ASSESSMENT OF INNOVATIVE BOUNDARY MAPPING: THE CASE OF KIGALI CITY IN RWANDA

HAGUMA JEAN DE DIEU

March, 2013

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ABSTRACT

A Land tenure regularisation (LTR) program is being carried out in Rwanda. It is one of large scale land administration projects. This project is different from others: It is low cost project, uses Para surveyors, adopts general boundaries and utilizes orthophotos. Around 10.3 million parcels have been demarcated in three years in the whole country. Specifically in the study area, the program is now complete. At the beginning there were doubts regarding errors and the speed of the process. The aim of this research is to examine the nature, extent, and number of geospatial mismatches that arises using the process. The methodology utilized open and semi-structured interviews, data acquisition and analysis techniques.

It is concluded that geospatial mismatches in LTR process exist. They are observed in legal documents issued after boundary recording. They are many in dense and unplanned areas in which land use changes appeared after orthophoto aquisition. Their number decreases significantly in less populated and planned areas where it is easy to distinguish the boundary on orthophotos and where lots of changes in land use did not occur after orthophoto acquisition in 2008.

(Key words: geospatial mismatches, LTR, land administration, orthophoto)

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LIST OF ACRONYMS

GIS: Geographic information systems
GoR: Government of Rwanda
GPS: Global positioning system
KCC: Kigali City Council
LAIS: Land Administration systems
LAP: Land Administration Project
LTR: Land Tenure Regularisation
NLC: National Land Centre
MINAGRI: Ministry of Agriculture and Animal Resources
MINFRA: Ministry of Infrastructure
MINIRENA: Ministry of Natural Resources
MINITERE: Ministry of lands, Environment, Water and Mines
RNRA: Rwanda Natural Resources Authority
REMA: Rwanda Environmental Management Authority
OLL: Organic Land Law
PGIS: Participatory GIS

GLOSSARY OF TERMS

Adjudication: is defined as the process of investigation of the existing rights in land for recording purposes (Henssen, 2010) .

Boundary: It is often seen as the intersections of vertical surface (running from the centre of the Earth into the endlessness of space) with the surface of the Earth; giving the boundary line (Zevenbergen, 2002a).
Demarcation: This is the physical marking of boundaries. It consists of two types: The exact boundaries of parcel is fixed (high accuracy) on the ground or approximate under general boundary principal which means that the exact line of the boundary is left undetermined (Henssen, 2010).

Cadastre: Cadaster is part of country's social infrastructure that contains more evidence about the physical size and shape of areas, and data on land values or land value(United Nations, 2004).

Fixed boundary: is a boundary that has been accurately surveyed and recorded so that the surveyor can find any corner in the recording survey of measurements, even when the boundaries themselves are not visible in the terrain (Lemmens, 2011).

General boundary: also called approximate boundary, is a boundary which is not as well defined in space as a fixed one. The boundary as recorded is indicative not definitive (Lemmens, 2011).

Geospatial mismatch: In this research, it is the spatial difference between the extent of parcel on the ground (reality) and the extent of recorded boundary.

Parcel: is a single closed area (or volume) that is determined geographically by its boundary, contains land under homogenous property rights and is held in one ownership (Inan, Aydinoglu, & Yomralioglu, 2010).

Land adjudication: is the first step in the registration of title to land where the ownership of land is not officially known and encompasses procedures for determining existing land rights on the ground(Dale & McLaughlin, 1999).

Land registration: It is the process of recording rights in land either in the form of register of deeds and other documents associated with ownership of land rights or else in the form of a register of titles to land(United Nations, 2004).

Recording: is the final step for issuing title. It embraces textual or descriptive part of administrative data and mapping part of spatial data collected on ground (Henssen, 2010).

Surveying: is cadastral process for boundary surveying, frequently undertaken using aerial photography, maps or images such as orthophotos or enlarged photo prints to reduce cost in special areas, especially when systematic approach is used (Henssen, 2010).

Spatial error: Spatial error refers to the spatial difference between the reality and its representation for spatial data displayed in different ways such as point, line, polygon, surface, volume and pixel(Jason, Gurdak, & Michael, 2009).

