in the SDI process.
- **A steering committee**: this organ is made by a sample of stakeholders in charge of analyzing the outcome of activities undertaken and making recommendations.
- **Technical Working Group** deals with specific problem areas of SDI development and operation such as drafting standards, policies and suggesting capacity building programs.

In practice, an organizational structure of SDI might not be as suggested by UNECA. It may vary from one country to another, depending on factors such as the level of awareness of Geospatial Information usefulness and the diversity of the stakeholders involved (UNECA, 2004). The NSIF of South Africa provides an example of SDI Organizational structure in Africa (Figure 2-2).

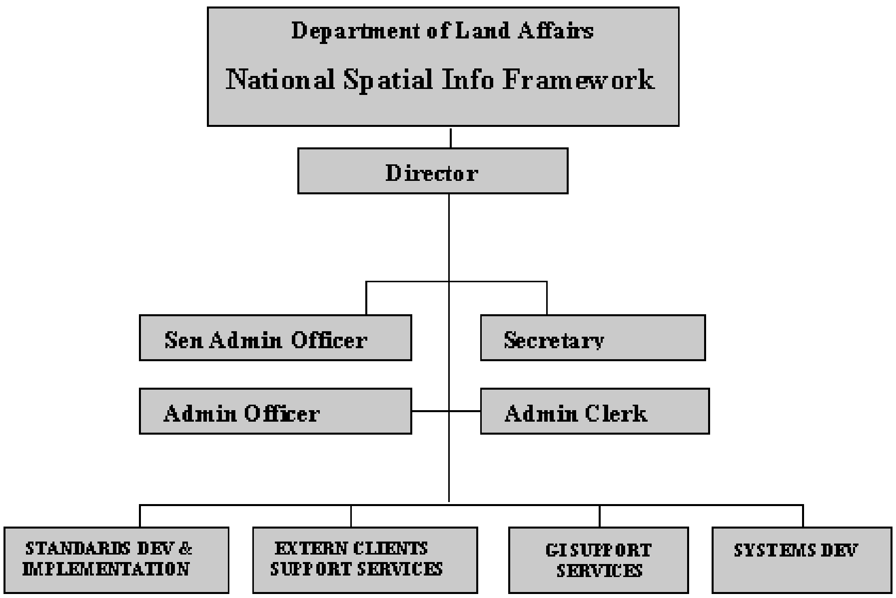


Figure 2-2: Organisational Structure of NSIF (UNECA, 2004)

From the South African SDI example, it is the Ministry of Agriculture and Land Affairs which is in charge of NSIF. The NSIF membership includes the Chief Surveyor General, the Surveyor General, the Director National mapping, surveyors, geographers, planners and IT technologists. The working groups deal with policies, standards, marketing and education. The committee for Spatial Information membership is composed of representatives of:

- All departments of State
- All provincial governments
- One rural municipality
- One urban municipality
- One GIS Association
- One GIS tertiary education institution
- Public finance management experts

- State data custodians

(ii) Custodianship: see 2.2.2.2

(iii) Financial flow: when developing SDI programme, it is important to include how the programme is to be funded in the framework. It is quite impossible to implement an SDI and to ensure its maintenance without a proper financing (UNECA, 2004). Funding mechanisms must be adapted to the economic context of every SDI implementation environment. This is the reason why different funding models are designed for developed and developing countries. The ANZLIC argues that SDI should be founded by the governments, since it is an essential infrastructure (Nasirumbi, 2006). This was the case of early SDI's initiatives. Nevertheless, the new generation of SDI's is being affected by measures adapted by government to reduce financial responsibility towards infrastructure development. The figure 2-3 shows how different mechanisms of financing SDI can be combined.

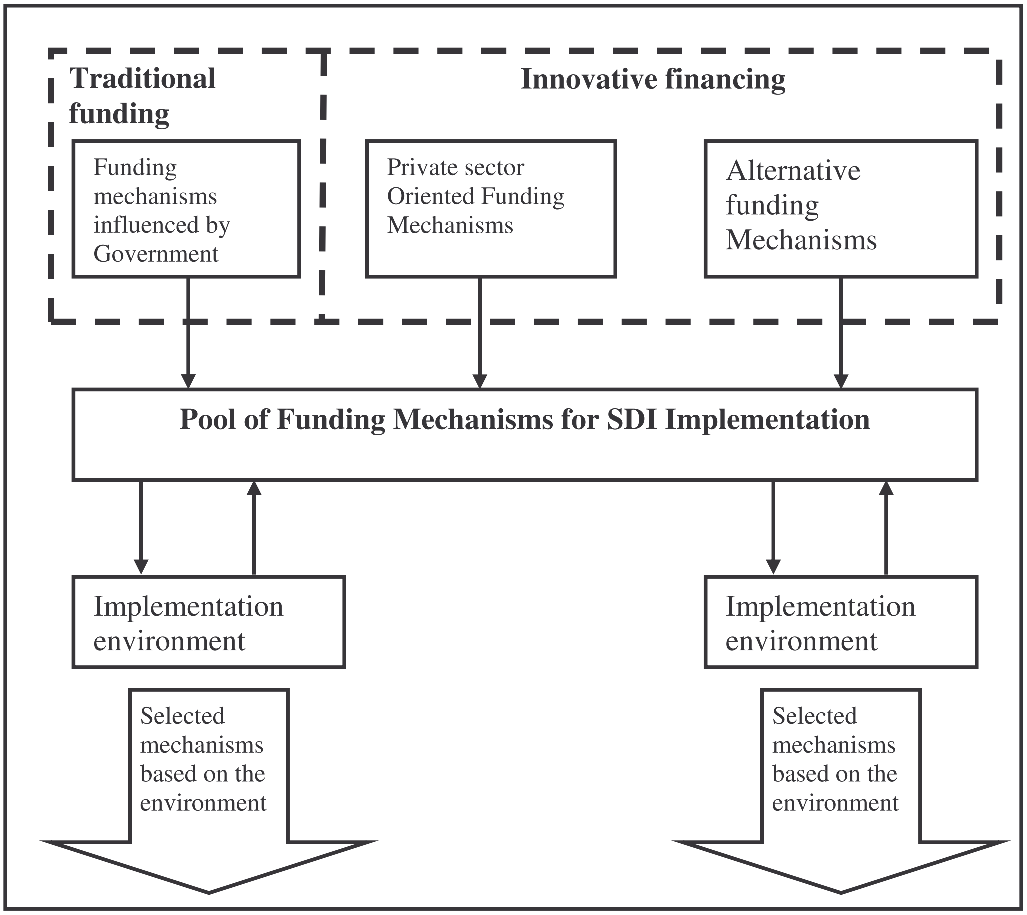


Figure 2-3: Funding Pool for SDI Implementation in Developing Countries (UNECA, 2004)

From the figure above, the SDI-Africa Guideline proposes both government funding and private investments in developed countries. However, in developing countries those funding mechanisms are not applicable, it is rather alternative mechanisms such as fund raising, national lottery and annual telethon that are suggested (UNECA, 2004). The main reasons are insufficiency of resources for these countries to generate investments, on one hand, and an economic instability that limit local and international private sector investment on the other hand. Moreover, the information sector in poor countries is still new; consequently it does not attract private sector investment and is not considered as a priority by the governments.

(iv) Capacity building: capacity building has received increasing attention in the international community during the past decades. The concept is viewed in a wider context as related to education, training and human resource development (Enemark, et al. 2003). In a SDI environment, it encompasses the development of individual human resources as well as organisational and institutional strengthening (UNECA, 2004). The SDI vision will remain unclear and unachievable, especially in poor countries, since it is still evolving and unclear to many and due to a lack of commitment to capacity building that support of its development.

According to FAO and SKE (2001), GSDI (2004), and FGDC (2006); dimension of capacity strengthening may include areas such as policies, legal framework, management and accountability at institutional level the. Organizational strengthening may focus on strategies, competencies, processes, and resources. Following the Australian model, the process of capacity building at individual level can include the activities listed below:

- Short courses,
- SDI components of university degree programs,
- Conferences, seminars and workshops,
- Research training (for masters and PHD students),
- Preparation of books, articles and reports (Enemark, et al. 2003).

(v) Policies and legislations: spatial data related policies and legislations are of fundamental importance, even though these take more time and effort to establish (Janssen and Dumortier, 2006). In the context of SDI, spatial data policy aims at providing basic principles specific to spatial data to be observed by all stakeholders when generating, collecting, transforming, disseminating and making use of spatial data (UNECA, 2004). The basic objective of data policies in various countries around the world is to promote partnership with regard to data sharing, to ensure appropriate access and maintenance of spatial data and protect personal privacy in spatial database (UNECA, 2004; FGDC, 2006; EIS-AFRICA and HSRC, 2006; ANZLIC, 1999).

According to the SDI implementation guideline in Africa, policies that are relevant to SDI are those regarding access, pricing, copyright, privacy and standards (UNECA, 2004). With policy to access information, SDI requires that countries recognise the right of access to information. This is exemplified by South Africa, which has developed legislation that determines the rights people have to access information held by both public and private sector bodies (Republic of South Africa, 2000).

Regarding pricing policy, it is advisable to have a uniform pricing policy of spatial datasets in order to make spatial information more accessible and affordable (UNECA, 2004). It is argued that the high cost of such products is an effective barrier to the access to such information for the majority of users (ANZLIC, 2001). Furthermore, it is a handicap to the providers to provide data quality requested (FAO and SKE, 2001).

The policy for copyright/ownership gives effect on use and reuse of spatial data. However, it is not easy to legally support copyright of a GIS database (Onsrud and Lopez, 1998). It is argued that spatial data is mainly factual, which facts are not subject to copyright, according to the Berne Convention (Berne, 1986). Moreover, copyright becomes a complex issue in cases where data is shared and co-maintained in partnership. There are some arguments stipulating that data should be disseminated at zero at copying cost given that the more users the greater the value (FAO and SKE, 2001).

It would be better that where the State is the holder of the copyright, other organs enjoy the use of spatial information product without a need for permission to copy. However, any third party, outside the state, must acknowledge the state copyright and ownership of that information by the state. It is the Researchers opinion that any private body using spatial products owned by the state does not need to ask a specific authorisation as far as the copyright is acknowledged.

With regards to privacy policy, the provisions of the privacy legislation need to be clear on how to protect the privacy and confidentiality of personal information (FGDC, 1998, FAO and SKE, 2001). This policy is needed because geospatial database may include personal information (Groot and McLaughlin, 2000). These inlude individual's names linked to property addresses and cadastral records that identify land parcels and land owner names. This policy applies to all geospatial data from which, personal information is retrieved.

The policy for standards regards standards development. Details on this point will be given when describing standards as a component of SDI.

A legal framework with an appropriate legislation is required to support policies. The examples to illustrate this can be the Copyright Act or Privacy Act in US, the South

Africa's Local Government Municipal Demarcation Act, Access to Information Act in many countries, and others.

2.2.2.3 Standards

The standardization of geographic data is in response to the need to develop, use and share a wide range of spatial data (FGDC, 2006). The development of standards is the duty of national standards bodies, as well as international standards organizations on which other countries can adhere to as members. Standards groups include the Open GIS Consortium (OGC), the International Organization for Standardization (ISO/ TC 211), Worldwide Web Consortium (W3C) and national coordination agencies of many countries.

Where spatial data policies exist, they are responsible for standards development. This comprises the following components (FAO and SKE, 2001 and UNECA, 2004):

- Spatial data standards,
- Data acquisition/ Collection standards,
- Database structure and Contents standards,
- Data processing standards,
- Data quality standards,
- Database maintenance standards,
- Data usability standards,
- Data dissemination standards,
- Terminology / Symbology standards,
- Presentation standards,
- Quality control and assurance standards,
- Data classification standards,
- Storage procedures standards,
- Data analyzing procedures standards,
- Data integration standards,
- Data transfer standards,
- Metadata standards.

2.2.2.4 Technology

(i) The metadata is commonly defined by many as "data about data". The Southern Africa SDI Workbook defines metadata as a kind of a descriptive document of datasets information (FAO and SKE, 2001.). It describes the actual data, where it can be found, in what format it is, and other details. An example of metadata is given in Annexe I. Metadata includes the content, quality, access and availability of spatial data. Even though metadata has become widely used recently owing to the popularity of World Wide Web, the concept has been in use for a long time under different forms. Library catalogues or map legend can serve as examples.

However, the metadata of spatial information differs from other metadata due to the emphasis on the spatial component (GSDI, 2004). For spatial information, metadata deals with the "what, when, who, where and how" questions (ANZLIC, 2006). The most important benefits of a metadata is to minimize the cost of data collection and maintenance, because it indicates the user and the producer, the existing data (GSDI, 2004 and FAO and SKE, 2001). Therefore, absence of knowledge of other organizations' data leads to a duplication of effort in data collection and maintenance.

Metadata standards are a prerequisite for geospatial data sector. Metadata standard is referred to as a common set of terminology and definitions for documentation when describing information holdings (FGDC, 2006).Without standardization, it is almost impossible to compare data from different sources. Moreover, metadata standards are needed so that producers can provide common information on their datasets. A number of regional and national initiatives have developed metadata standards for spatial data (GSDI, 2004):

- FGDC in US,
- Comité Européen de Normalisation (CEN TC 287),
- ISO metadata standard 19115 (ISO/ TC 211),
- ANZLIC,
- OGC,
- Canada, United Kingdom, and South Africa (adopted FGDC standards slightly modified version).

Those standards provide the content that provides common terminology and definitions for the documentation of spatial data. They indicate information about spatial reference. They define the data elements and information about the quality that can be assigned to the data elements.

For instance, FGDC standards specify structure with content of more than 220 items grouped in seven categories. These are identification information, data quality information, spatial data organization information, spatial reference information, entity and attribute information, distribution information, and metadata reference information (FGDC, 2006).

(ii) The clearinghouse: this acts as an engine that enables all users to access geospatial datasets (Rajabifard, 2002b). The clearinghouse provides access to spatial information and other related online services to the users (FGDC, 2006). According to FGDC, the clearinghouse is a decentralized system of servers located on the internet which contain the description of available geospatial data and services (FGDC, 2006). The clearinghouse can be summarized in three main parts (FAO and SKE, 2001) which are metadata that enables user query, the internet providing the backbone for the transfer of information by means of a clearinghouse server, and software discovery tools.

Groot and MacLauglin (2000) extend the definition of a clearinghouse to five components which are local server, clearinghouse server, user interface, global metadata and local metadata. The difference made on metadata is the level of information details. The local metadata must be more detailed than the global one. The latter contains the general information about all databases connected to GSDI. The local server is composed of several modules to facilitate access to local metadata. It also provides the security controller modules.

The clearinghouse is the heart of a distributed catalogue concept of a SDI (Warnest, 2005). The clearinghouse takes the form of a distributed network of spatial data producers, managers, and users that are electronically linked together to facilitate discovery, evaluation and downloading of digital spatial data. With a distributed catalogue, it is possible for a user to query distributed collection of spatial data through their metadata, which reside on many different servers. A user is directed to the web pages according to their query criteria, which are housed on servers all over the world. The following figure briefly describes access of data in a clearinghouse.

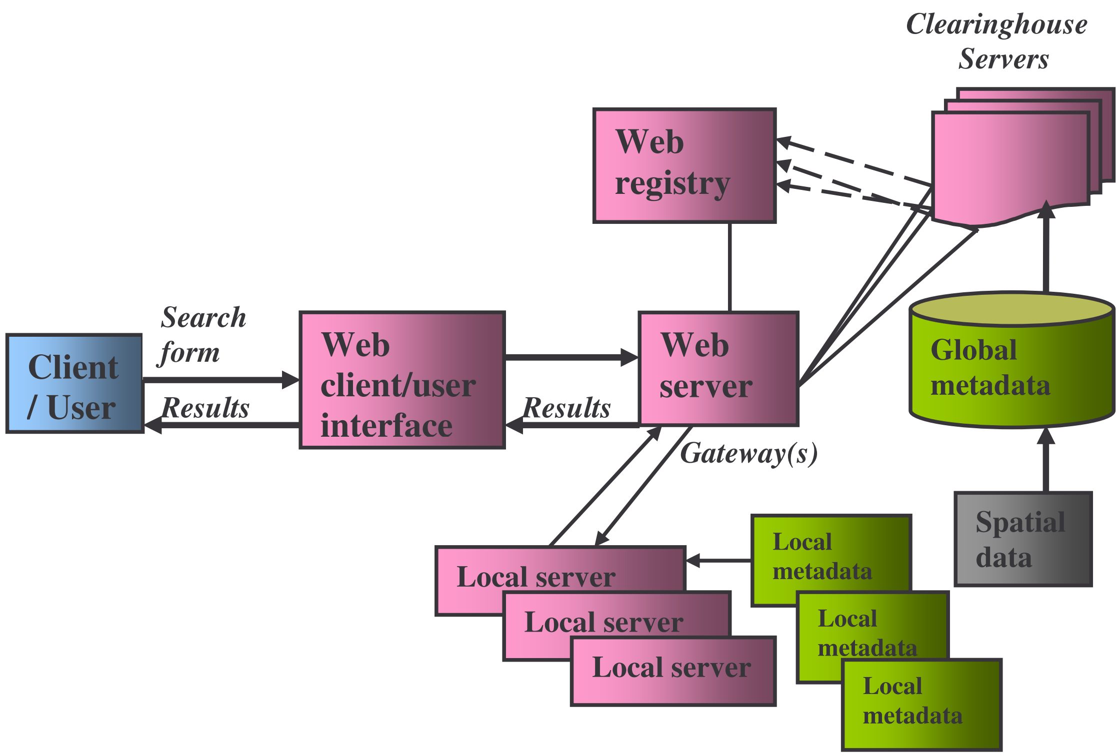


Figure 2-4: Access to data in a clearinghouse (FAO and SKE, 2001; GSDI, 2004; Groot and McLaughlin, 2000 adapted)

As described by the figure above, a user or client uses a web client browser to fill a search form for his or her queries for data. From the user interface via the web sever, the search request poses the query to one or many registered clearinghouse servers. Each clearinghouse server goes through the metadata entries and makes spatial data available following the access instruction specified in metadata. The results are gathered by the gateway and sent to the user.

2.2.3 SDI drivers

The development of SDI has been globally driven by common factors like globalization, sustainable development, economic reform, political instability and war, urbanization, environmental awareness, and human rights (Williamson, 2002). All these drivers have been dictated by the advances in information and communication technology. Furthermore, SDI development is particularly commanded by the needs of its user community

(Rajabifard, 2002). African countries have been motivated to develop SDI by different circumstances (UNECA, 2004). For instance, environment, natural resources management and sustainable development have forced in Ivory Cost, Kenya, Namibia, Uganda and Zambia, to seek reliable and up-to date information infrastructure. Duplication of efforts in spatial data capturing and accessing to geospatial information were the main concern of South Africa and Nigeria.

2.3 SDI initiatives in Africa: Best practices

There are some good examples of how geospatial information and the related technologies are being exploited within Africa. This exploitation has resulted in many SDI initiatives evolving across the continent, even though still, they are on their early stages. It would be valuable to pick up some good experience (South African's SDI and Nigerian SDI project), with the belief that this would assist the African geo-information community to raise awareness and to learn from others. The table 2-4 summarizes the best SDI initiatives to date in Africa based on their components.

Table 2-4: Descriptive summary of SDI best practices in Africa (FAO and SKE, 2001, UNECA, 2004, NSIF, 2006, Federal Ministry of Science and Technology, Nigeria, 2003)

<table>
<tr><th>Country</th><th colspan="6">SDI components</th></tr>
<tr><td rowspan="2">South Africa</td><th colspan="6">Institutional framework</th></tr>
<tr><td colspan="3">***Leadership***: NSIF established by the department of Land Affairs
Custodianship: an organ of state, officially responsible for the capture, maintenance, management, integration, distribution or utilization of spatial information on behalf of the state and the public example Chief Directorate of Surveying and mapping.
Capacity building
• Workshops to promote map awareness and literacy.</td><td colspan="3">• Creation of SDI booklet
• GIS programme in schools
Policies and legislation: access to information act, pricing policy, copyright, standards.
Funds: public budget allocated to the development of SDI</td></tr>
<tr><td>Nigeria</td><td colspan="3">***Leadership***: the National Space Research and Development Agency (NARSDA)
Custodianship: a body or a person designated as having a certain right and responsibility for development and or management of spatial data for instance Federal Survey Department.
Capacity building
• Training on SDI and its components
• Research on geo-information (GI) applications
• Development and review of geoinformatics curricula on high institutions level.</td><td colspan="3">• Promote awareness on importance of GI and SDI
Policies and legislation: GI policy, pricing policy, acts for copyright, intellectual property, access to public information.
Funds
• government budget for some aspects
• Public and private partnership funding and donor-driven funds for other aspects.</td></tr>
<tr><td rowspan="2">South Africa</td><th colspan="6">Core dataset</th></tr>
<tr><td colspan="2">***Content***
• Transportation data
• Hydrographic data</td><td colspan="2">• Elevation data
• Digital ortho-imagery data</td><td colspan="2">• Utilities and services data
• Cadastral features data</td></tr>
</table>

<table>
<tr><td></td><td></td><td colspan="2">• Administrative boundaries data</td><td colspan="2">• Cadastral land ownership data</td></tr>
<tr><td>Nigeria</td><td>Content
• Geodetic control database
• Topographic database
• Administrative boundaries data</td><td colspan="2">• Cadastral databases
• Transportation data
• Hydrographic data</td><td colspan="2">• Land use/ land cover data
• Geological database
• Demographic databases</td></tr>
<tr><td rowspan="2">South Africa</td><td colspan="5" align="center">Technology</td></tr>
<tr><td colspan="5">Access to data: an electronic metadata catalogue is provided to enable users to search for and gain access to spatial information. Each data custodian captures and maintains metadata for any geo-information held by it. The clearinghouse (the Spatial Data Discovery Facility) was established in 1998.</td></tr>
<tr><td>Nigeria</td><td colspan="5">Access to data: every data producer will provide metadata for its data holdings. The lead agency is in charge of establishing an electronic geospatial metadata catalogue and clearinghouse.</td></tr>
<tr><td rowspan="2">South Africa</td><td colspan="5" align="center">Standards</td></tr>
<tr><td colspan="2">• Data standards have been developed based on ISO 19100</td><td colspan="3">• Set up FGDC-type clearinghouse as part of Spatial Data Discovery Facility (metadata and clearinghouse)</td></tr>
<tr><td>Nigeria</td><td colspan="5">National standards to be developed in conformity of ISO</td></tr>
</table>

In light of Rajabifard's (2001) argument that SDI environment is still far from perfection, it is important to note that the chosen examples, as they appear in Table 2-4 are not the perfect models, since they still face various challenges. However, there is a lot to learn from them when focusing at their achievements in terms of organizational structure (Nigeria), standards, policies, legislations and clearinghouse (South Africa).

2.4 Relationship GIS-SDI

It is estimated that approximately 80% of all information has a "spatial" or a geographic component (Chou, 1997). In other words, most information is tied to a place. This is where Geographic Information System (GIS) comes in. A geographic information system has been described in several ways during its development and emergence as a technology. One can define GIS as a system of hardware and software, procedures and people designed to capture, to store, to manipulate, to analyse, and to display geo-referenced information (Longley, et al. 2005). A GIS can perform complicated analytical functions and then present the results visually as maps, tables or graphs, in that way allowing decision-makers to virtually see the issues before them and then select the best course of action.

GIS uses layers called "themes" to overlay different types of information. There is a widespread recognition that data layers in most GIS come from multiple organizations (University of Melbourne, 2006). Each GIS organization develops some, but not all of its data content. At least some of the layers come from outside the organization. Thus, the necessity for sharing GIS data becomes crucial among users.

With the era of technology, the days of standalone GIS are mostly over. GIS systems are being connected on the World Wide Web (WWW) through GIS catalogue portals, which provide access to geographic information (Longley, et al. 2005). The interconnected GIS have evolved into a global network that can be used in many ways by both GIS professionals and society in general (ESRI, 2006). This vision has been described since the last decades as the foundation of SDI, given that the notion of geospatial data infrastructure has been, since its emergence, a mechanism for providing an effective access to spatial data.

SDI interconnects GIS servers-based across the internet. As stated by Groot and McLaughlin (2000), a SDI encompasses first the networked geospatial databases and data handling facilities, and then other components. This leads to Budic and Budhathoki's (2006) argument that GIS can be considered as the SDI block. The role of GIS within a SDI is vital. It first creates, manages and serves spatial information, then plays the same role for metadata and finally GIS tools will provide access to users. Briefly stated, GIS is an underpinning technology for SDI.

2.5 Conclusion

SDI has become an important tool since the last decade. It is crucial in supporting decision making by governments and in meeting the social, economic and environmental imperatives of the community. This chapter overviewed the concept of SDI, its components and drivers, the current best practices in Africa and finally considered the SDI-GIS interaction.

According to these reviews; SDI is understood and described differently by stakeholders from different discipline and administrative levels, and some definitions fail to adapt themselves to the dynamic nature of SDI. Each SDI has been defined following the factors that motivated its establishment. Accordingly, there have been different SDI drivers. Some are common on global level, while others are still specific to every SDI jurisdiction. It is agreed that SDI as a whole comprises not only core data, institutional framework, standards technological aspects, but also people who drive its development. Institutional issues are known to be difficult to address while the technological aspects are advancing rapidly. This is common to the more advanced SDIs and particularly the early ones.

Some countries such as US, Australia, and others from Europe and Asia, had embraced the concept earlier on. African countries are not left out; several of them have initiated policies towards the establishment of the National Spatial Data Infrastructure. Some, like South Africa have advanced further and can serve as a model to other countries. However, SDI cannot just be copied; it is not often possible to undertake its development in the ideal way. Furthermore, it has to fit in economic context and respond to the users needs.

The SDI-GIS interaction is of great importance. GIS is more than a SDI building block, it is its foundation. The distributed nature of GIS enabled the development of SDI. Organizations with distributed GIS data, integrated them into a larger geography network for a broader information sharing.

CHAPTER 3: A BRIEF OVERVIEW OF THE NEW LAND ADMINISTRATION SYSTEM IN RWANDA

3.1 Introduction

This chapter provides a short description of the new LAS in Rwanda with emphasis on spatial data management perspectives. It gives a partial solution to the research questions related to the gaps and assets proper to the Land Administration geospatial data. The chapter draws on a number of key documents to bring a definition, components and functions of Land Administration such as the Land Administration Guidelines produced by the United Nations Economic Commission for Europe (UN-ECE), the International Federation of Surveyors (FIG) Statement on the cadastre, the Land Administration book of Dale and McLaughlin (1999).

3.2 Land administration: definition, components and functions.

3.2.1 Definition

The definition of Land Administration that is used mostly is the one produced by the Meeting of Officials in Land Administration (MOLA) set up by the UN-ECE. According to the Land Administration guideline published by MOLA, the term land administration is defined as:

> *… the processes of recording and disseminating information about the ownership, value and use of land and its associated resources. Such processes include the determination (sometimes known as the "adjudication") of rights and other attributes of the land, the survey and description of these, their detailed documentation and the provision of relevant information in support of land markets. (UN-ECE, 1996:14).*

Important from this definition is that both land and information about land are resources that must be husbanded in order to achieve efficient management. Land administration is mainly concerned with the administrative and operational processes dealing with information about the tenure, value and use of land, and the cadastre component. Authors such as Dale and McLaughlin (1999), and Williamson (2001) also refer to the above definition.

In the Rwandan context, LAS is mainly about administrative processes regarding land tenure through land registration. Other aspects reflected in the definition (land use and tenure) are less developed and carried out by other institutions not necessarily those in charge of Land Administration. Fortunately, the new LAS has taken into account all building blocks of Land Administration, and led to one institution is being established for an overall control of the whole system.

3.2.2 LA components

Land Administration entails three main components which are land registration, land value and land use planning (UN-ECE, 2005). To these traditional commodities, one more important component, especially with regards to this thesis; "information management" is added by Dale and McLaughlin (1999).

3.2.2.1 Land registration

This deals with recording legally recognized rights on land ownership and regulating the transfer of these rights (FIG, 1995). According to FIG (1995), there are three basic types of land registration:

- Private conveyancing: whereby land transactions are handed by private arrangement without any public notice, record or supervision. This is most prevalent in Rwanda.
- Registration of deeds: public repository like deeds and plans of survey must be provided for property transactions and their associated registering documents.
- Title registration: this system seeks to describe the current property ownership and the outstanding charges and liens.

3.2.2.2 Land valuation

It is all about valuation and taxation of land and properties. Valuation is an estimate value based upon market data, logical analysis and judgment of a professional valuer (Dale and McLaughlin, 1999). Since the classical economy era, land has been regarded as the basic element from which a nation can derive wealth (Steudler, 2004). Land and property are important components in market driven economies and their value is a measure of wealth for any society and are estimated to account for more than 20% of the national Gross Domestic Production (UN-ECE, 1996). Land and property taxes have a number of advantages both in terms of providing revenues to government (the main owner of the land) and as a tool for guiding land use and development (Dale and McLaughlin, 1999). Land valuation is underdeveloped in Rwanda. Land itself in Rwanda has a poor market value. Land value is determined by its improvements.

3.2.2.3 Land-use planning

According to FAO and UNEP (1999), land use is defined as an ensemble of different human activities that act on the land cover, in order to change or to maintain it. Land use defined in this way establishes a direct link between land use and land cover. The latter is referred as the visible physical cover on the earth's surface. Land-use plan is an official document providing, in a general way, the design for the future use of land (UN-ECE, 1996). Land-use planning must ensure the achievement of the following objectives of Land Administration (Dale and McLaughlin, 1999 and UN-ECE, 1996):

- Land use control i.e. zoning, site plan control, building regulations, development control,
- Monitoring environmental impact,
- Sustainability.

Land use activities in Rwanda are more oriented to environmental management and sustainability rather than to land-use control.

3.2.2.4 Land Information management

This is integral to all above components because they share common information. Land and property related data are being increasingly computerized, and managed within a Land Information System (LIS). According to the FIG, the LIS includes, at the same time, the geo-referenced land related database and techniques for data collection, distribution and updating (UN-ECE, 1996).

GIS is increasingly becoming the technology that drives the LIS. GIS is nowadays highly appreciated by its capability to collect, store, process, maintain, retrieval, analyze and disseminate geo-information.

Dale and McLaughlin (1999) argue that the common form of land information system is "the cadastre". The FIG statement on cadastre defines it as a parcel-based system containing a geometric description of land parcels linked to other records describing rights and restrictions in land, the control of these interests, the value of the parcel and its improvements (FIG, 1995).

The increasing flexibility due to information technology supports the concept of multi-purpose cadastre (Dale and McLaughlin, 1999) that may be established for fiscal purpose, legal purposes, conveyancing, land management and land-use. With a GIS based cadastre; other information can be connected to land parcels and be accessed by different users. This has been further highlighted by the FIG-Statement on the cadastre (1995), which re-iterated the cadastral concept in which land ownership related information is captured and maintained in digital format, enabling the linkage and integration of other data. The Bathurst Declaration stated that cadastre does not only support land ownership and land market, within a LAS; but also increasingly sustainable development (UN-FIG, 1999). The main conclusion of the declaration was that good land information is at the outset of better land-use and that sustainable development is not attainable without sound LAS.

3.2.3 Functions of Land Administration

Globally, Land Administration System offers a mechanism that supports the management of land and properties. The process can be fragmented into different functions listed below (Dale and McLaughlin, 1999):

- Regulation of land and properties development,
- The use and conservation of land,
- Resolution of ownership and land-use related conflicts.

These functions of Land Administration are organized around the agencies responsible for surveying and mapping, land registration and land valuation.

3.3 A short description of LAS in Rwanda.

The new LAS of Rwanda, as stipulated in the new Land Reform Programme initiated in January 2006, is still at its embryonic stage. The existing situation is a mixture of the conditions before the land reform programme and some new aspects of the new system. This is due to the fact that the new institutional arrangements are not yet well settled. Thus, the present description will first briefly discuss the situation prior to the land reform, and then highlight the new orientations of the new LAS. The sources of information for the following summary are the results of the Rwandan Land Administration assessment conducted by the Department of International Development of the Greenwich University in 2004, the National Land Policy, the Organic land law, and the Draft Law establishing the National Land Centre approved in February 2007.

3.3.1 Land registration and cadastre prior to land reform

The MINITERE had the mandate and authority for Land Administration at national level, except the capital city Kigali. There were no Land Administration structures existing at the provincial and district level. Registration activities only were decentralized to the former municipalities.

(i) At national level the process of land registration was carried out by the MINITERE through the Directorate of the Land Registrar office based in the Ministry. Only small portions of land (land owned by the church, and for commercial and industrial purposes) in rural areas; and some residential land in urban areas were formally registered. Ground surveys were carried out by surveyors other technical staffs from the titles registry department were in charge of follow up land titles delivery. All land records (survey diagrams and original copies of titles); were in paper format and maintained by the department of Land registry and cadastre of MINITERE. Copies were sent to the owner's respective districts. In the former urban municipalities, now merged into districts with the new administrative reform; land survey and registration were decentralized with the overall control of MINITERE. These municipalities had to send all land records to the MINITERE, and keep copies in their archives.

The bulk of existing data is merely about cadastre (land rights). The whole system was a centralized manual and paper based. In addition to the basic cadastral data, which are directly connected to the land ownership, other components related to spatial data are produced and managed by different agencies and departments within different ministries as indicated below.

- ❖ The service of cartography based in the Ministry of Infrastructures. It is responsible of the topographical information and imagery.

- The Centre of GIS and Remote Sensing based at the National University of Rwanda manages the land cover database and provides thematic layers on land-use, and land cover.
- Pedologic Map Project based at the Ministry of Agriculture has a GIS database of the soils of Rwanda and land suitability.

(ii) The capital City: since 1998, the capital city Kigali was not only autonomous in terms of land registration, but also with regards to the LAS as a whole. The city had only to follow the main directives regarding the land registration, land taxation, and land-use planning provided by the MINITERE. Land registration is being conducted by a Kenyan company GEOMAP, which has introduced a GIS based cadastral system since 2002. Parcels are surveyed using aerial photographs and GPS equipment, and land records are stored in a GIS database. Prior to the GEOMAP project, the whole cadastre and registration system was paper and manually based. The project is also extracting existing records digitally.

3.3.2 Land use prior to the land reform

The MINITERE was also in charge of national land-use. However, the activities of land-use planning department were very limited. It merely monitored the conditions in which land is used and assisted on land-related conflict resolution and there was no spatial information for that. Other activities regarding land-use and respective spatial data maintenance are carried out by other ministries or agencies. However, there is no formal mechanism of information exchange between different institutions involved in land-use activities.

3.3.2 The new LAS trends

Prior to the description of the LAS, it is important to note that before embarking on the new LAS, a transition period led by the Land Reform Task Force was set up, and the National Land Reform Programme supported by the Department For International Development of United Kingdom (DFID). These were established to finalize legal frameworks, the structural organization, and other requirements related to the new structure of LAS.

The provisions of the National Land Policy dedicate the authority of overall supervision and coordination of all activities related to land in the country, including those related to information and mapping to the National Land Centre (MINITERE, 2004). The Figure 3-2 gives details on the structure of the Centre.

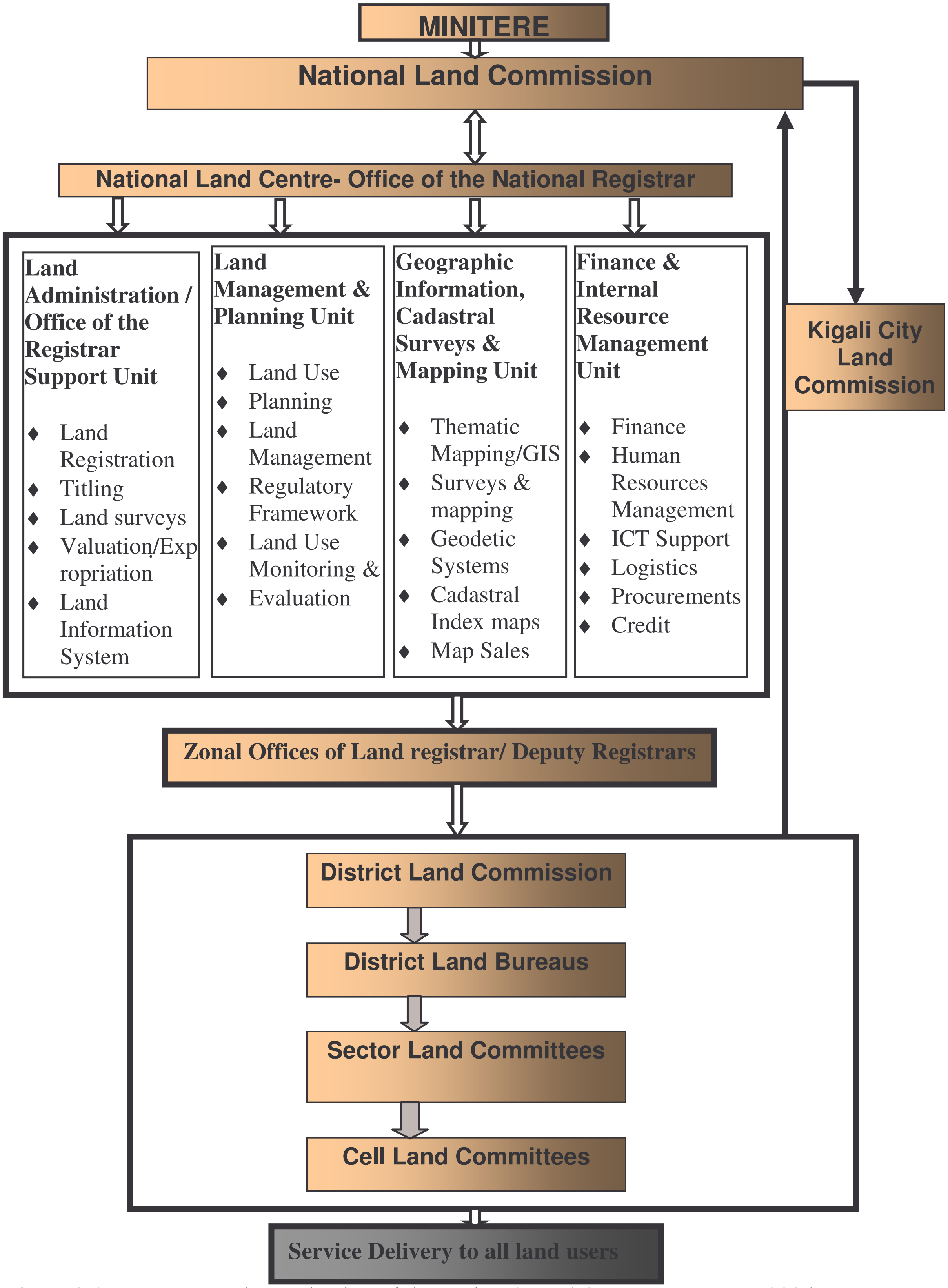


Figure 3-2: The structural organization of the National Land Centre (Rurangwa, 2006)

Figure 3-2 reveals that Land Administration at national level will operate through the National Land Centre under the Ministry of Land, Environment, Forestry, Water and Mine, (MINITERE, 2004). The draft law establishing the NLC was approved in February, 2007 (Office of the President, 2007). The overall control of the Centre is conferred to the National Land Commission which will also coordinate the land reform implementation activities.

The NLC headquarters is based in the capital city Kigali, and houses the National Office of the Land Registrar, which is the lead agency. This includes four supporting units. The Land administration unit which is in charge of all Land Administration activities. The unit of Land Management and planning, which coordinates and supports land-use planning activities. The unit of GIS, Cadastral survey and Mapping charged with carrying out mapping activities and spatial data management. Finally there is the unit of finance and internal resource management responsible for administration, finance and human resource management.

At local level, the structure of the Office of Registrar of Land Title is set following the administrative subdivision of the country into province, district, sector and cell. Five zonal offices of the Land Registrar corresponding to four provinces of the country and the Capital City will coordinate the activities of land administration and management. There are district land commission and district land bureaus at district level. Land committees will be established at sector and cell level. The new LAS breaks down the autonomy of the Capital City.

3.3.2.1 Land registration and Valuation

The office of the Registrar of Land titles coordinates all functions of national land registration and titling through the five regional offices. With the support of the Land Administration unit, the Office of the Registrar also oversees and coordinates all activities related to Land Administration in the whole country. The Land Administration unit will perform the activities of land valuation, expropriation and maintaining of national land registry database. However, the Land Centre will not register land itself. This activity will be performed by the District Land Bureaus.

The latter will have to check, approve and certify all land surveys carried out at district level and later on deliver the land titles.

Two models of land registration are proposed. In rural areas, individual parcels will be registered using photo mapping and land rights documents (certificates of registration) will be distributed. In urban areas and other commercial properties, the formal title to individual parcel will follow the demarcated boundaries with the use of ground surveying as enacted by the legislation. Districts will maintain all land registration related data and provide access to them to the National Land Centre.

3.3.2.2 Land-use planning

In terms of land-use planning, the National Land Centre shall develop and enforce a land planning regulatory framework in all its aspects and shall be responsible for all issues related to national and local planning. Under the supervision of the Office of the Registrar, the unit of Land Management and Planning is charged with fulfilling that function and providing support in land planning initiatives at district level. According to the National Land Policy, a national master plan of land-use must be established, as well as regional development plans for a good land management (MINITERE, 2004). The unit of Land Management and Planning will develop them and conduct the land-use monitoring and evaluation tasks. Nevertheless, the unit of land planning is not responsible for planning schemes of municipalities. The provisions of Land law stipulate that Districts-municipalities will hire a private company to establish planning schemes and then submit them to the District Land Bureaus for checking and approval (MINITERE, 2005).