Textual error: It is either an error related to inaccurate attribute identified verbally or an attribute editing error (Jason et al., 2009)

1. INTRODUCTION

This research presents the assessment of an innovative boundary mapping in Kigali city in Rwanda. The focus is on examining the nature and causes of geospatial mismatches in the data acquisition using orthophoto and Para surveyors. The geospatial mismatches are identified by case studies of known reachable cases by comparing different cases of parcels in the field (reality on the ground) and parcels on the output maps of RNRA (RNRA) based on land claims of landowners.

1.1. Background of the study

The absence of official written records to prove the legally existing rights on land has persisted in Rwanda for many years in most areas. Lands were originally governed under customary law. Around 90% of lands were not legally recognized until 2005(D. Sagashya, English, & Ltd., 2010). According to Organic Land Law, land in Rwanda is categorized into two: individual land and public land(MINIRENA, 2010). Only, few of these lands were held under statutory law in urban areas and business communities for small group of people and Christian missions (Official Gazette of Republic of Rwanda, 2007).

In the period before 2005, many people suffered from lack of effective resolution process of land-related disputes they were facing. Those land problems included ownership dispute, boundary encroachment between individuals, individuals versus community and individuals versus the state. The de facto tenure security under customary land tenure system could not help in many cases of land disputes. Because of that tenure system and without legal documents of landownership, land conflicts were difficult to resolve. The customary law was not the best guarantor of tenure security for the population in land disputes resolution(D. Sagashya & English, 2009).

The results of pilot project before systematic registration showed that land disputes were problematic for Rwanda and took long time to resolve during land adjudication (MINERENA, 2008b). One of them which is boundary conflict was serious between 1994 and 1999 due to the settlement of returnee refugees and land sharing(D. Sagashya & English, 2009).It was also noticed as one of the main causes of land conflicts during the trial pilot project before land adjudication in Rwanda(DFID & HTSPE, 2007). This problem is much more linked to unclear and unrecorded boundary without legal document of ownership.

Formalizing evidences of ownership on land in cases where no earlier register information is available or where the existing information has limited or bad quality is very important. It provides tenure security for social, economic and environmental benefits to the society. (Griffith-Charles & Opadeyi, 2009).

For the case of Rwandan society, people need tenure security for their properties. It is perceived as part of continuing process for national unity and reconciliation(D. Sagashya & English, 2009). According to (DFID & HTSPE, 2007) across all the four trial districts, there was a general and widespread demand of formal title and land registration, as proof of ownership which can be clearly known, thereby providing the legal basis for resolving disputes locally and reference to properly registered land records.

That reason has stimulated the government of Rwanda to take different actions in order to overcome land related problems as mentioned before and confirm the existing rights to, in or over land (RNRA, 2007).The following measures have been taken: Rwanda cadastral system was reformed and given the

mandate of providing maps and recording land rights(Muvala, 2011). Land related regulations were also created. These include the 2004 Land policy, the 2005Organic Land Law. The ministerial decree determining the modalities of land registration was enacted in 2008 referring to the results of pilot project that aimed primarily to test and decide various procedures, resources and time needed for that. All these regulations determine who owns which property(Nkurunziza, 2010) and parcel boundary which is the unit to be determined as much as possible (Official Gazette of Republic of Rwanda, 2008). It also established the land institutions including the Cabinet of Ministers, Ministry of Natural Resources (MINIRENA), National Land Commission, the cadastre composed of National Land Centre (NLC) and The Office of Registrar of land titles, District land bureaus, Sector and Cell land committees. These are in charge of enforcing the above regulations(D. Sagashya & English, 2009). Since 2009, NLC launched a five year systematic land registration program called Land Tenure Regularization (LTR). This a set of administrative procedures for converting land rights into legal form. It aims at giving tenure security to Rwandan society and particularly one of its specific objective is to be a transparent mechanism of solving land disputes (MINERENA, 2008a).The output of the process is the issuance of land title and land registration accompanied with a cadastral plan of the parcel of land owner(RNRA, 2007).

At the moment, around 10,200,000 parcels have been demarcated(Geospatial World, 2012).In general the process has been completed in Kigali city and most of the people received their legal documents(RNRA, 2012a). This job was completed within 3 years(RNRA, 2012b). However, there are problems in LTR program as indicated by recent researches.Milindi Rugema (2011) states that they were spatial errors in the process because the analogue method used for data collection had many steps leading to errors. Also Singirankabo (2011) has raised the issue of people who did not participate in the process as expected. For all parcels demarcated in Kigali city, some landowners do not have yet legal documents, others have issued document with geospatial mismatches parcels or are claiming for correction of wrong information on it(J. C. Nkurunziza & Mukashema, 2011).