3.3.2.3 Land information management

The unit of GIS, Cadastral surveys and mapping will be in charge of all aspects regarding spatial data and mapping. The Unit will be responsible for commissioning aerial photography and its rectification. Furthermore, it will play a role in archiving the national map and aerial photography collection. It will be responsible for geodesy network maintenance, cadastral survey, mapping and spatial data management. The unit is also responsible for updating the information.

3.4 Conclusion

The new LAS structure recently introduced in Rwanda is now being implemented, and however, it is too early to find out its achievements. The current picture of Land Administration is rather dominated by the aspects of the old system. Land Administration deals mainly with land registration activities. However, the formal registrations are still few in urban areas as well as rural areas. Other components' (land-use and land value) related activities are less developed and distributed among other ministries which are not necessarily in charge of Land Administration. Land information management is critical. Existing data are in most of the cases in paper and the maintenance is manual. Some data even lack spatial dimension. Computerization is being introduced slowly, and it is the ultimate objective of the new LAS which seeks to implement a GIS based Land Information System.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

This chapter describes the methods used to fulfil the objectives of this study and to address the research problems. These include primary sources and secondary sources methods of data collection such as documentation, field observation, informal interview, and the questionnaire method.

4.2 Location of the study area

The field work of this study was conducted in Rwanda. Rwanda is a small, mountainous and landlocked country located near the equator. It is bordered to the North by Uganda, to the West by the Democratic Republic of Congo (DRC), to the South by Burundi, and Tanzania to the East. It has an area of 26,337 square kilometres and a population of 8.1 million people as pointed out by the Ministry of Finance and Economic Planning (MINECOFIN), (2002). The Figure 4.1 presents a geographic location of Rwanda.

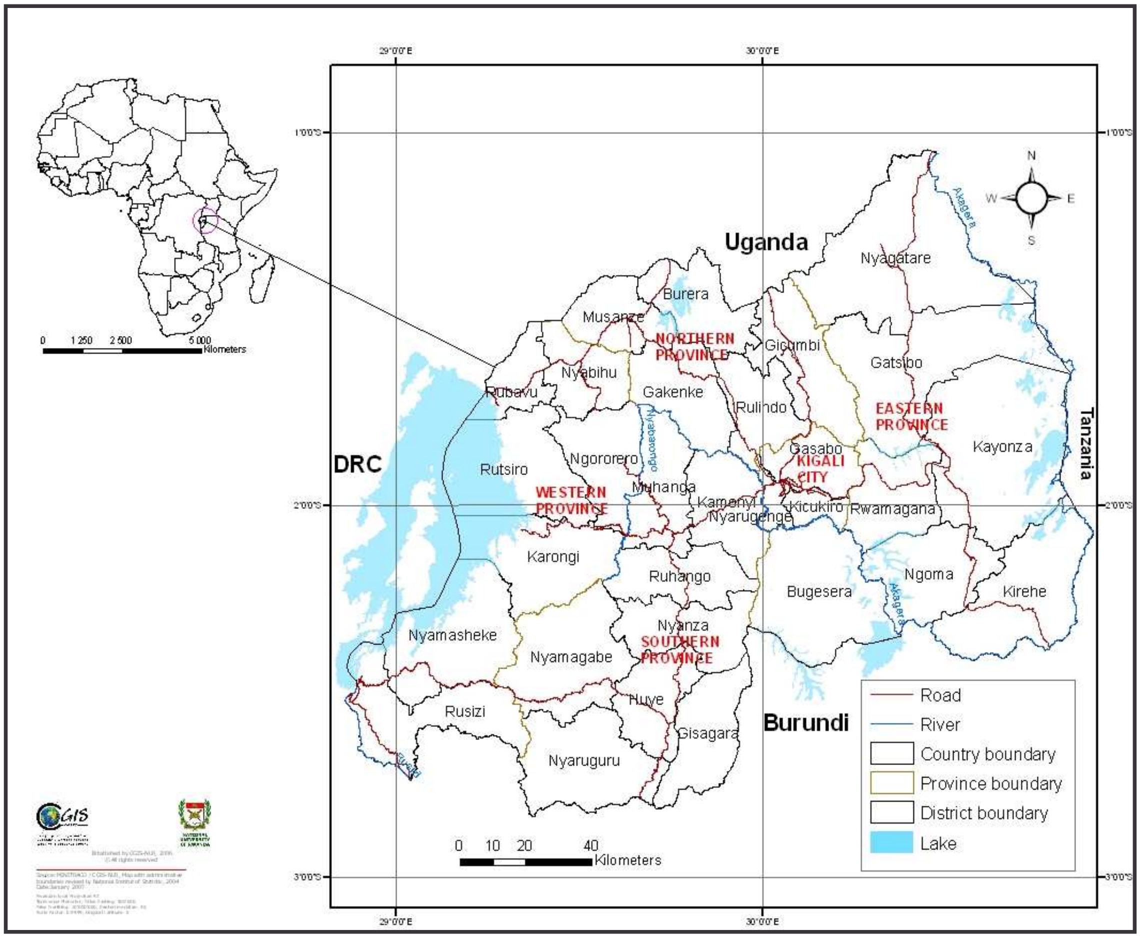


Figure 4-1: Rwanda: Geographic location
(MINITRACO/ CGIS-NUR, 2007 Map with administrative boundaries revised by National Institute of Statistic, 2004)

4.3 Data collection methods and type of data collected

By analogy with the barometer used to measure air pressure, researchers need some instruments to measure the population they are studying (Goddard and Melville, 2001). Thus the following are methods used to gather information on the study in a flowchart (Figure 4-2) followed by the details.

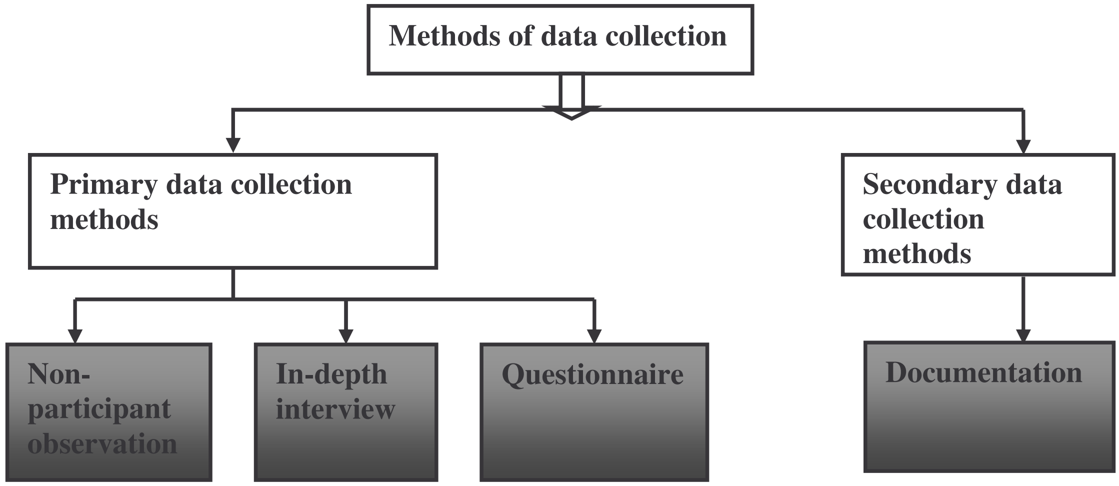


Figure 4-2: Methods of data collection

4.3.1 Primary data collection methods

4.3.1.1 Questionnaire

The questionnaire normally aims at drawing accurate information from the respondents (Hague, 1993). The main purpose of the questionnaire was to assess the current gaps and assets of Land Administration-related spatial data based on SDI requirements.

(i) The structure of the questionnaire: one questionnaire was designed for institutions and organizations producing and or managing spatial datasets needed for Land Administration (see annex 2). It comprises two sections. The first is the identification of the respondent and its respective institution/ organization. The second is a series of twenty one (21) questions. There is a mixture of open-ended and close-ended questions. A list of potential answers was provided in response to close-ended questions and the respondents were supposed to tick one or more answers where applicable. The possibility of giving other answers was given to any respondent who felt that the list was not exhaustive or not adequate. The open-ended questions were constructed in a way that the respondent should provide his/her own answer. The respondents were those in charge of spatial data management departments or units.

(ii) Sampling: this was of relevance given the time and resource constraints of the researcher. As stated by De Vos et al. (2002), the use of samples results in more accurate information than might have been obtained if one had studied the entire population. These authors argue further that money and time can be concentrated on a sample to produce a research of good quality.

The “purposive sample” was found efficient for the purpose of our study. With this method the definition of a sample is based on the judgment of the researcher (De Vos et al., 2002). The researcher only targets those people who in her/his opinion are likely to have the required information to achieve the objectives of the study (Kumar, 1999). The total size of a sample was 19 departments drawn from an entire population of 28 institutions, the equivalent of 68%. The population was made by public or private institutions producing or/and managing fundamental spatial data used for Land Administration.

When the population is small, it is advisable that a sample comprises a large percentage of the population rather than 10% or 30% as proposed by authors like Alreck and Settle (1995). It is true that larger samples enable researchers to draw more representative and more accurate conclusions (De Vos at al., 2002). However, the Researcher did not apply the guideline for sampling (De Vos at al., 2002) where a sample is suggested to be 80% when a population is around 30, in order to ensure representativeness. The size of the sample was influenced by the homogeneity of the population. A number of institutions were homogeneous in terms of spatial data managed and produced. Therefore, there was no need to include a large number of that kind of institution in the sample. For instance, on eight districts holding the cadastral records, only three were part of the sample. Table 4-1 lists different organizations and their respective departments that were objects of the sample.

Table 4-1: The units surveyed

Institution or Organization	The departments/ units surveyed
CGIS-NUR	Mapping unit
Ministry of Infrastructures	Cartography Service
Ministry of Agriculture	GIS unit
Ministry of Land, Forest, Water and Mine	Unit of Deeds and Title registry & GIS unit of Land Reform Project
Ministry of Local Government	GIS unit
National Institute of Statistics of Rwanda (NISR)	GIS init
Rwanda Environment Authority	GIS unit
Nile Basin Initiative/ KIGALI	GIS unit
Rwandan Office of Mine and Geology (OGMR)	GIS unit
Ministry of Defence	Patrimony unit
ELECTROGAZ	GIS unit
Kigali City/ GEOMAP	Cadastre
Rwandan Office Of Tourism and National Parks	GIS unit
Dian Fossey Gorilla Fund International (DFGFI)/ Karisoke Centre	GIS unit
MTN	Information Technology unit
SHER	GIS unit
Huye District	Unit of Land, Settlement, Urbanism and infrastructure
Muhanga District	Unit of Land, Settlement, Urbanism and infrastructure
Rubavu District	Unit of Land, Settlement, Urbanism and infrastructure

4.3.1.2 In-depth Interview

Interviews were useful in order to clarify a number of issues in the questionnaire and to make the results of this study more reliable. They also helped in obtaining background information from main stakeholders. This instrument allows certain flexibility to the interviewer over what he/she asks the respondent which becomes an asset to elicit rich information (Kumar, 1999). A total of five people were to be interviewed face to face, within a period of about 30 minutes. Specific issues to be discussed during interview were on the progress and follow-up of SDI implementation, related technology, institutional arrangement aspects and the new LAS perspectives.

4.3.1.3 Observation

A non-participant observation was used to view events on the field. This was mainly limited to the existing GIS infrastructure. The narrative method (Kumar, 1999) was chosen as a form of recording observation. Brief notes were taken while observing different offices visited.

4.3.2 Secondary data collection methods

4.3.2.1 Documentation

The written materials available in library of University of KwaZulu Natal, Pietermaritzburg, in Rwanda's libraries (NUR, CGIS-NUR, UNECA), in ministries' and organizations' archives were reviewed. Other books, journals, conference proceedings, articles available on internet were consulted. The information gathered through theses documents served to build the literature review of the concept of SDI (components, drivers, best practices); the concept of GIS, and LAS of Rwanda. The literature review has also assisted in the identification of stakeholders to be surveyed.

4.4 Data collection

Data collection started on the 11th of December 2006 and took a period of four weeks. The researcher visited all selected organizations and institutions in order to distribute the questionnaire. The purpose of the study was first explained to the respondent before distributing the questionnaire. The researcher had to ask for an appointment to come back and collect the completed questionnaire. This was of great importance in a sense that the researcher could bring more clarification where the respondent had difficulties. All distributed questionnaires were completed and collected, except one for IT department of MTN, making a total of 18 questionnaires representing a 95% return rate. The respondent was on leave and on resumption of official duties, said that he had urgent work and deadlines to meet making it difficult for him to attend to the questionnaire. Time constraints meant this questionnaire had to be discarded. Thus, the number of respondents (N) for the statistical analysis in chapter five is set at 18 respondents instead of 19 respondents that were designed for the sample.

The interviews were carried out on the basis of agreed appointment with the interviewees. Notes were taken and at the end the interviewee could go through the written notes for an approval. The interviewees were the Coordinator of the Land Reform Task Force in MINITERE, the National Registrar of Land Titles, the Director of CGIS-NUR, and the Team leader of National Land Reform Project in MINITERE. The firth person was supposed to be the one in charge of the National Information Communication Infrastructure (NICI) in Rwanda Information Technology Authority (RITA). The meeting with him failed because by the time field work started, he was out of office, on a mission overseas. The Researcher only had a chart with his colleagues in the same department.

4.5 Data analysis

On completion of data collection, data was captured and analyzed using Microsoft SPSS. Coding data was imperative given that all data collected was qualitative or categorical. De Vos et al. (2002) explain that qualitative or categorical data are those that denote quality or the group a subject belongs to.

4.6 Pitfalls and problems

- The period of field work coincided with the end of the year when some respondents were on holiday. The Researcher had to wait for them and this resulted in delays on the field work schedule.
- The LAS of Rwanda made some interviewees reluctant to give their points of views during the transition period as it was regarded as not yet official. It should be noted that the transition period was ended by the appointment of the National Registrar of Land Titles and Deputy Registrars in January 2007. However, the draft law for establishing the National Land Centre was not yet approved by the time of field work and was approved later on in February 2007.
- It was difficult to some respondents who did not have a GIS background to understand technical words related to GIS used in the questionnaire.
- Most of the units in charge of spatial data management had one technician; which means that his or her absence meant nothing could be done.

4.7 Conclusion

This chapter reviewed different methods of data collection and analysis used in order to fulfil the objectives of this study and to answer the research questions. The documentation helped to bring an understanding of the SDI concept that has been newly introduced in Rwanda. It also served to clarify the LAS of Rwanda. This information was not enough without a fieldwork aimed at assessing SDI implementation feasibility in the Land Administration spatial sector.

The fieldwork utilized three main techniques which are the questionnaire, in depth interview and a non-participant observation. The questionnaire provided a speedy way of collecting information on the current constraints related to policies, people, institutional and technical aspects of Land Administration related geospatial data. Interviews with the key personalities were useful at learning more about the background information. Observation enabled gathering complementary information regarding GIS infrastructure on visited institutions.

Few challenges were faced during fieldwork including holidays shortening the data collection time, cancellation of interviews, availability of some respondents and reluctance to provide some information. Overally, the fieldwork provided sufficient information. At the completion of the fieldwork, quantitative methods of data analysis were used by means of SPSS software.

CHAPTER 5: TOWARDS AN ESTABLISHMENT OF A SDI IN RWANDA: LAND ADMINISTRATION RELATED SPATIAL DATA CHALLENGES.

5.1 Introduction

This Chapter will present findings from the field work and interpretation of the results. It attempts at answering the second, third, fourth, fifth and sixth research questions regarding the general assessment of Land Administration spatial sector. A situational analysis of the geospatial sector is carried out in order to find existing data, their providers and users, issues related to data management, data access, and other requirements of SDI. Various constraints and assets existing in Land Administration spatial data sector with reference to SDI components will be analyzed as well. This aims at assessing the possibility of establishing SDI.

5.2 Existing Land Administration spatial data and their respective providers in Rwanda

5.2.1 Providers

Land Administration-related spatial data are provided by different institutions that include ministries' departments, district units, public institutions, international organizations and private companies. For the purpose of this study, these institutions are classified into two categories which are "spatial data providers and users" category and "spatial data providers". The spatial data providers and users differ with other users in that such institutions maintain and manage the spatial databases. Moreover, they can supply, to other users, the same datasets they use for their applications. For the purpose of this study, they are called "providers". Most of these agencies are based at national level (61.1%), and district level (27.8%). Only one organization is based at the sub-regional level (5.6%) and another one at local level (national park) (5.6%).

Even though the MINITERE has Land Administration in its attribution, it is not the custodian of the core data of that sector. Apart from the cadastre, other spatial data are held by the Ministry as a user since last year when the Land Reform project started. According to the Team Leader of the project, the data is being collected for the purpose of a pilot project of rural land registration (C. English, 2007, pers. Comm.).

From the results obtained on the type of institutions that were the object of the survey (Figure 5-1), a big number of providers of Land Administration spatial data are public (77.8%). Only one research institution, which is also public, was identified among providers-users (6%) and one international (6%). The NGOs, private institutions or other companies; are not represented much in this field. However, they play a big role in providing financial support.

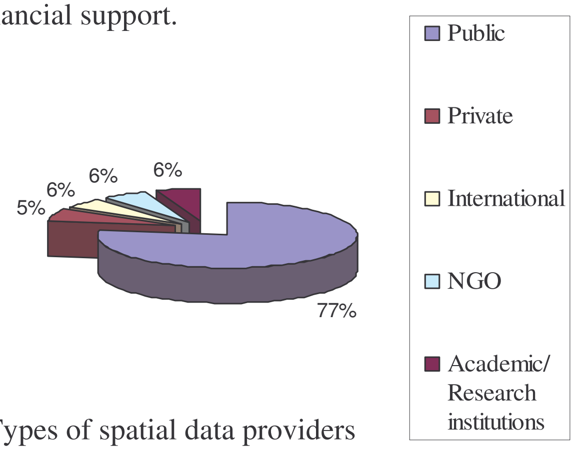


Figure 5-1: Types of spatial data providers

5. 2. 2 Spatial data provided

It was found that only some fundamental datasets based on Land Administration's main components (land registration, land-use, and land value) and other supporting spatial data are produced. Supporting data, here, refers to other framework data used in Land Administration. Table 5-1 presents detailed spatial data produced and respective providers.

Table 5-1: LA related spatial data produced in Rwanda (Survey, December 2006)
*Foundation data (Groot and McLaughlin, 2000)

Data Theme	Data set (with details)		Current providers
Land management	**Cadastre**		MINITERE, District's Units of Land, Settlement, Urban Planning and Infrastructure. Proposed custodian MINITERE
	Land tenure		MINITERE, District's Units of Land, Settlement, Urban Planning and Infrastructure. Proposed custodian MINITERE
	Land-use		
	• Urban schemes		Kigali City, the former Kibuye and Kabuga municipalities Proposed custodian MINITERE
	• General plans		Kigali City, the former Butare and Gisenyi municipalities Proposed custodian MINITERE
	• Land suitability		CGIS-NUR, MINAGRI. Proposed custodian MINAGRI
	• Land cover		CGIS-NUR. Proposed custodian MINITERE
	Infrastructures	roads network	CGIS-NUR. Proposed custodian MININFRA
		power line network and water infrastructure	ELECTROGAZ Proposed custodian ELECTROGAZ under MININFRA
		location of health, commercial, education infrastructure, socio-economic infrastructures	CGIS-NUR Proposed custodian MININFRA, MINEDUC, MINICOM

Data theme	**Data set (with details)**		**Current providers**
	Conservation	protected areas, location of tourism sites	ORTPN, DFGFI, CGIS-NUR Proposed custodian ORTPN
	Mining and geology		OGMR Proposed custodian OGMR under MINITERE
Boundaries	**Administrative boundaries** national, provincial, districts, sectors and cells		MININFRA, MINALOC, CGIS-NUR, Proposed custodian NISR
***Orthoimagery**	**Aerial photography**		MININFRA, CGIS-NUR, Kigali City Proposed custodian MININFRA
	Satellite image		CGIS-NUR, Kigali City, Proposed custodian MININFRA
***Topography (1/50000 map)**			MININFRA, CGIS-NUR Proposed custodian MININFRA
***Geodetic control network**	**Geodetic control points**		MININFRA Proposed custodian MININFRA
Population	**Population census, populated places**		NISR, MINALOC, CGIS-NUR Proposed custodian NISR

Table 5-1 gives various datasets identified in the different institutions that were surveyed. The following paragraphs provide a descriptive explanation of the datasets. Land registration data or cadastre, the cornerstone of Land Administration is however less developed. The existing data are about small portions of residential land mainly located in urban areas, and the other land under commercial agriculture, industry or the church in rural areas. Therefore, there is a bulk of geo-information on land ownership that is non-existent, as result, poor land tenure and land value related spatial data.

The information currently provided in the cadastre is limited on land rights records, delivered by means of a survey diagram which gives a physical description of the property. Parcel surveys are carried out on request without necessary survey general plans. The survey general plans have only been developed for few suburbs in the capital city Kigali, the former Butare and Gisenyi municipalities, through the use of aerial photography. By the time of data collection, the custodian of the cadastre was the MINITERE, through the units of Land, Settlement, Urban planning and Infrastructure based on district level.

Land-use spatial data available can be described as follows. The urban schemes (not updated) only exist for the Capital city, the former Kibuye and Kabuga municipality. The general plans are developed for some places of the capital city. Other data include land suitability and land cover databases, protected areas, geological units, infrastructures like roads network, power line network; water infrastructure; communication network; location of health; commercial and education infrastructure, and other services.

Supporting data include:

- Administrative boundaries: the updated ones corresponding with the new administrative reform introduced in 2006.
- Aerial and satellite photography: the last aerial coverage of the country was carried out by the French mission in 1990. Other photography has been produced on different dates but at municipalities or other low levels for specific projects. For instance, the aerial coverage of Kigali City done by a Belgian mission in 2002, aerial photography of all former municipalities captured by the Project of Infrastructures and Urban management (PIGU).

  The satellite images were produced by FAO Africover project in 1999 and METEOSAT second edition in 2006.

- Topography data: the topographic maps available were last updated in 1984, and these comprise 43 sheets at the scale of 1/50000, covering the whole country.
- Geodetic control points: the system is made up of a total of 56 control points.

Population: a spatial database of the population exists since the last general census of 2002.

Currently, there is no custodianship policy or legislation in Rwanda. Some providers are recognized as custodians simply because mapping activities is one of their attributions. The proposed custodians are made following the propositions that emanated from the National Information and Communication Infrastructure (NICI) plans and SDI initiatives in Rwanda, supported by the UNECA.

The main challenges in Land Administration spatial sector with regard to existing geo-information are:

- Poor land management and property information: in addition to a poor cadastre, a total absence of a national master plan and local land-use plans. Land use planning is not integrated in the whole LAS.
- Spatial data held by different institutions, which are not connected. Consequently, there is a high level of duplication of effort in collecting and maintaining data.
- The presence of multiple producers for the same fundamental data (for instance ortho imagery). This results from an absence of custodianship policy. Normally, according to SDI requirements, the responsibility for development and maintenance of the core data should reside with a particular agency or organization known as the“data custodian”.

5 3 Users of Land Administration spatial data

Users were grouped into nine categories including decision makers, institutions involved in spatial data sector or spatial data providers, commercial users, value adders, academic community, NGOs, consultants, donors and the media. The classification of users was done on “who needs what data for what” basis. This was done in the line of SDI perspective, thus, all existing and potential users (individuals or organizations), were considered. This explains why the categories include users who are not necessarily in Land Administration related activities. An assessment of user categories was carried out in all institutions (Figure 5-2).

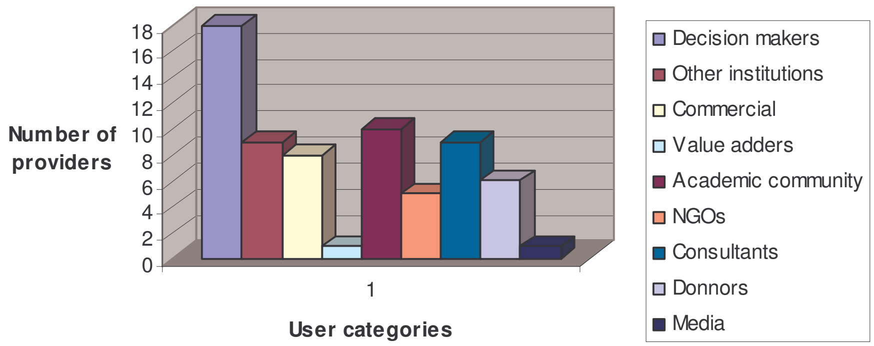


Figure 5-2: User categories per providers

It is important to note that not only agencies involved in Land Administration activities need data, but also other different users as well. This is an indicator of the crucial need for an efficient mechanism of data sharing. Furthermore, even the data providers still need each other. 50 % of providers stated that they have other institutions involved in spatial data as their users. However, this results in duplication of data maintenance.

Among all users, decision makers occupy the most prominent position. This category was identified to all providers (100%). This proves that decision makers are aware that spatial information plays a critical role in meeting national development targets. Consequently, one assumes that they cannot hesitate to undertake any kind of initiative to promote spatial data sector. The academic community seems to be selective in terms of providers accessed. This category was found in ten institutions (55.6%). This can be explained by three assumptions. Firstly, data such as paper based cadastre and geological units, might be less used in researches conducted so far in Rwanda. Secondly, the same spatial dataset might be provided by more that one institution, and users might choose the nearest ones or those with easy access conditions. Thirdly, this could be an indicator that there are some institutions which do not allow easy access to their data.

Commercial users were found in eight institutions, and they are merely banks. They need cadastral records as proof of collateral. Only one institution declared to receive value adders. It is important to note that this category also includes all data providers, except one agency (the service of cartography), which exclusively provide data without any value added. Other important user's categories include consultants, Non Government Organizations and donors. The category of media is the least represented.

5.4 Access to spatial data

Access to available geo-information is generally unrestricted to all users. In practice, access to the spatial database operates between institutions dealing with spatial data activities and mapping. Individual users only get hardcopies or soft copies of data products (maps). What is common to all the custodians surveyed is that an authorization is required prior to access data. However, procedures to obtain authorization differ from one institution to another, depending on the internal administrative structure of each institution.

5.4.1 Access conditions

Data access conditions were only assessed on the basis of the price, either at the office or online. This assisted the Researcher for further analysis on policies. 17 % of respondents charge their users when they request data at the office. 83% of surveyed agencies declared that they do not charge their users (Figure 5-3).

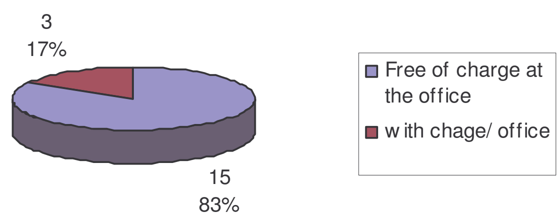
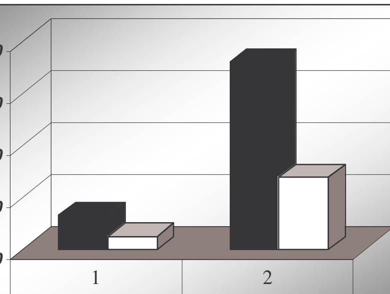


Figure 5-3: Access conditions

The results of the survey have shown that the institutions which charge their users are the ones that receive all categories of users. Those providers are CGIS-NUR, NISR, and MININFRA/Cartography. The reason could be that those institutions are the most active mapping agencies in the country. Moreover, they offer various datasets, the most often used and their access condition seems to be only the cost. It is clear from the previous observations that the cost as the only access condition to spatial data, seems to be much easier for users than written authorization. Nevertheless, the prices must be reasonably fixed and take into account all potential users. The amount charged depends on the institution. All institutions visited do not yet provide spatial data online, except the CGIS-NUR that provide static maps on its website. This is a serious access constraint because, once there is a need of data, one has to acquire them by office visit, which is time consuming. Moreover, the absence of metadata (Figure 5-4) is another handicap to existing geo-information access.



	1	2
Don't have	13	72.2
Have	5	27.8

Figure 5-4: Use of metadata

Institutions that managed to develop the metadata (27.8%) for their spatial datasets do not have any online linkage. This is critical because users cannot know what information is available and where it can be sourced.

5.5 Issues related to data management and data sharing

5.5.1 Data capturing and storage

Tools used in data capturing were assessed (Figure 5-5). It was found that 61.1 % of respondents use GIS, 22.2 % use theodolite, 11.1% use GIS and theodolite, 5.6 % use GIS and remote sensing. The use of GIS is common to a total of 87, 8 % of respondents. Theodolite is an instrument used by the agencies of cadastre for ground surveying. All of these agencies generally use theodolites, while only two of them, Kigali City and the MINITERE, use both GIS and theodolite. As explained in chapter four, Kigali City has introduced a GIS-based cadastre since 2002, but at the same time, theodolite is still used. Furthermore, the use of GIS was introduced by MINITERE in January 2006, for the Land Reform Project which is now experiencing a rural registration on a pilot zone.

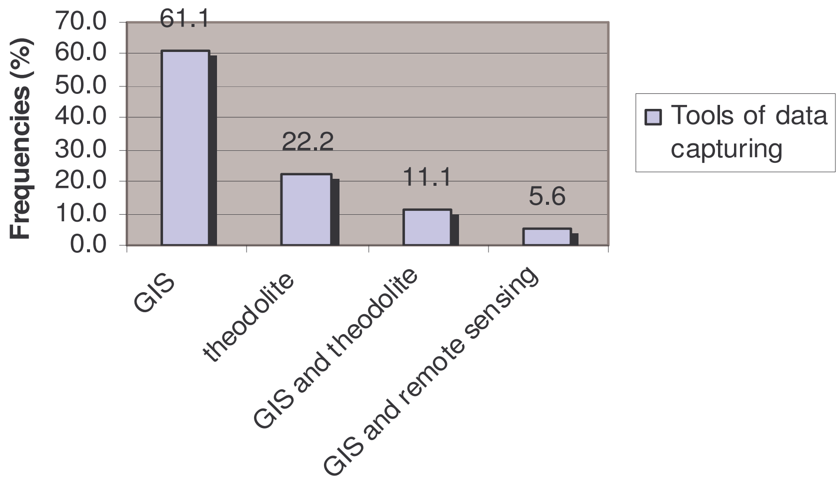


Figure 5-5: Tools of data collection

Land records captured from ground surveying with theodolite are manually manipulated and stored in hard papers. With GIS tool, spatial data capturing is done either by means of GPS in the field, or by scan and then screen digitizing at the office. Remote sensing operates by aircraft, satellite or other sensors to gather spatial data. Appropriate GIS software are then used to manipulate, analyze and store the data. It was observed that, the GIS software packages most commonly used by respondents are Arc View and Arc GIS.

The results of this study on the use of GIS technology in Land Administration spatial sector may however be misleading when looking at the cadastral system which is almost manual in the whole country. While other providers are mostly based on the national level, the cadastral management is based on district level. So far, any district is using the GIS tool to manage cadastral system. This highlights that there is still a long way to go in promoting the use of GIS in Land Administration spatial sector, particularly in cadastre management.

5.5.2 Format of data

Data format was examined on the basis of paper files, hardcopy maps, and digital spatial data (Figure 5-6), in order to find out different issues related to data storage and others.

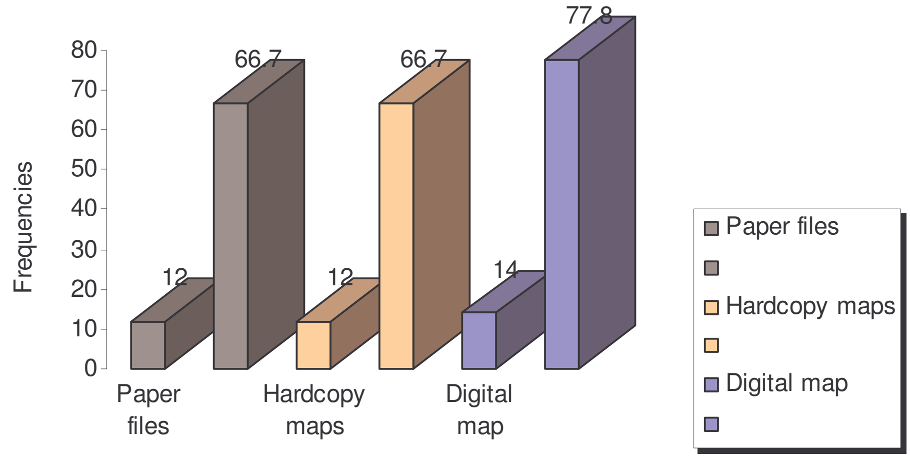


Figure5-6: Comparative data formats frequencies

The figure above shows that paper files are used at the same rate as hardcopy maps. Digital maps were found in 14 institutions. Where data are computerized, all formats are generally in use. Where the system is still manual (cadastre in districts), two types of format are only applicable and these are paper files and hardcopy maps (survey diagrams, general plans).

As explained in chapter two, paper files can be reports or tables. The main issues related to paper based spatial data format are as follows:

- Loss of information,
- The system fails to cope with an increasing volume of geo-information,
- Difficulties in data updating,
- Slow service delivery ,
- The system favours duplication in data collection. It does not allow the outside users to know what exists or not,
- The system almost excludes data sharing,
- The system does not allow open access to data and information,
- The system definitely does not favour SDI goals.

5.5.3 Duplication of financial resources

There is a significant relationship between institutions that have so far implemented GIS and their source of funding. It was found that in most case these institutions either have a financial donor, or both a financial donor and public budget. A total of 11 data providers have donors (61.1%), and all use GIS tool. For seven institutions that use the public budget, only three of them managed to implement GIS. It is important to note that even though one of these three agencies (Cartography) were using the government budget by the time of the survey, it had been supported by the French embassy in 2001, the year GIS was first used in the department. Table 5-2 list the financial donors found by the time of the field work.

Table 5-2: Financial donors of spatial providers

Institution	Financial donor
REMA	African Bank of Development
MINAGRI	Belgium University of Gand
MINALOC	USAID
DFGF	DFGF
NISR	DFID
CGIS-NUR	ESRI Germany, DFGF, SIDA/SAREC, Rwanda Development Gateway, NUFFIC, FAO, Zurich University
MINITERE	DFID
ORTPN	WCS, PICG
OGMR	Royal Museum for Central Africa of Turvin/ Belgium (Musée Royale de l'Afrique Centrale de Tervin/ Belgique)
NELSAP	World Bank
SHER	KFW

The big challenge highlighted here is the duplication of financial resources from the national budget and outside donors. It was found that more than one institution can be involved in collecting and maintenance of the same dataset. Huge money spent to collect and maintain the same data twice or more can be used to strengthen a data custodian and to underpin the mechanism of data sharing.

Another pertinent issue associated with the source of funding is the long-term sustainability of the use of GIS technology. The challenge is on what is going to happen if the project funding terminates. If GIS can serve as an efficient tool of land data management within a SDI, the mechanism of funding one, must not compromise the other ones.

5.5.4 Data updating

From SDI perspective, the cadastral system should provide details on ownership rights, legal restrictions that may apply to the land and changing patterns of land use. However, a paper based cadastre is unable to provide such data as it has not been kept up to date, and data are not sufficiently accessible. This problem is only solved when the system is computerized with use of GIS.

Furthermore, the issue of spatial database updating is not exclusive to the manual cadastral system. It was found that GIS users encounter the same challenge. When respondents were asked to indicate how often they update their data, GIS users indicated that only some datasets like boundaries are updated on a regular basis.

5.5.5 Gap in human resources

The gap assessment was limited to the qualification of the staff in charge of data collection and maintenance. This is not the only challenge regarding human resources. With respect to this study, the aim was to assess the existing qualification in terms of Geo-information skills. Qualifications included national GIS specialist to, expatriate GIS specialist, Information Technology specialist (IT), qualified surveyors, trained surveyors, civil engineering and GPS users. The following table shows the different qualifications of spatial data managers in surveyed agencies.

Table 5-3: A comparative table of human resources qualification (Survey, December 2006)

Qualification	No applicable (N: 18)		Applicable (N: 18)	
	Number of respondents	%	Number of respondents	%
National GIS specialist	10	55.6%	8	44.4%
Expatriate GIS specialist	12	66.7%	6	33.3%
IT Specialist	15	83.3%	3	16.7%
Qualified surveyors	16	88.9%	2	11.1%
Trained surveyors	14	77.8%	4	22.2%
Civil engineering	17	94.4%	1	5.6%
GPS users	14	77.8%	4	22.2%

The activities of data maintenance at the office are run by one staff in average. However some institutions have two or three spatial data managers. According to the results of the survey, there are national GIS specialists in eight institutions, expatriate specialists in six institutions, Information Technology (IT) specialists in three institutions, qualified surveyors in only two institutions, trained surveyors and civil engineers in respectively four and one data provider. GPS users are employed part-time to collect data on the field. They are trained prior to the field work. Expatriates are often attached to the project-donor.

Table 5-3, shows that not only are GIS specialists few, but professional land surveyors too. Rwanda has no tradition of academic training in land administration and land information management related disciplines. The so called "GIS specialists" or "GIS professionals" are from different backgrounds mainly geography, agriculture or engineering and acquired that qualification either by a relative long experience in cartography or short training in GIS in the country or abroad.

Since 2001, GIS courses have been introduced in the Geography department of the National University of Rwanda. Progressively, GIS is being incorporated in other disciplines such as social sciences, agriculture, and civil engineering at the same university. The new graduates in geography now attract spatial data provider institutions. In fact these graduates possess immediate job readiness in terms of developing and implementing applications using GIS and in addition, they have cartography skills. However, they are few in number to satisfy the current market in the country. Furthermore, they require additional investments in the new skills training in order to keep them updated and productive.

5.5.6 Data sharing

Data exchange was assessed on three most common means of data exchange. These were paper maps, CD-ROM and email (Figure 5-7).

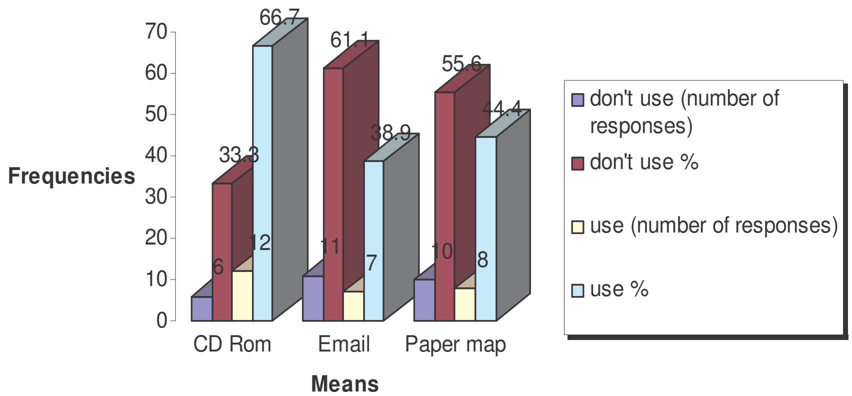


Figure 5-7: Means of data sharing

Responses indicated that CD-ROM is the most frequently used mode of data exchange, as shown by the Figure 5-7. Paper maps and emails are almost equally used. Data sharing is done by electronic means which require a computerized system. The paper maps serve for scanning and digitizing. It was found that cadastre services do not exchange data. This may be due to the issue of data format highlighted earlier on, which is not flexible enough for data exchange. From SDI perspectives, these means of data sharing are inappropriate, given that they all favour duplication of data maintenance and data capturing in cases paper maps are used.

5.6 Policies and institutional arrangements: assets and gaps

There is a big gap regarding policies and institutional arrangement in the Land Administration spatial sector and in the country's spatial sector as a whole. Nevertheless, a number of assets can be found out.

5.6.1 Assets

(i) Information and Communication Technology (ICT) is now the central priority of the country, as stated in Rwandan 2020 Vision. Therefore, the government is interested in implementing policy initiatives to achieve widespread applications of IT in all possible areas. The first step has been the Rwandan ICT for Development policy which began in 1998 under the auspices of the African Information Society Initiative of the Economic Commission for Africa (ECA). The first ICT for Development plan (2001-2005) for Rwanda, the National Information Communication Infrastructure (NICI) policy was initiated in 2001. Currently, the process is on its second phase, NICI-2010. The key areas of the policy include some clause relevant to SDI:

- Policy on human resources development
- Policy to facilitate the deployment of ICT in educational system
- Policy on the development of standards
- Policy on promoting universal access to information and communication technologies and systems.

However, the two phases of the policy do not include the spatial data sector specifically as a sub-plan as it is done for other fields such as education, social development, and national security. In fact, these phases were implemented before the launch of SDI in the country (October 2006), therefore they do not make provision for the ways of collecting, accessing and using geospatial data.

(ii) The National Land Centre recently established, is dedicated the task to work on all policies and laws relevant to land and those can have an impact on SDI.

(iii) Organic land law whose provisions stipulate registration of title act, land acquisition law and other issues.

5.6.2 Gap analysis

5.6.2.1 Lack of policies and legislation relevant to SDI

In this context, not only is it important to examine the current existing policies and legislations, but also to recommend policy initiatives necessary to promote the development of SDI. Currently, there is no spatial data related to policy existing in Rwanda. Respondents were asked whether they have any policy or guideline regarding spatial data use, pricing, access, standards, custodianship, and metadata. None of the providers had any of those policies. Only providers that charge their users indicated that they follow the pricing guidelines for public documents, lastly revised in 2003. However, this has been declared by two out of three providers although all of them are public institutions. The third one indicated that the cost of data is fixed following internal organization. It is based on the costs incurred by the agency to produce what the user has requested. It was found that spatial data prices are not the same for providers that follow the same guideline.

The absence of appropriate policy was mentioned among some of the reasons that could impede collaboration or partnership between geo-information providers. An assessment of the main reasons which can be the basis of non-collaboration was done as shown on the Figure 5-8.

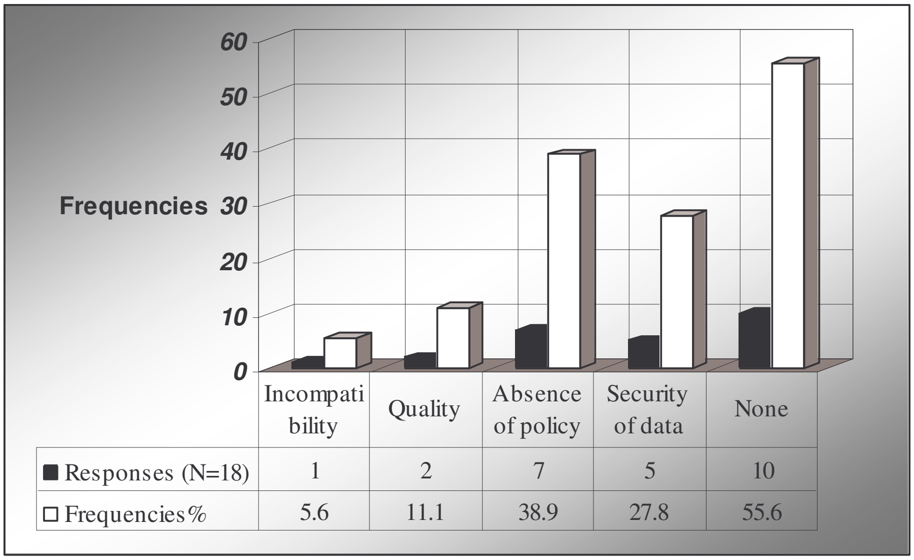


Figure 5-8: Main reasons of not having collaboration/ partnership between providers

The results revealed that in general, providers (55.6%) do not find any reason of not collaborating. Nevertheless, some issues like incompatibility of data, quality of other's data, and lack of policies are considered by some respondent as causes that prevent them from collaborating with others especially in data sharing. The lack of policy was pointed out by seven providers (38.9%) as preventing collaboration.

In addition to the absence of policies, there is no legislation that impacts on SDI in Rwanda. The lacking legislation includes:

- Access to information Act that provides advancement in support of data access and data sharing. The government is the largest provider of geospatial data and all information created by the government is considered as state resource. This information is to be made available to other government and private agencies.
- The copyright Act: the custodian agencies retain the copyright on all data generated by them. The legislation must enable value added use of datasets belonging to the government.

- Pricing Act: the regulation must ensure that different agencies involved in the spatial sector, especially public departments, provide spatial information on a non-profit basis.
- Privacy Act: such kind of regulation has to provide a certain level of protection of personal data.
- SDI Act: it enables the organizational structure of SDI and the functioning of institutional arrangements.
- And any other.

These legislations are needed to enforce SDI policy after it has been implemented.

5.6.2.2 Institutional arrangements

(i) Custodianship remains critical, given that from past experiences, any legal custodianship has not been recognized in Rwanda. The recently approved National Land Centre, is the only legally accepted custodian of Land Administration related to datasets as well as geodetic control network, satellite images and aerial photography, digital elevation model, spot heights, bathymetry, cadastres, land-use planning, land tenure, land cover, and topographic maps.

The above framework data are currently held by different institutions and some of them were known traditionally as formal custodians. This requires a consistent custodianship policy and regulation which must be put in place before anything else could be done. Furthermore, it encompasses mechanisms of how right of ownership must be agreed on. However, this is not stipulated by the law establishing the centre.

According to the law, the National Land Centre is also a new custodian and a value adder institution. Article 23 of the law states that from the publication of the law in the official gazette, all land management-related technical functions and movable property (land records, various maps, and databases), must be transferred to the NLC. Normally, this approach is good because quality control becomes much easier under a single agency and this reduces duplication between different authorities. However, the agency must be sufficiently resourced enough. This is the main concern for a newly established institution like the NLC. Another challenge is that, the institutional arrangements regarding the transfer of equipment, and the financial and human resources that were used in data management are not stipulated in the new law. Instead, the law stipulates the recruitment of new staff. This discourages an SDI approach which seeks to minimize any kind of duplication of effort in spatial data management.

(ii) Partnership is one of the requisite aspects of the SDI environment. However, it was found that, there is not any formal partnership policy or regulation in Land Administration field. The figure below describes the basis of partnership.

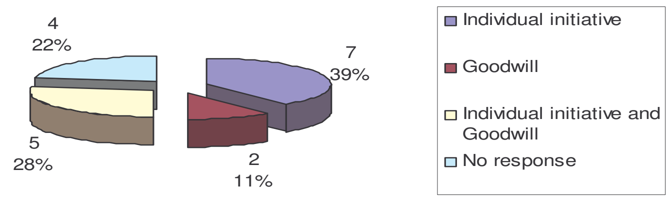


Figure 5-9: Description of existing partnership

Respondents revealed that whatever they do, in terms of partnership, is dictated either by goodwill or individual initiative (Figure 5-9). One of the responsibilities of the NLC, as stipulated in article 5(22), is to promote cooperation with other agencies involved in land management. However, the basis of the partnership is not specified, therefore the enforcement of this law can take effect after many years.

During the interview held with the Director of CGIS-NUR (M. Schilling, 2006, pers. comm.), the issue of partnership with other mapping agencies, especially the new NLC, was raised. The interviewee indicated that a well-functioning partnership can contribute to the efficient use of available resources (human and financial). She argued that in the line of collaboration, some duties of the NLC can be carried out by the more experienced mapping agencies. Giving an example of her institution, she pointed out that there were new Masters and PHD holders, who can contribute to the drafting of policies, standards and development. However, the institutional arrangement seemed to be not flexible enough.

5.7 Technological aspects, assets and gaps

To this regard, the standards, IT and GIS infrastructure will be examined. The analysis is mainly based on the information derived from interviews and observations. Some interviewees used documents to support their ideas and the Researcher referred to those documents. This is the case of NICI 2010 plan document.

5.7.1 Assets

5.7.1.1 IT infrastructure

ICT is developing rapidly in Rwanda and a national body, the Rwanda Information Technology Authority (RITA) has been created in order to coordinate and to promote information technology in the country. This may have a positive impact on SDI development. Some indicators include ICT for development policy, created in 1998, an increase telecommunication infrastructure; human resources development and internets' availability (Government of Rwanda, 2006).

Increasing skilled ICT manpower in areas such as networking, systems development and support, programming, software developement, system administration and management. There are three main internet service providers. Terracom communication is in fast progress laying the fibre optic across the country. By the end of 2005, 256 km of fibre optic across the country and 20 km in and around the capital city Kigali were laid (Government of Rwanda, 2006). This has greatly improved internet speed. Artel communications boasts a network of 257 Very Small Aparture Terminal (VSATs) in Rwanda. Rwandatel bandwidth for internet asynchronous, 9 Mbps downlink, 5 Mbps uplink

An effort is being made to extend connectivity to rural areas through various initiatives that include the USAID Telecenters Program, the School Net-World Link and the International Telecommunication Union National Telecenters Project. Presently the majority of Ministries and public sector organizations has their corporate computer networks and high speed access to the internet, in most cases spread throughout the entire organization. Some of them, in the capital city are inter-linked with the government wide fibre backbone network. Table 5-4 summarizes some achievements from 1995-2005 distinguishing the period before the start of the NICI plan and the period after.

Table 5-4: Some ICT indicators 1995-2005 (Government of Rwanda, 2006)

Indicators	**Before implementation of ICT policy**			**Achievements of NICI-2005 plan**
	1995 (after the 1994 Genocide)	**1998**	**2000**	**2005**
Telephone lines	6,900	10,800	17,568	23,903
Internet service providers	None	1	2	4
Internet subscribers	None	100	1,400	2,949
Internet bandwidth (Kbps)	None	128	256	1,024

5.7.1.2 GIS infrastructure

Basic GIS infrastructure or equipment (GIS software, hardware, GPS, printers/plotters, internet connectivity, and other facilities), are in place in the institutions visited. Only external infrastructures were observed during our field work. Table 5-5 details the available equipment.

Table 5-5: GIS infrastructure

Type of equipment.		
Software	**Hardware**	**Other equipment**
-ArcView 3.2 -ArcGIS 9 -Mapinfo 7.5 -IDRIS 32 -DBMS, web mapping software: ACCESS, ArcIMC, ArcSDE, ArcPAD, Adobe Photoshop 7.0, Front Page	Computers Dell, IBM Pentium, INTEL ® Pentium,	-Plotter A0 -Printers A3, A4 -Scanner A4 -Table for digitizing -GPS (handheld and DGPS receivers) -DGPS station -Database servers
Facilities		
Offices		
Training lab		
Internet connectivity		
Databases		

In general, all GIS units are in possession of offices where at least one computer runs GIS software. Other common equipment include printers A4 and handheld GPS. The computers are connected to the internet. The most active mapping agencies are more equipped than the others. In addition to the common infrastructure described above, they have got other GIS software like Mapinfo, IDRIS; printers A3, plotters, table of digitization and scanners. The DGPS are used by few institutions. The CGIS-NUR is the only institution that has a web based GIS server. The CGIS-NUR has got two training labs in line with its mission of training and research.

5.7.2 Gap analysis

Currently, there is a shortfall in fixed line installation, thus affecting the network access. The internet is still very expensive for individuals and organizations. In 2005, the monthly fees were estimated at $1,250 for 256 kbps line connected to fibre optics (Government of Rwanda, 2006). The internet is at least affordable in cyber cafes where it costs an average of RWF 400 ($0. 71) for an hour. However, the cyber cafes are only available in urban areas. This is an obstacle to spatial data users in a SDI environment where data is available via internet.

The level of utilization of computers to support organizational activities and operation is still low. The use of computers buy the majority is limited to basic applications like word processing, spreadsheets, and other common programmes. Computer-based high applications, like information management, are used by few institutions. Moreover, the use of the internet is largely for emails and occasional web browsing. A small number of NGOs and international agencies use the internet to support the organizational activities.

On the same line of gaps, there is a serious lack of skilled human resources in the fields of geo-information sciences, web mapping and geomatics. Furthermore, it is important to note the absence of a spatial data clearinghouse which can provide electronic mechanism for data sharing and access. Other challenges are related to the shortage of electricity and other source of energy in the country, as well as the absence of GIS infrastructures at local level (districts and sectors), where Land Administration activities are being decentralized.

Issues related to standards need to be highlighted as well. Rwanda has got a bureau of standards but its capacity is not yet extended to the geospatial information. All issues regarding standards could not be assessed given that they are very broad. Standards of importance to geospatial data users range from the details of computer hardware and network to the design of databases and map products. The researcher has picked up afew key issues that can affect spatial data format, sharing and integration.

For this purpose, providers were first asked on which standard organization they adhered to. All spatial data providers stated that they did not have any standard organization which they are subscribed to; they all follow standards of their GIS software providers. It is known that formats for storing geospatial information are almost as numerous as vendors of GIS software. This was found as a minor problem because the most GIS software used are the products of one company ESRI, therefore they use ESRI shape file. As result, the issues of data exchange related to GIS packages from different standards are quiet limited.

Nevertheless, the absence of a national body of spatial data standard regulating the spatial data sector activities is a source of the one of the major issues: inaccuracy of data**.** In the case of this study, this is the main issue that affects the quality of data. It is explained earlier that the suspicion of the quality of the third party is one of the reasons for not sharing spatial data.

One source of inaccuracy is in primary data acquisition. It results from the fact that different agencies are involved in primary data acquisition and have different capacities in terms of human resources and instrumentation. For instance, nowadays GPS has become a major mapping tool, thus enabling unskilled workers to measure positions. In addition, some institutions are in possession of the cheapest hand-held GPS receivers, with a precision of 15 meters which cannot be improved by post processing or any real–time differential method. Others use the more accurate GPS (0.2 m or less) like Differential GPS, with qualified surveyors or other skilled measurers. Consequently, those that use simple hand-held GPS receivers are likely to have positional inaccuracies in their data. Another source of inaccuracy is associated with digitization which is frequently used in Land Administration spatial data areas in Rwanda, as means of secondary data acquisition. The inaccuracy could be due to data managers who are not skilled enough.

Secondly, the spatial reference systems (projection, datum, coordinate system) and scale or resolution used by different providers were found out. It was found that existing spatial data are in different spatial reference system as shown in Table 5-6.

Table 5-6: Referencing system and scale used by providers

Projection and datum	**Coordinate system**	**Scale (range)**
Projection: Gauss-Kruger Projection or Transverse Mercator and Universal Transverse Mercator (UTM)	Global system	1:50000 topographic maps
Datum Arc 1960, World Geodetic System 1984 (WGS 84), Clake 1880	UTM	1:500 to 1:10000 cadastral diagrams and plans
		1:25000 to 1:1000000 other maps

From the above table, the three types of projections mentioned are quiet similar. Gauss projection is the same as transverse Mercator. They use the same formula for mapping directly from spheroid to map. The UTM uses the Gauss Kruger formulae with some conventions and factors added. It is normally used for large-scale international maps and only extends up to latitude 85 degrees.

The coordinates in a global system consist of latitude, longitude and height. The UTM coordinates are “Northings” and “Eastings” instead of X and Y. There are no standard scales, except topographic maps which are standardized at 1:50000. Other maps are drawn at different scales.

When datasets are drawn from maps with different map projections and datum, positional errors may occur. The sources of inaccuracy may include errors associated with transformation and processing operations involving coordinate transformation, map projections change, use of raster data from different spatial resolutions, which occur during data manipulation and analysis. For instance, referencing geodetic coordinates to the wrong datum results in hundred meters of error.

The WGS 84 is the only world referencing system in place today and it is the default standard datum for coordinates stored in commercial GPS units. This requires the users of GPS to be cautious because they must always check the datum of the maps they are using. To correctly enter, display and to store map related map coordinates, the datum of the map must be entered into the GPS map datum field. With WGS 84, satellite surveying enables point positions to be accurately measured in a 3-dimensional space.

It was found that some geospatial managers encounter difficulties to integrate GPS data collected in WGS 84 format to the map of Rwanda. An example of such difficulties is that most of Rwandan maps are in Transverse Mercator projection. Therefore this always requires change of the coordinate system. This leads to errors and consequently incompatibility of data when GIS users are not aware of that.

5.8 Conclusion

This chapter has provided a brief description of gaps and assets existing in the Land Administration spatial data sector with reference to SDI framework requirements. The overall objective was to assess the feasibility towards the establishment of SDI. It was found that the Land Administration spatial sector in Rwanda is poor in its vital spatial data (cadastre and land-use planning related geospatial data) although other core spatial data are available. The legal custodianship of data does not exist; consequently, there are multiple producers for the same dataset. Therefore, there exists a high level of duplication of effort in human and financial resources in data capturing and maintenance. Even though the GIS is increasingly used as a tool of data management, it still fails to reach the cadastre, the central component of Land Administration which is still manual and paper based. Furthermore, most of GIS activities in Rwanda are project oriented; therefore their sustainability is uncertain. GIS technology is also facing a shortage of skilled human resources.

Various categories of users are available, but they lack an appropriate way to access data. So far, there is no spatial dataset that can be accessed via the internet except some static maps. Data sharing is currently limited to the exchange of digital mediums (CD-ROM, email) or paper maps between spatial data producers.

A big job needs to be done in terms of spatial data related policies and institutional arrangements in order to fill in the existing gap. For this purpose, a number of policies and regulations can be added to the ICT policy that is already in existence. An awareness-raising campaign of the role of SDI among all stakeholders, especially decision makers, is of great importance. Rwanda is improving in the ICT sector, and already the foundation to support SDI on the technology has been established. However, computerization, internet access and its affordability are still critical, especially in rural areas.

Besides the bulk of constraints found in the results, there are assets that encourage the Researcher to conclude that it is feasible to implement SDI in Rwanda. One notes that there is an increasing awareness of the role of spatial data, especially in decision making. This indicates that any initiative to promote spatial data sharing and efficient access can be encouraged. The achievements of the Rwandan ICT for development policy, in its first plan, and the other three plans which will extend over 15 years to realize 2020 vision, are an asset to the technological issues regarding SDI. The institutional arrangements, which in most of the time are difficult to address, can take a long process. However, the creation of the NLC is another step further. The funding mechanisms are influential to SDI development that is why sometimes SDI cannot be implemented in a perfect scenario. In this case, insufficient funds can only allow the development of some aspects on a step by step progress.

CHAPTER 6: A PROPOSED LAND ADMINISTRATION SDI PROTOTYPE

6.1 Introduction

This chapter aims to show how possible it is to implement SDI within Land Administration sector and the benefits it can bring in line with this research's fifth objective. For this purpose, a Land Administration SDI prototype (LA-SDI) is proposed. After a situational analysis of Land Administration spatial sector, it is possible that a SDI can be established. Once established, it can bring remedies to the challenges demonstrated in the previous chapter. However, in a developing country like Rwanda, resources are not often available to undertake the whole SDI programme in an ideal way. There is need to start developing some elements, step by step. Therefore, the development of the proposed prototype can be done in different stages.

6.2 General framework

Figure 6-1 illustrates the framework of LA-SDI prototype. The Researcher has been inspired by SDI conceptual framework and the concept of a clearinghouse described in chapter one.

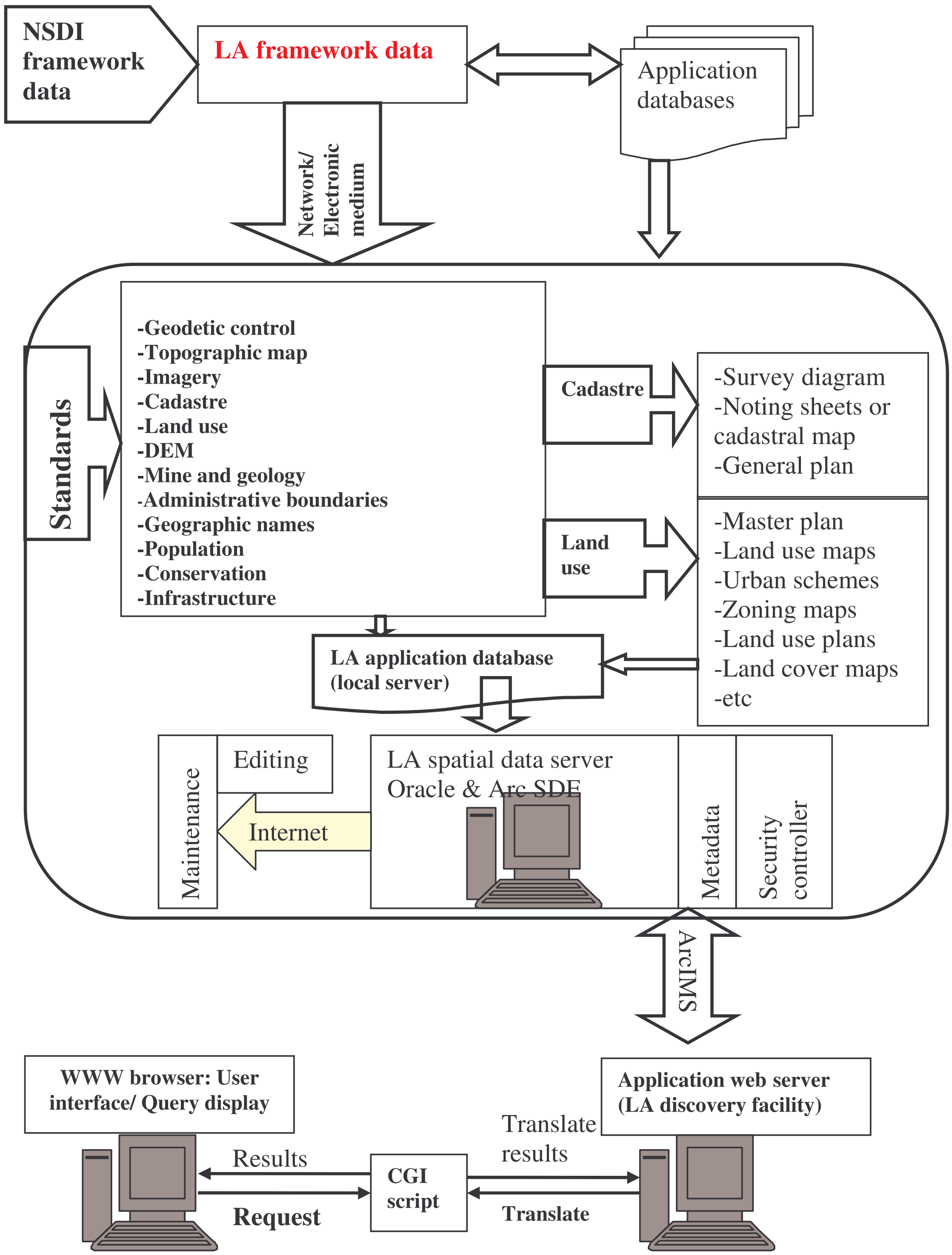


Figure 6-1: LA-SDI prototype general framework

6.3 The Land Administration SDI prototype explained

The development of the proposed SDI is a process which can be carried out in different stages. In this context, the term development encompasses the design of the general framework, the implementation, and applications development.

6.3.1 Spatial datasets and Custodianship

The framework data used in Land Administration as listed in Figure 6-1, reside with respective custodians who are in charge of maintenance and data updating. Data exchange is done on line.

The framework data most needed are listed below

- Spatial reference data including the control points,
- The topographic map sheets covering the whole country,
- Aerial and remote sensed imageries,
- Infrastructures, including sewer, road network, communication network, power line network, water infrastructure, socio-economic infrastructures (schools, hospitals, etc),
- Administrative boundaries: national boarders, provincial, districts, sectors, and cells boundaries,
- Geographical names and addresses for the purpose of locating and querying. They must include different types, such as administrative names, names of rivers, mountains, buildings, roads, etc,
- Conservation data: extend of conserved zone, tourist site,
- Mine and Geology data showing present entities and potential ones,
- Population data: population distribution,
- DEM: elevation points, contours,

6.3.2 Land Administration application data

The core data listed above serve as a basis for the production of application spatial data for Land Administration. The examples include the cadastre, including the registered parcels in rural and urban areas. The cadastral documents to be provided comprise survey diagrams, cadastral maps, and urban schemes. For land use, there is the national master plan that shows present land development and future ones, plans specifying residential areas, areas for agriculture, industry and conservation out of urban areas. Urban schemes that indicate urban zoning and provide site plan control, building regulations, water protection areas, and the green land protection area. Finally, data on land suitability, and land cover maps.

6.3.3 The system architecture

The Land Administration SDI prototype is built within the network environment. For spatial data storage and management, a Relational Spatial Database Management System is created. The database management software Oracle and the spatial data gateway ArcSDE will be used. Presently, the server-based GIS technology offers a variety of products. ArcGIS server products can be used to display query, updating, manage and maintain the spatial database. ArcSDE is an application server that facilitates storing and managing spatial data (raster, vector, survey) in a database management system and makes data available to many applications. ArcSDE offers an advantage in managing spatial data in different databases (oracle, Microsoft SQL Server, IBM DB2, Informix). In addition, it serves data to ArcGIS, ArcIMS and ArcGIS server. It is wise to build this prototype on ESRI software given that they are widely used by most of the spatial data providers in Rwanda.

The whole system is divided into sub-systems including the data maintenance sub-system, data query sub-system, and the information publish sub-system. The maintenance sub-system is developed using ArcGIS and the ArcMap is used for spatial data mapping and editing. Batch import, export and updating data is performed in ArcCatalogue. The data query sub-system is developed using ArcGIS Explorer. The information publish sub-system is carried out using ArcIMS, which is widely used for GIS Web Publishing to deliver maps, data and metadata to many users on the web. The security controller within the database is critical for the prevention of unauthorized access and interception of valuable information.

6.3.4 Data organization

Large volume of data with different spatial content and format should be organized and integrated. The researcher’s suggestion is that data could be organized in different layers such as buildings, boundaries, and road network. According to data category, different a feature datasets are designed in order to store the data. A feature class will be selected within each feature dataset, to represent a layer. The following table shows some feature datasets and feature classes that can be developed.

Table 6-1: Data organisation

Feature dataset	**Feature class**	**Feature type / Spatial object**
Administrative boundaries	National boarder	Polygon
	Provincial_boundaries	Polygon
	District_boundaries	Polygon
	Sector_boundaries	Polygon
	Cells_boundaries	Polygon
	Umudugudu_boundaries	Polygon
Geographic names	Names	None
Topographical map	Sheets (1,2,3,…)	Raster
Cadastre	Parcel	Polygon
Infrastructure	Roads	Lines
	Communication_network	Line
	Power_line	Line
	Health_infrastructure	Point
	…	…
Natural resources	Minerals	Point
	Land cover	Polygon
Land use	Land use plan	Polygon
	Protected areas	Polygon
	Tourist sites	Point
	Land suitability	Polygon
	Master plan	Polygon, line, and point
Imagery	Aerial photo	Raster
	Satellite image	Raster
DEM	DEM	Raster
Population	Density	Polygon

Most of the feature dataset are organized as feature layers except remote sensing imagery and DEM organized in raster datasets. The topographic maps are also available in scanned images in Tiff format (43 sheets) covering the whole country. For the physical storage of the data, feature data and raster data have to be stored in different oracle tablespaces, located in different hard discs in order to enable oracle to optimize performance.

6.3.5 Data processing and maintenance

All data are processed, standardized, and then loaded into oracle via ArcSDE spatial data gateway using ArcCatalogue and other customized tools, A detailed data update plan and mechanism is made to make the database up-to-date. Since the data came from different agencies, the data custodians are responsible for data updating. The lead agency is responsible for data integration and data maintenance.

Access to the database must be strictly controlled. The users of the database can be divided in three groups these are the administrator, the data owner, and data viewer. The administrator is the only one who has the privileges to control the database. The data owner has the privilege to select and update the specified feature dataset. The data viewer has the privilege to view, query, and select specified feature datasets. Other security measures to ensure that the users will not be able to directly manipulate the data beyond their internet browser must be designed. There is a need to create a backup job to backup the data, to ensure the database security. Professionals recommend that two or three backups of all files can be made and should be kept in different locations.

6.4 Developments of Land Administration SDI prototype

Since everything can not be done at once, it is proposed a phased approach for the development of this LA-SDI prototype.

6 4 1 The first phase: design of Land Administration SDI general framework

Tagets: the main activities that will ensure the success of the project at this stage are:.

1. To set up a LA-SDI structure and sort out institutional issues. The structure may consist of leadership, a stakeholders' forum, steering committee and technical working group. The stakeholders' forum includes representatives of all custodians; the most interested users of Land Administration related geospatial data including user-providers agencies, and the institutions in charge of Information and Technology at national level. This forum will be chaired by the lead agency. The

steering committee will ensure the implementation of decisions from the stakeholders' forum. Two tasks teams will be made within the Technical Working Group, one working on policies, and another on standards.

2. An inventory of stakeholders, their needs in terms of geo-information, problems and interests, in order to find out spatial data producers and users.
3. To raise awareness of geospatial information availability, and to bring a common understanding of SDI and create awareness of its benefits.
4. To find an appropriate approach that will raise the awareness of decision makers to the role of geospatial information and SDI., The concept of SDI should be understood as important to the development of the nation as any other infrastructure (such as health and education) through awareness meetings, workshop and advertisement.
5. To define:
    - Core datasets and metadata using the fundamental data identified in the frame of NICI-SDI activities led by RITA. An effort must be put on developing the cadastre, urban schemes and land use plans. The current topographic map must be updated as well.
    - Data policy: the development of policy can start with critical issues like data ownership, data sharing, data access conditions, data management and data discovery mechanism. Other examples of policy documents can serve as a model, instead of developing policy from scratch. This requires raising awareness and discussions on elements needed for inclusion in the policy framework.
    - Data standards: it is better to adopt the existing standards where applicable and preferably international ones. It is advisable to identify a minimum set of standards to which databases must comply in order to be inter-operable.
6. Training and capacity building: short courses must be organized for the staff in charge of geospatial information management. They can be trained on basics of GIS, spatial database design and management and web mapping. The expertise for this is available in the academic sector such as CGIS-NUR.

6.4.2 The second phase: Implementation of Land Administration SDI

***Targets*:** the ultimate goal of SDI is to provide a basis for spatial data discovery, evaluation, download, and application for users. As a result, the database including standardized data themes must be built up, and the web based spatial data discovery facility for Land Administration designed and developed. This will allow users to discover the location and/ or existence of spatial data.

The researcher provides a brief demonstration on how the system can work. For this purpose, the Land Administration Spatial Data Discovery Facility (LA-SDDF) website was developed using Microsoft Front Page 2003 and published to a local folder. However, given the Researcher's limited expertise, a simple website was designed. The testing was done using one physical machine connected to the internet as a user browser and the memory stick playing the role of a database server. Limited time and resources couldn't allow us to demonstrate the system as it is in real life. If it was in real life situation, the website of LA-SDDF could be visited online. Through a uniquely assigned internet address that can be given to the web server, the LA-SDDF is able to mark its presence on the internet. Additionally, an operational system is supposed to run within an internet network environment with a web server and other related technologies.

6.4.2.1 LA-SDDF architecture

The LA-SSDF consists of three main components these are the Land Administration related spatial database, the server and the user or client web browser. The spatial database comprises specific datasets for the Land Administration sector (land use, land cover, cadastre) and other supporting data like topographic data, imagery, and elevation data. The Land Administration spatial database server can be managed and maintained by any national institution or organization such as the National Land Centre that has the mandate for Land Administration related activities in the country, which can develop the LA-SSDF. As highlighted in chapter six, there are a few Land Administration application datasets developed in Rwanda. The datasets used for this demonstration are from the Landcover Multipurpose Database produced by the Africover project in 2002. The Africover database is being used as reference data in government and other institutions in Rwanda.

The server connects and searches the database. In practice, there must be a web server and a map server. The web server contains the user query and has the ability to connect to the database by means of additional technology such as plug-ins[1], and java scripts[2]. The map server provides the user with the requested map images. The user web browser interprets and displays the user query based on the web pages generated by the web server.

6.4.2.2 The user interface

The home page of the website presents a friendly user interface which connects the spatial data user directly to the Land Administration spatial database (see Figure 6-2).

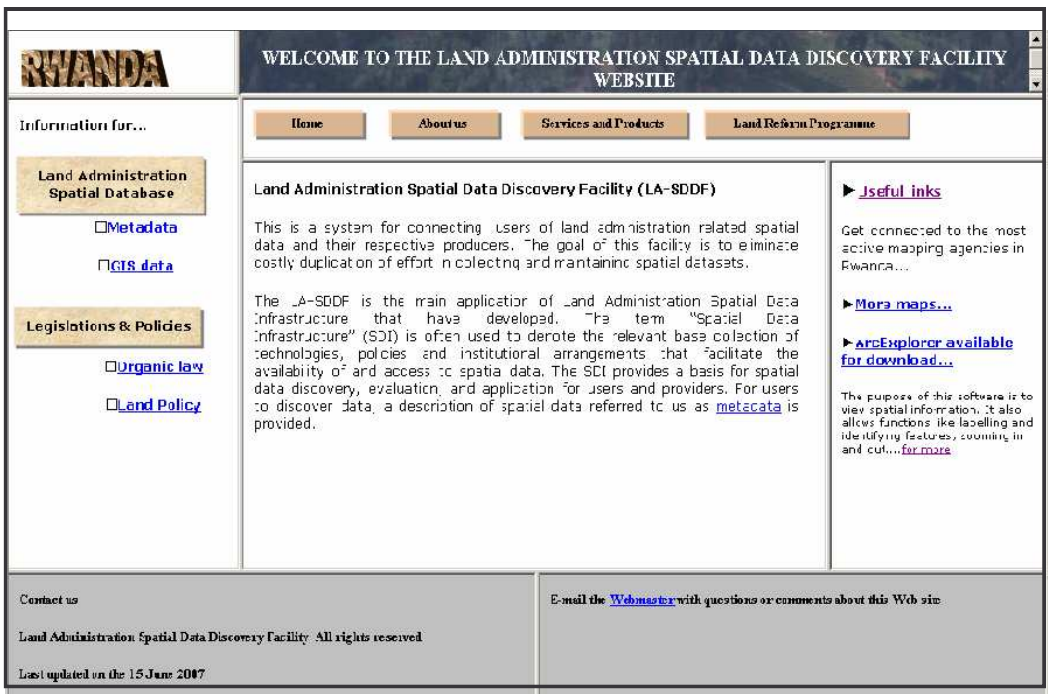


Figure 6-2: LA-SDDF user interface

In real situation, available technologies can be used in order to provide the user with an advanced interface that allows selection of the spatial search criteria. The interface also provides other useful links and some general information. For instance the user can download ArcExplorer free of charge (Figure 6-3).

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[1] Plug-ins are designed to extend the web browser functionality to support new data types such as vector image. They can be inserted into web browser to view the vector images on the we browser (Majid, 2000).

[2] Web-based scripts used extensively to add navigation buttons, scrolling banners and simple querying of GIS data on web document (Majid, 2000).

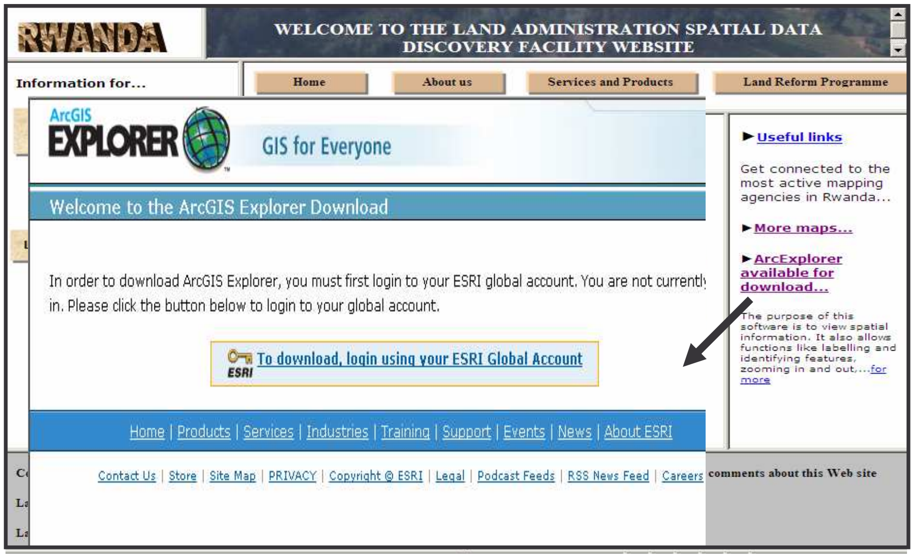
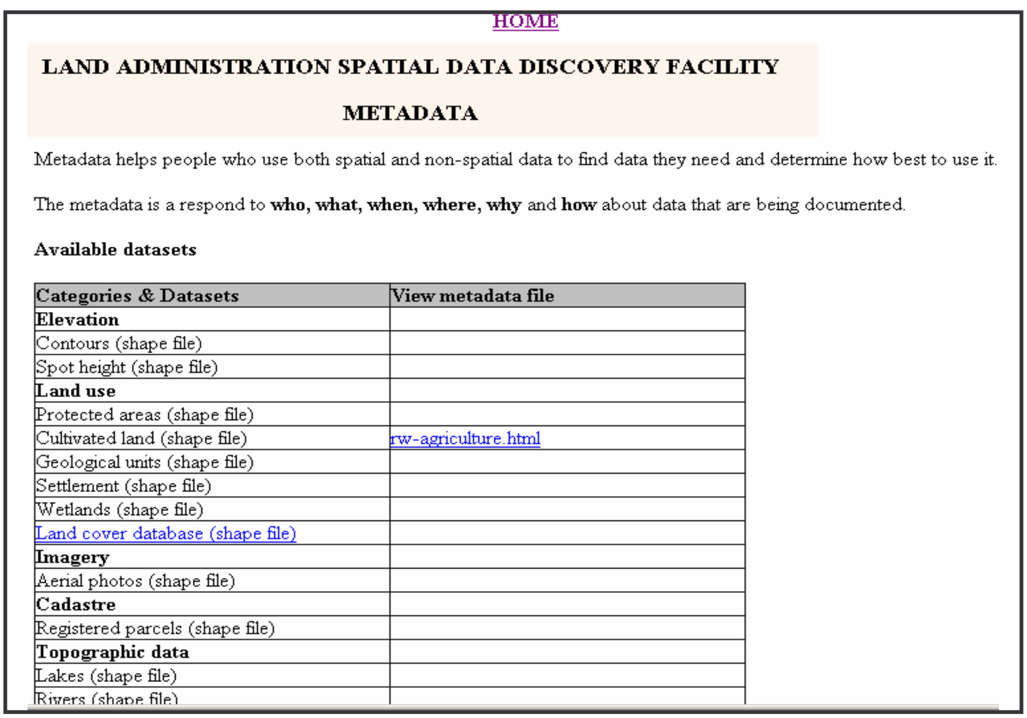


Figure 6-3: LA-SDDF: Free download of GIS viewer.

6.4.2.3 Spatial data discovery

The user interface presents a link to the metadata and the GIS data. The user can browse through from the metadata link and get connected to the web (HTML) pages describing the metadata of available datasets. The following figure shows a user connected to the web page of metadata, where he/she can view the metadata file of the dataset needed.



HOME

LAND ADMINISTRATION SPATIAL DATA DISCOVERY FACILITY

METADATA

Metadata helps people who use both spatial and non-spatial data to find data they need and determine how best to use it.

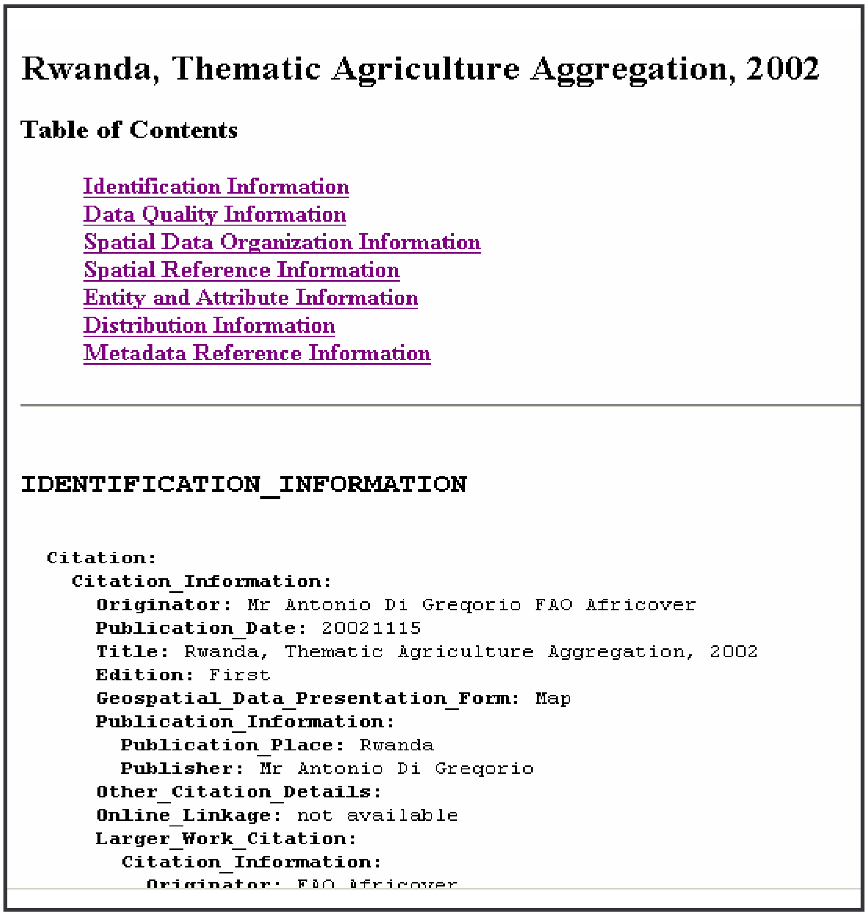
The metadata is a respond to **who, what, when, where, why** and **how** about data that are being documented.

Available datasets

Categories & Datasets	View metadata file
Elevation	
Contours (shape file)	
Spot height (shape file)	
Land use	
Protected areas (shape file)	
Cultivated land (shape file)	rw-agriculture.html
Geological units (shape file)	
Settlement (shape file)	
Wetlands (shape file)	
Land cover database (shape file)	
Imagery	
Aerial photos (shape file)	
Cadastre	
Registered parcels (shape file)	
Topographic data	
Lakes (shape file)	
Rivers (shape file)	

Figure 6-4: LA-SDDF: metadata webpage

From the webpage above, the user can view the metadata by clicking on active link. An example is given in the Figure 6-5. The metadata of the spatial datasets producer (FAO Africover) was adopted, and captured using metadata tools of ArcView based on FGDC standards and format.



Rwanda, Thematic Agriculture Aggregation, 2002

Table of Contents

- Identification Information
- Data Quality Information
- Spatial Data Organization Information
- Spatial Reference Information
- Entity and Attribute Information
- Distribution Information
- Metadata Reference Information

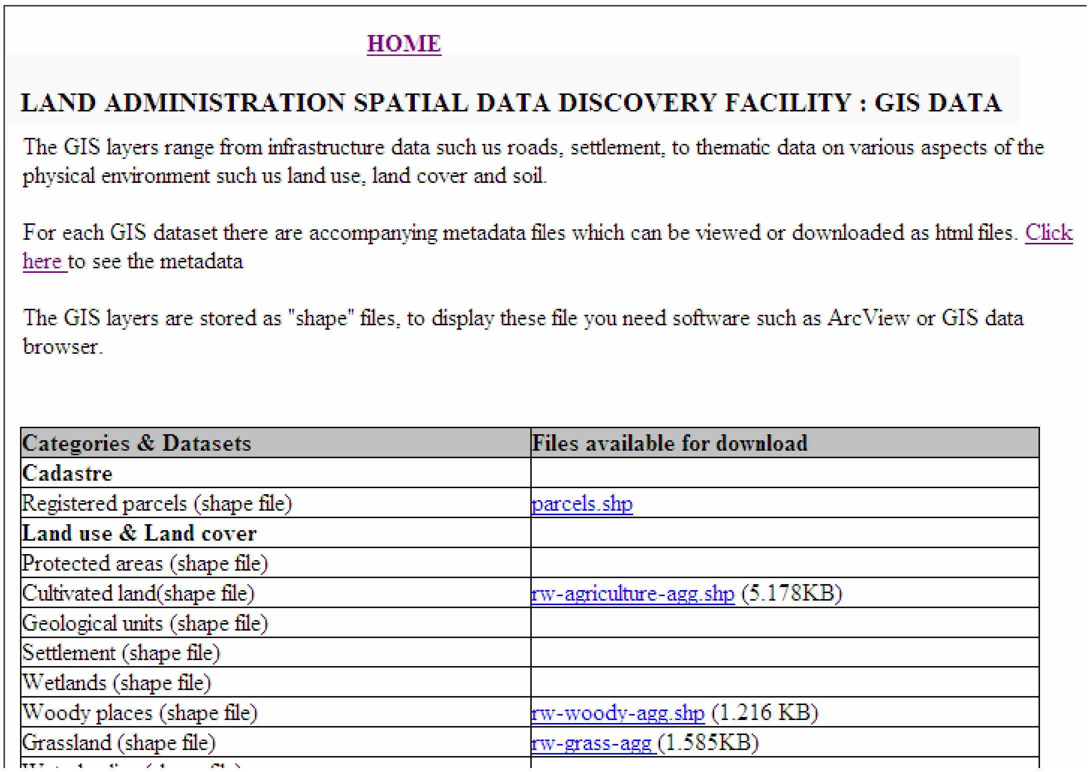
IDENTIFICATION_INFORMATION

```
Citation:
  Citation_Information:
    Originator: Mr Antonio Di Gregorio FAO Africover
    Publication_Date: 20021115
    Title: Rwanda, Thematic Agriculture Aggregation, 2002
    Edition: First
    Geospatial_Data_Presentation_Form: Map
    Publication_Information:
      Publication_Place: Rwanda
      Publisher: Mr Antonio Di Gregorio
    Other_Citation_Details:
    Online_Linkage: not available
    Larger_Work_Citation:
      Citation_Information:
        Originator: FAO Africover
```

Figure 6-5: An example of metadata in LA-SDDF

The metadata describes the data and informs the user where he/she can find it and in what format. It gives detailed information on identification, data quality, spatial data organization, spatial reference, entity and attribute, distribution and metadata reference. It is important to note that the metadata may lack some useful information for the user. A suitable example for this research is data quality information. To solve this problem, a standardized metadata format must be provided and must guide the spatial data producer. Once the system is implemented, it can be developed in such a way that the data producer can update the metadata online.

The user can be connected to the GIS datasets web page through the GIS data link. Some datasets are available for downloading (Figure 6-6) according to the access and use conditions indicated in the metadata. The user must have GIS software or browser to view the data. For users who cannot have GIS software, a free download browser (ArcExplorer) is provided on the user interface.



HOME

LAND ADMINISTRATION SPATIAL DATA DISCOVERY FACILITY : GIS DATA

The GIS layers range from infrastructure data such us roads, settlement, to thematic data on various aspects of the physical environment such us land use, land cover and soil.

For each GIS dataset there are accompanying metadata files which can be viewed or downloaded as html files. Click here to see the metadata

The GIS layers are stored as "shape" files, to display these file you need software such as ArcView or GIS data browser.

Categories & Datasets	Files available for download
Cadastre	
Registered parcels (shape file)	parcels.shp
Land use & Land cover	
Protected areas (shape file)	
Cultivated land(shape file)	rw-agriculture-agg.shp (5.178KB)
Geological units (shape file)	
Settlement (shape file)	
Wetlands (shape file)	
Woody places (shape file)	rw-woody-agg.shp (1.216 KB)
Grassland (shape file)	rw-grass-agg (1.585KB)

Figure 6-6: LA-SDDF: GIS data webpage

From this page, users can download some datasets online for free. An example can be taken from Grassland shape file as illustrated by Figure 6-7.

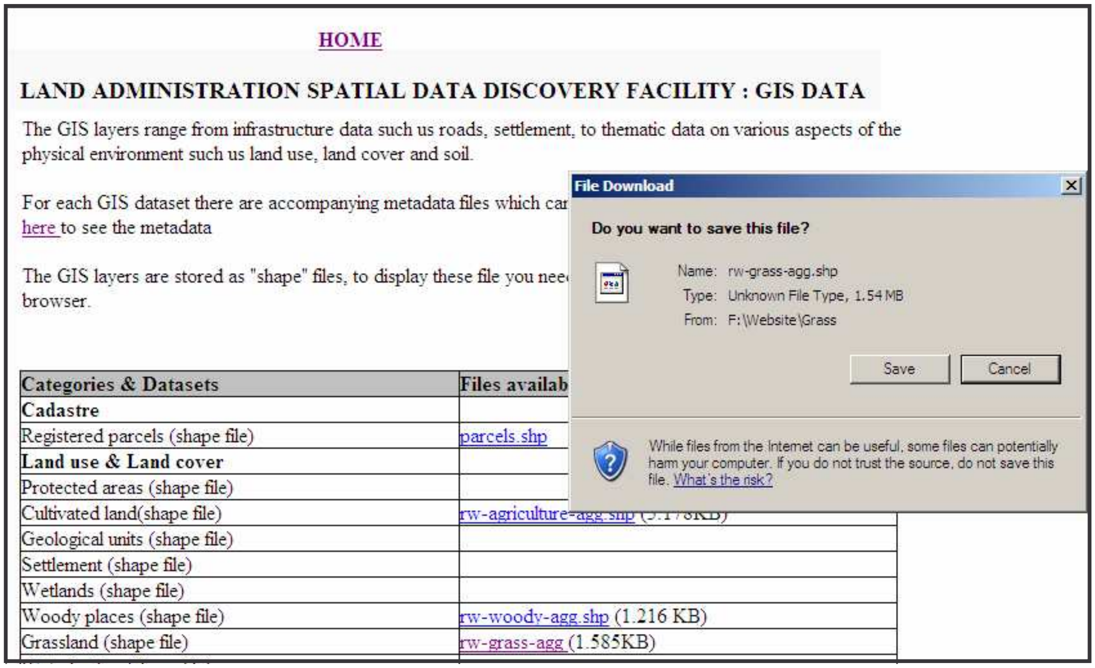


Figure 6-7: LA-SDDF: Datasets downloading

This thematic layer (grassland) is ready to be downloaded, as it appears on Figure 6-7. The user is given the option to save the file on his/her working directory. Once the downloading is completed, the user can open the folder with a GIS viewer. To illustrate this, Figure 6-8 and Figure 6-9 show, respectively, the dataset displayed with ArcExplorer, a free download GIS viewer and ArcMap.

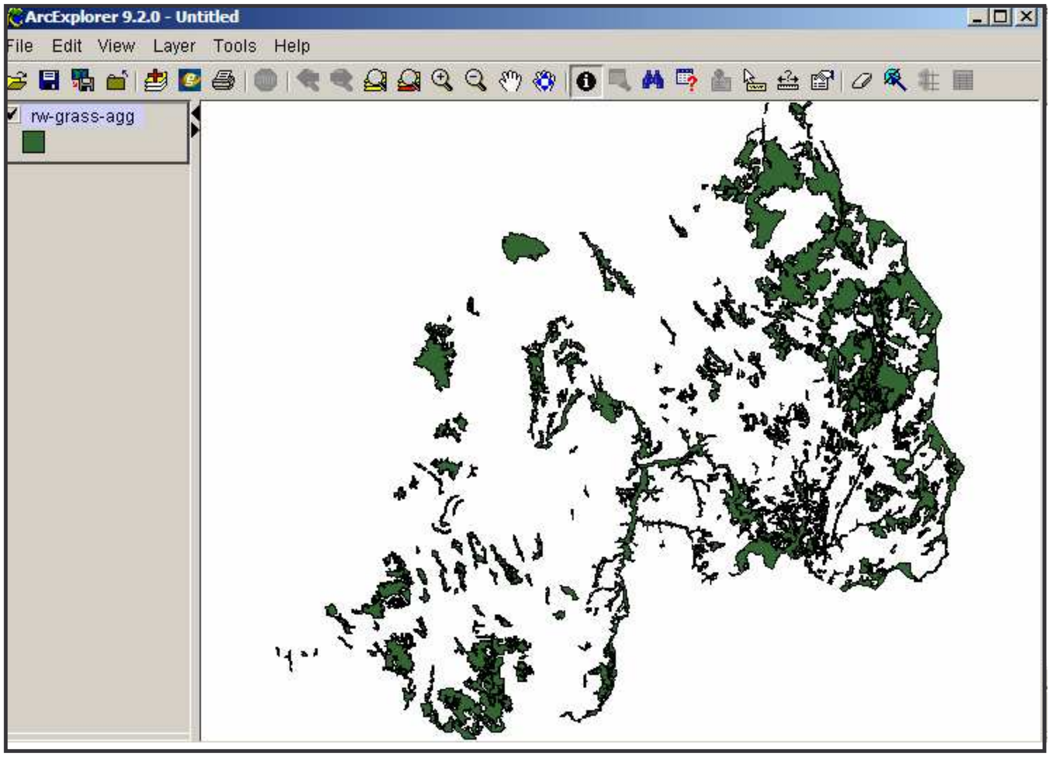


Figure 6-8: Spatial data displayed with ArcExplorer.

In addition to view spatial information, the user can zoom in or out, perform other functions like to identify the feature, to select features, labelling, measuring, and build a query.

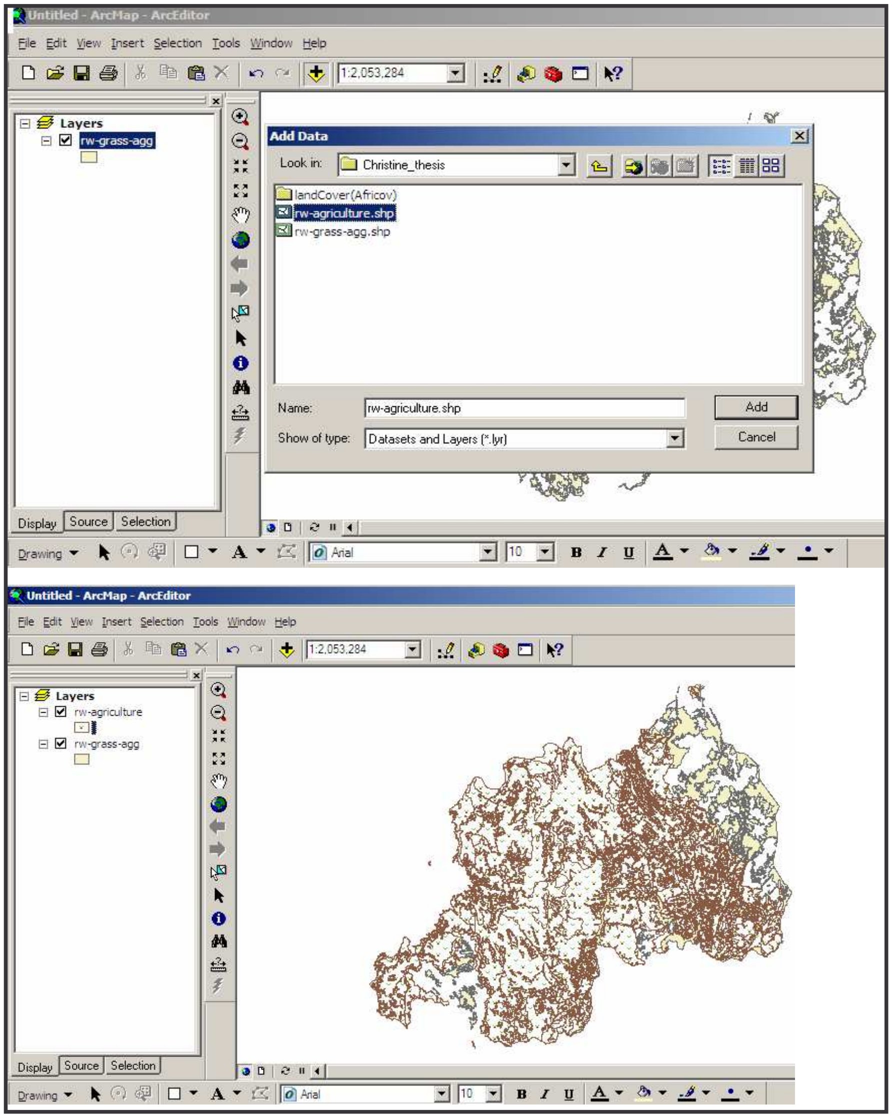


Figure 6-9: Spatial data displayed with ArcMap

However, all datasets available through the LA-SDDF cannot be downloaded directly online; some can be obtained on demand. For this, a user is required to fill in the registration form (Figure 6-9) which must be approved for the on demand dataset release.

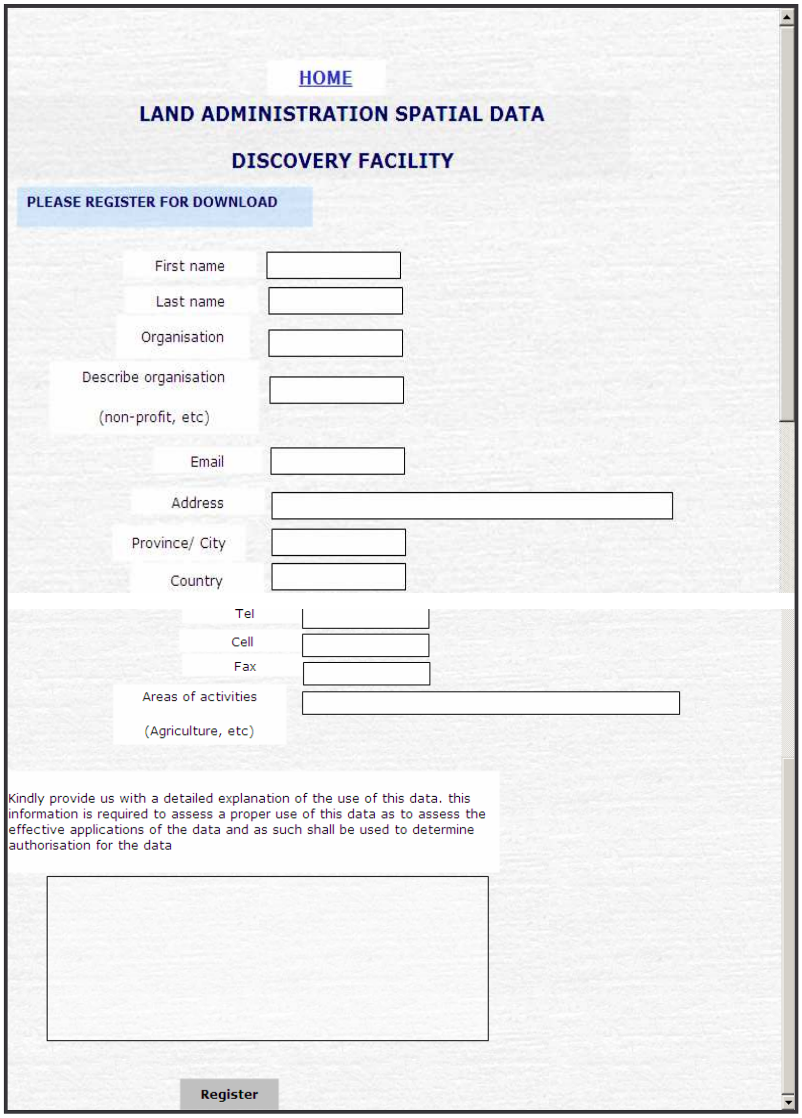


Figure 6-10: Registration form for data download

The use of "on demand" data can be applied on restricted data for different reasons like security or privacy policy measures.

6.4.3 The third phase: Applications development

Targets**:** this phase will be consecrated to an intensive development of different applications for mean and long term. Once the LA-SDI is successfully established, it can offer numerous benefits and can contribute to various applications. These include urban planning and land administration, environmental assessment, and decision making.

An example of the relocation of an industrial zone in Rwanda can be used to illustrate the above applications. The majority of the few industries existing in Rwanda are located in the capital city, Kigali. The industrial area, which is not far from the capital city centre, has grown on a wetland area hat is surrounded by a residential zone. Several decision makers' institutions have recommended that the industrial zone be relocated. However, no proposition for the new site has been made yet.

The department in charge of urban planning in the capital city can take advantage of the LA-SDDF for a situational analysis based on spatial data to decide on compensation schemes. Such an analysis requires the latest satellite images that show the current extent of the industrial zone, and land ownership information on parcels.

In order to decide on an alternative site, the topographical map, the DEM, the land use plan, land suitability, the road network together with other data can be selected to determine the best site, using a multi criteria GIS query. Here SDI plays an important role on site selection decision making.

An environmental assessment can be carried out before the establishment of the new industrial zone. For this purpose, a topographic map, population density, infrastructure distribution in the place and land cover data can be used as relevant data. In a classic situation without SDI, obtaining the needed information requires that one gets in contact with the relevant offices. However, the availability of SDI, makes the task much easier. A computer connected to the LA-SDDF is enough to retrieve the required information in a short time.

Other applications: in addition to the examples of applications given in the previous paragraphs, other field of application could be land market analysis**,** land and property taxation**,** land related dispute resolution and development projects.

6.5 Funding mechanisms

LA-SDI can benefit from the budget allocated to its leader agency. However, the budget might not be enough and that is why other alternative funding mechanisms must be identified. For instance, the lead agency can inter into cooperation with ESRI, the world leading company in GIS software, which has already expressed interest in Rwanda. The benefits from this kind of partnership would be investments in capacity building, software application development, and other sectors. Another alternative is to establish a partnership with the most active mapping agencies or private sectors interested in spatial data sector. In this case, together with the two partners, they can pool the resources in collection or data development.

6.6 Benefits from a LA-SDI

(i) Solution to spatial data custodian: LA-SDI abolishes the major issues of data custodianship. Since the data used is gathered from databases of providing agencies, these agencies will remain the respective custodians of the data in their databases. Therefore, producers will produce data that is free of duplication of efforts and share them so that it be accessible to value adders and users. In addition, data being used by the users is a copy of the original; therefore data quality remains the same in each of the databases.

(ii) Improvement of data sharing: with online services offered by LA-SDDF, it becomes easier for the geospatial communities to share data. Moreover, users do not have to buy GIS software but can access GIS data and analysis functions over the internet. This is of great advantage, because the situation in Rwanda is that potential users have more access to the internet than GIS infrastructures.

(iii) Reduction in duplicative spatial data maintenance activity: LA-SDI will change the way of information usage. Before SDI, all data needed are shared by copies, thus the maintenance of spatial data becomes difficult. The departments had to maintain all the spatial data themselves and the spatial data updating is time consuming. With LA-SDI, the government departments can access the data via the network. They only need to maintain data produced by them.

(iv) Promotion of spatial data access: LA-SDDF allows the users to save the time used before for requesting data at the office. Consequently, there is an improvement in service delivery. The metadata that tells the user where and how to find the data is also an asset for an efficient access. The LA-SDDF offer a quick access to data needed for decision making. Moreover, access conditions become the same for all users. While a user’s access was limited to soft or hardcopy maps, with SDI he/she can download various datasets and thematic layers.

(v) Contribution to SDI understanding: LA-SDI can be the first step of SDI development process in Rwanda. Once successfully implemented, it can serve as a driver of the NSDI. It also constitutes an excellent tool to raise awareness among the spatial data user community.

(vi) Use of standardized data: SDI promotes the use of standardized spatial data, the only way to allow data exchange and sharing. As spatial data used for the LA-SDDF are produced by different agencies with different format and different accuracies, data standardization is necessary for integration of data in a database using the same software. Accordingly, LA-SDDF is an incentive to the spatial data standards development.

(vii) Computerization of land information: although many improvements to LAS depend more on good organization and management rather than computerization, SDI offer an effective way of data storage in a computerized system. Therefore, risks of data loss are minimized.

(viii) Integration of Land Administration components: LA-SDI allows integration of all Land Administration components' spatial databases which have been traditionally isolated from each other. Different datasets can be merged and processed together for an efficient and sustainable land information management.

6.7 Conclusion

In nutshell, this chapter presented a prototype of a LA-SDI, which can bring remedy to some issues related to the LA spatial sector, and further serves as driver to the establishment of the NSDI. Prior to the implementation of the general framework of the prototype, a number of requirements must be decided on and put in place. Thus, the whole project is phased into three stages due to the limited resources to undertake the whole development at the same time.

The first phase is dedicated to the design of SDI framework. During this phase, an emphasis must be put on strengthening institutional arrangements, awareness raising, capacity building and technical aspects. These aspects require a huge effort, especially in a country like Rwanda since the SDI concept is still new, and the fact that related legislations, policies and standards are almost unknown. This is why this phase can be extended to a long period compared to the other stages.

The second and the third phases are respectively allocated to the implementation and application development. By means of a web based LA-SSDF that can be developed during the implementation phase, LA-SDI promotes access, use and sharing of available spatial data and other different benefits. All phases are interdependent; the expected benefits of the prototype will result in the success of the whole project. To avoid the shortage of government support, which can slow down the process of SDI development, other alternatives funding mechanisms, must be found.

CHAPTER 7: CONCLUSION AND RECOMMANDATIONS

7.1 Conclusion

The main objective of this study was to examine the feasibility of SDI establishment in Rwanda with Land Administration spatial data sector as the case study. The overall aim of the study was to carry out an assessment based on SDI framework requirements in Land Administration related spatial data, and then demonstrate the benefits of a proposed LA-SDI prototype. For this, a number of five sub-objectives and nine research questions were formulated to carry out the research. The following paragraphs summarize the main findings according to the corresponding objective.

(i, ii) In line with the first and the second objective, this study contributed to fill in the gap in understanding SDI, a concept which is new in Rwanda. A review of various literatures was done for this purpose. According to these reviews, SDI is now widely recognized by most nations as an important development tool for the organization, dissemination and use of spatial data. Nevertheless, SDI is understood and defined differently by individuals and stakeholders from different SDI initiatives. Interestingly, a large number of definitions is built on common components. Based on this, SDI framework may be defined as a set of not only the four basic components (fundamental datasets, institutional framework, standards, and access network) but also another important component, namely people (users, data custodians, and value adders), which interact to promote an efficient management, exchange, access and use of spatial data. The experience has shown that institutional issues are more difficult to address than the technological ones.

Presently, many countries around the world are at some stage on the road to establish SDI. Developed countries are at a fairly advanced stage, while developing ones are only at the beginning of their journey. These initiatives are driven by factors such as globalization, sustainable development and environmental awareness, led by the progress of information and communication technology. In African countries, SDI drivers become more particular to each and every country. On one hand, some have been motivated by environmental management, land information management, and sustainable development. On the other hand, there was issue of duplication of resources in data capturing and management.

Even though African countries are among the countries where SDI development is just starting, some countries are already ahead and can serve as a model to the others. Many lessons regarding SDI development plan can be leant from the Nigerian SDI project. However, SDI cannot be copied and pasted. It must be adapted to the economic environment and priorities of the particular country. South African SDI can inspire other countries on SDI related policies and legislations, spatial data custodianship, standards and the use of GIS as SDI technology. It is now recognized that the GIS tool is an engine of SDI and that there is no way to develop the latter without implementing and promoting that tool.

(iii) Institutions or agencies managing and providing fundamental dataset for Land Administration were identified. The majority of providers are public. As in other developing nations, spatial information in Rwanda does not attract significant private sector investments. However, the involvement of the private sector in SDI development is of greater importance and can solve funding issues that sometimes cannot be addressed by the government. The vital framework data for a pertinent Land Administration (cadastre, land use), are the poorest ones and less developed among other framework datasets produced. Consequently, the application spatial data are quiet inexistent. This has a negative impact on the planning activities of the country, the socio-economic development and the sustainability of the environment. The results are likely to be the growth of slums, insecurity of tenure, limited rural investments, loss of substantial revenue from land and properties taxes, and mismanagement of natural resources. Users of available data are varied in terms of category; however a quantitative study was not done. The way all spatial information is used in decision making is interestingly. Decision makers might be the only ones to have unlimited access to geospatial information while other groups of users are subject to unclear conditions. The access to spatial data is not open and clear. Although the metadata plays a key role for geo-information access, only few datasets have a documented metadata. Moreover, data access is restricted by authorizations or the cost required for obtaining data. Office visits are the most used method to obtain spatial data.

(iv) In addition to access constraints, other challenges were specifically analyzed for the purpose of the forth objective. Although the use of GIS as a tool of data capturing and management is penetrating in most of spatial data providers, the cadastral system is manual in the whole country, except in the capital city. This manual system or paper-based cadastre was found as one of the strong barriers of the SDI process. With such a system, it was found that data updating is difficult, access is very limited and data sharing quiet impossible. In addition to the lack of efficient tools of data management, there is a serious problem of inadequate qualified people for data collection, processing and analysis. Even though there is an increasing number of ICT qualified human resources in the country, people with appropriate qualifications in geographic information management skills are few in number. Capacity building initiatives need to be developed in parallel to the process of SDI establishment.

Regarding the issues of policies and institutional framework, there are more gaps than assets. No formal policy framework has been put in place in Rwanda up to now to facilitate the development of SDI. Although the country has put in place the ICT for development policy; the geospatial data sector is not included. There is no legislation for information access, ownership, copyright, pricing, privacy, and SDI. These were recognized as the main cause of poor partnership and the existence of multiple producers for the same framework data. Consequently, there is duplication of financial means invested by the government and donors. This issue of multiple producers of the same dataset can only be addressed via a specific policy or legislation that would give a clear guideline on how spatial data are to be collected, managed, updated and distributed to users.

Technological aspects present a number of assets like increasing telecommunication infrastructures, increasing skilled ICT manpower, internet availability, and others. An effort is being made through different initiatives, to extend the ICT in the rural areas. Nevertheless, some significant challenges have been found. A lack of standards for spatial data can limit data sharing. Users meet difficulties when trying to integrate data due to variations in projections, coordinate systems, and other data quality aspects. GIS infrastructure is limited on basic equipment. With regard to SDI there is a need of GIS servers, internet map servers, and other components.

(v) After the feasibility assessment, it was found that the challenges identified are not unique to Rwanda. Many countries in the world are facing the same issues in their SDI development. The current new LAS orientations in Rwanda and the national priorities in terms of ICT constitute assets which can serve as a starting point of SDI implementation. Thus, the fifth objective could be achieved, but on condition that the development of the prototype adopts a phased approach. The first phase which is the most critical, will address the issues related mainly to institutional framework. That is organizational structure, policies development, and capacity building. Other technical aspects like the development of spatial data (framework and application data), metadata and standards, will take part of this stage. This phase encompasses a strong effort for awareness raising and requires political support. Experiences have demonstrated that SDI initiatives cannot be successful without support from the highest national level.

The second phase will be dedicated to the implementation. This phase will be marked by the development of a web-based spatial data discovery facility that enables users to browse the internet and access Land Administration related datasets. With limited resources, the Researcher has demonstrated that the system can work. Other requirements for a proper system to be operational in real situation are provided for the future implementers. The last stage will deal with applications and these will be part of benefits of SDI. There are other expected benefits in addition to the applications. Duplication of work will go down, consequently effective use of public and donors resources. Moreover, there will be an improvement of SDI understanding, data management, data sharing, data quality, data access, and GIS use. However, due to the limited time of the study, the design of an operational LA-SDDF can be pursued by other researchers in the future. The areas of further work are mentioned under recommendations.

7.2 Recommendations

The key recommendations that emerge from this study are grouped into two main categories. These are future researches that could be further investigated and other recommendations.

7.2.1 Future researches

The LA-SDDF needs to be built and tested in a real environment. The use of modern ICT can improve and provide a more advanced client application. Furthermore, an automated metadata updating system can be developed.

Research efforts should be expanded to include SDI to other sectors of activities such as social and economic sectors. A bulk of social and economic information is tied to location. However, these sectors are not spatially enabled. An assessment of the geospatial datasets existing for those sectors can be carried out.

There is a great need to conduct research on different mechanisms that can be used to facilitate the diffusion of SDI in Rwanda. Different approaches which have been used in the field of GIS diffusion can help researchers to identify appropriate approaches for SDI environment.

7.2.2 Other recommendations

(i) Economic assessment study of the benefits of SDI: it was found that in developing countries, SDI is not considered as important as other social or economic infrastructures. Consequently, SDI initiatives face a serious challenge of poor political support. To fill in this gap, there is a need for economic measures and indicators, convincing high level government of the benefits of SDI in developing countries. At present, few SDI have been able to conduct an economic assessment of the value of SDI to the community. The Infrastructure for Spatial Information in Europe (INSPIRE) study on benefits realised through integration of SDI initiatives in Europe cannot serve as a model to the developing countries, given that the social and economic environment of the two worlds is not the same.

(ii) Involvement of the private sector: the role of private sector in spatial data sector is very low in Rwanda. However, the country has embarked on a process of privatisation. Therefore, utilities and services will increasingly be provided by the private sector. It is important that the private sector has a greater involvement in SDI development, beyond the existing data provider role.

(iii) SDI and GIS awareness: there is a need to raise SDI and GIS awareness through different ways. These include workshops, seminars, short courses, conferences and advertisements.

(iv) Capacity building: an emphasis must be put on capacity building, which is one of the most important issues to be solved for the success of SDI. It is vital to build geographic information science capacity, nationally. The GIS component must be introduced as part of a national curriculum from high school level. At university level, SDI courses must be incorporated in the geography program and environmental studies, currently existing in Rwandan universities and other tertiary institutions. Moreover, there is a strong need to initiate post-graduate courses in surveying engineering, geomatics, and geographic information science. In the meantime, alternatives to post-graduate degrees with one year post-graduate diploma can be offered. This can be supported by the program of human resources development under the ICT for development policy. We suggest that this policy could be reviewed in order to incorporate the geo-information sector.

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ANNEXES

ANNEXE 1: Example of Metadata

Title	Rwanda - Thematic Agriculture Aggregation (Africover)
Dataset Reference Date	2002-11-15
Dataset Reference Date Type	Publication
Dataset Edition	First
Presentation Format	mapDigital
Abstract	This dataset is a reaggregated version of the original national Africover landcover multipurpose database. It contains all cultivated land. The land cover has been produced from visual interpretation of digitally enhanced LANDSAT TM images (Bands 4,3,2) acquired mainly in the year 1999. The land cover classes have been developed using the FAO/UNEP international standard LCCS classification system.
Purpose	The purpose of the Africover landcover database is to provide the information required for natural resource assessment and management, environmental modeling and decision-making.
Completeness/Progress Code	Complete
Theme Keywords	Landcover, environment, natural resources, agriculture, forest, rangeland, management
Place Keyword	Rwanda
ISO Topic Category	Earth Cover
Supplemental Information	This data set is a reaggregated version of the original national data set; it is intended for free public access. Thematic aggregation is the way that the end user customizes the Africover database to fulfil his/her specific requirements. The Africover database gives equal level of detail to Agriculture as well as Natural vegetation or Bare Areas etc. Generally a single user does not need this level of detail for each class type; therefore he/she will enhance the information of one land cover type and will generalize or erase the information related to other land cover aspects. The most powerful way to conduct an aggregation exercise is to use the classifiers as basic elements of the exercise. This gives the user the maximum flexibility on the use of data. See 'Inside MADE' for more details.

Direct Spatial Reference Method	Vector
Data Format	ESRI ArcView Shapefile (.shp)
Scale of the Dataset	1:100 000
Dataset Language	English
Dataset Character Set	usAscii
Resource Provider	Mr. Antonio Di Gregorio - FAO Africover
Point of Contact	Mr. Antonio Di Gregorio - FAO Africover
Custodian	Mr. Antonio Di Gregorio - FAO Africover
Owner	M. Eugene Rurangwa Burabyo - Ministere des Terres, de la Reinstallation et de la Protection de l'Environnement
Originator	Mr. Antonio Di Gregorio - FAO Africover
Processor	Mr. John Latham - FAO
Publisher	Mr. Antonio Di Gregorio - FAO Africover
Distributor	Mr. John Latham - FAO
Lineage Statement	The land cover was interpreted from LANDSAT imagery (Bands 4,3,2) acquired mainly in the year 1999, verified by field work, digitised, checked for topological and attribute errors and mosaiced. Thematic aggregation was then performed.
Data Quality Comment	Creation of the aggregated classes takes into account the Africover cartographic standards. In the Africover database, due to the MMA (Minimum Mappable Area) chosen, the concept of Mixed Unit is introduced using the inherent characteristics of the study area. For example Land cover class A can be spatially represented in different ways · As single map unit A · As mixed map unit were A is the dominant feature (more than 50% of polygon area) A/B · As mixed map unit were A is not the dominant feature (from 20 to 49% of polygon area) B/A · As mixed map unit were A is not the dominant feature (from 10 to 20% of polygon area) B/A (this is valid only for “Isolated Agricultural Fields”) Due to the fact in Africover a mixed unit can have up to three classes A/B/C an aggregation class (called 1) can be represented in four (five for agriculture) different ways · 1 (where 100% of polygon area represent the aggregation class) · 1a (60% app.) · 1b (40% app.) · 1c (20-30% app.) · 1d (15% app. Only for agriculture)

	The user can further aggregate these classes according to his/her needs. See 'Inside MADE' for more details.
Restrictions	The data remains full property of the owners. It can be accessed, reproduced and distributed given that the owner information is explicitly acknowledged and displayed in the copyright information (I.E. Produced by FAO - Africover). The Authors do not assume any responsibilities for improper use of the data.
Update Frequency	As Needed

Reference System Information

Geographic Reference System

Units	Decimal Degrees
Ellipsoid	WGS 84
Datum	WGS 84

Spatial Representation

East Bounding Longitude	30.9
West Bounding Longitude	28.86
North Bounding Latitude	-1.05
South Bounding Latitude	-2.84

Extended Information

Project Code	GCP/RAF/287/ITA
MCDB File Type	normal
Entry Type Code	dataset
Minimum Viewing Scale	1:1 000 000
Maximum Viewing Scale	1:100 000
Data File Name	rw-cult-agg

Metadata Information

Metadata Language	English
Metadata Character Set	usAscii
Metadata Provider	Mr. John Latham - FAO
Metadata Time Stamp	2002-11-12
Metadata Standard Name	ISO 19115
Metadata Standard Version	DIS

Data Definitions	
Data Classification	Public Domain
Data Type	Thematic Aggregation
Web Map	
Link(s)	Not Available
Data Access	

File

File	Size	Class
rw-cult-agg	*3502080 (bytes)*	Public

Proceed to Download >>

Request Custom Aggregation >>

CD: If you require the data set on CD instead of download >>
Be advised that you shall be required to pay for the Packaging and Postage of the CD to your location. Africover shall take case by case consideration for the provision of the data set on CD using the reason supplied

ANNEXE 2: QUESTIONNAIRE SURVEY.

QUESTIONNAIRE SURVEY

I am a student at Centre of Environment, Agriculture and Development at the University of KwaZulu-Natal, Campus of Pietermaritzburg in South Africa. I am undertaking a masters' research on "**DEVELOPPING A SDI IN RWANDA A FEASIBILITY STUDY. Case study of LAND ADMINISTRATION SECTOR**". I kindly ask you to complete the present questionnaire.

Researcher M.C DUSHIMYIMANA SIMBIZI

Supervisor Dr Denis RUGEGE

Co-supervisor Mr Dorman CHIMHAMHIWA

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Privacy statement

We acknowledge and respect your privacy. All information obtained from the questionnaire will be only used for the purpose of this study. The objective of this questionnaire is ***to assess the current challenges on Land Administration related spatial data with regards to Spatial Data Infrastructure (SDI) requirements.***

Completing questionnaire

- Please respond to questions with a tick or a cross
- Tick one or more answers when applicable
- Please provide details for open questions

I. Identification

Name of respondent (optional) ....

Job status of the respondent ....

Name of institution/Organisation ....

Status of institution Public ☐

Semi-public/ Para-statal ☐

Private ☐

International ☐

Non government ☐

Academic/Research Institute ☐

Other ☐

Please indicate the area of jurisdiction or interest of your organisation

Regional (Africa-wide) ☐

Sub-regional ☐

National ☐

District ☐

Local ☐

Date ....

II. Questions

1. How would you best describe your institution given following categories?

- Spatial Data provider ☐
- Spatial Data user and provider ☐
- Spatial Data value adders ☐

2. What sort of spatial data (Land administration related data) do you provide and manage?

- Land registration data (cadastre) ☐
- Administrative boundaries data ☐
- Land cover/use data (zoning, infrastructure) ☐
- Aerial or satellite photography ☐
- Topography data ☐
- Geodetic control data ☐
- Population ☐
- Others ....

3. Which tool do you use in data collection and storage?

- GIS tool ☐
- Other tool ....

4. Are you the one that capture your data with your budget (public budget)?

- Yes ☐
- No ☐

5. Kindly mention your financial donor if any ....

6. In which format are your spatial data stored?

- Papers files ☐
- Paper/ Hardcopy maps ☐
- Digital (vector and raster) ☐

7. How do you update/ retrieval your database?

- Manually ☐
- On a regular basis ☐
- Kindly, specify the last year updated if regular ....

8. Specify your spatial referencing system and resolution of your spatial data

- Projection and datum ....
- Coordinate system ....
- Resolution or scale ....

9. What standard organisations for spatial data does your organisation subscribe, member or adhere to?

- International Standard Organisation ISO, Technical Committee for Geographic Information- TC 211 ☐
- Open GIS Consortium OGC ☐
- Others ....

10. Do you have skilled human resources to collect, maintain and manipulate spatial data?

- Yes ☐
- No ☐

11. How can you qualify your staff in charge of collecting, maintaining and manipulating your spatial data?

- National GIS specialist ☐
- Expatriate GIS specialist ☐
- IT specialist ☐
- Qualified surveyors ☐
- Non qualified staff ☐
- Other technicians ....

12. Beside the data you produce, how do you get others you need?

- Paper maps ☐
- CDROM or other portable (digital) medium ☐
- Email (attached file) ☐
- Other ....

13. What are your spatial data users?

- Decisions makers ☐
- Other institutions/ organisations involved in spatial data sector ☐
- Commercial users ☐
- Value adders ☐
- Academic community ☐
- NGOs ☐
- Consultants ☐
- Donors ☐
- The media ☐

14. How do they access to your data

- Unrestricted access ☐
- Authorisation required ☐
- Restricted ☐

15.What are the access conditions?

- Free of charge on request at the office ☐
- With charge when requested ☐
- Free of charge on website ☐
- With charge online ☐

16. Do you have a metadata?

- Yes ☐
- No ☐

17. If yes, kindly tick the information provided in your metadata

- Purpose ☐
- Metadata date ☐
- Originator ☐
- Language of data set ☐
- Theme keyword ☐
- Theme keyword thesaurus ☐
- Bounding coordinates (West, East, North, South) ☐
- Coordinate system name ☐
- Geodetic model (Horizontal datum name, ellipsoid name, semi-major axis, semi-minor axis denominator of flattening ration) ☐
- Lineage (original source, process (es) or step (s) ☐
- Access constraints ☐
- User constraints ☐
- Time period information ☐
- Status
  - Progress ☐
  - Maintenance and update frequency ☐
- Geospatial data presentation (vector, raster, grid) ☐
- Online linkage ☐
- Resource description ☐
- Native dataset format ☐
- Dataset size ☐
- Metadata contact information ☐
- Metadata standard name ☐
- Metadata standard version ☐

18. Do you have any partnership with other institutions involved in spatial data sector? If yes what is the basis of collaboration?

- Data sharing ☐
- Funding ☐
- Technology ☐
- License agreement ☐
- Technical skills (eg. Short courses) ☐

19. What are the main reasons which can hamper an open partnership?

- Avoid competition ☐
- Compatibility problem ☐
- Suspicion of the quality of other's data ☐
- It is not in the culture of organisation ☐
- Absence of appropriate policy ☐
- Security of our data ☐

20. How do you describe your partnership? Is it based on

- Goodwill ☐
- Tradition ☐
- A prescribed policy ☐
- Individual initiative or Friendship ☐

21 Does your institution have policies or guidelines of the following aspect of spatial data?

- Access ☐
- Pricing ☐
- Use or distribution ☐
- Data model (standards) ☐
- Data ownership (copyright) and custodianship ☐
- Metadata ☐
- Data sharing ☐

Please provide any comment you may have in completing this questionnaire.

Comments

....

....

....

....

Would your Institution/ Organisation be interested in receiving the outcomes of this study? Yes ☐

No ☐

Thank you very much!

Your time and assistance in completing this questionnaire is greatly