For the purpose of this research, the spatial mismatching is the difference between the reality on ground and the recorded boundary and should be understood as the misrepresentation that the community considers risky for the resolution process. It is important to ascertain this information to support the dispute resolution process. Without a fair and effective resolution process, the success of the adjudication process is put at risk.

1.2. Research problem

In land administration various approaches are adopted for cadastral data acquisition. These include conventional and unconventional approaches (innovative approach) (P van der Molen, 2006). From old school view of land administration, most cadastral surveys are undertaken using theodolites, steel tapes, electronic distance measuring system(EDM) systems ,including total station, and global position systems(GPS).The GPS is in increasing use and provide coordinate values for points on the ground to a high precision level, for instance to better than one centimetre(Dale & McLaughlin, 1999).Conventional ways of land administration for titling program are considered as being too complicated, too accurate, too slowly, too expensive and too much in favour of the middle and elite classes. Seeing that the conventional way is not helpful for what people really want to do in tenure security enabling payment of taxes and economic growth, the alternative view was for unconventional approach allowing simplified recording of spatial representation using the technology around. This is considered by UN/Habitat as one of necessary innovative approaches that came in the last decade(P van der Molen, 2006).

In many of less developed countries the choice of technology to use for data collection is constraint partly by the law and in partly by finance since modern technology must either be donated or else be paid from very limited amounts of hard currency(Dale & McLaughlin, 1999).

In choosing the technology to be used, Rwanda has opted for cheap and low technology .This was based on the real cost in both money and time of cadastral survey, education and training skills available with the aim of being faster.

This process is the first land registration. It has been completed in Kigali city where the total number of parcels surveyed and registered is 332,073 parcels.

With the implementation of land administration in Rwanda, both conventional and unconventional ways for spatial data acquisition have been used at national level and specifically in Kigali city. Before the start of Land Tenure regularization (LTR), the techniques for spatial data collection were to use theodolite, total station and GPS for fixed boundary survey. This was done under sporadic land registration on landowner demand basis in rural and often in urban areas(Österberg, Khadash, & Saad, 2006). With the innovative techniques in an unconventional approach, spatial data were collected under systematic land registration using orthophotos on the state demand across the country. In this process, aerial photographs of 0.25m have been used at national level including Kigali city.

At the moment, some surveyed and their respective recorded boundaries in the RNRA database show geospatial difference between them as this is illustrated by legal documents issued in Kigali City.

Obviously there has been this movement towards low cost, low accuracy, faster ,cheaper, and less prescribed land administration processes and this approach whereas cheaper and faster appears to create others issues or other potential conflicts. The LTR program introduced a range of differences relating to surveyed and recorded boundaries while it was supposed to come up with output map reflecting the reality on the ground. The specific problem in this case is that we do not know the size and the scale of geospatial mismatches in the process, so the research about this is needed.

1.3. Research objectives

1.3.1. Main objective

To examine the nature, extent, number and causes of geospatial mismatches in the land adjudication process under innovative approach for recording boundaries in Kigali city.

1.3.2. Specific objectives

1. To describe the policy, legal and institutional frameworks under which boundaries are adjudicated, demarcated, surveyed and recorded.

2. To determine the spatial nature, extent and number of geospatial mismatches in the boundary mapping under LTR program.

3. Identify the sources of geospatial mismatches appearing in the process from field surveying to spatial data post processing stages.

4. To propose legal and technical measures that can be adopted for overcoming geospatial mismatches under the maintenance phase.

1.4. Research questions

1.4.1. Main question

What are the nature, extent, number and causes of geospatial mismatches in the land adjudication process in Kigali city?

1.4.2. Sub-questions

The following questions linked to corresponding specific objectives served to operationalize the research:

Research objectives	Research questions
1. To describe the policy, legal and institutional frameworks under which boundaries are adjudicated, demarcated, surveyed and recorded.	Q.1 What are the policy, legal and institutional frameworks under which boundaries are adjudicated, demarcated, surveyed and recorded?
	Q.2 What are the objectives, guiding principles and stages of systematic land adjudication in Rwanda?
2. To determine the spatial nature, extent and number of geospatial mismatches in the boundary mapping under LTR program.	Q3: What are the spatial nature, extent and number of geospatial mismatches in boundary surveying and recording in LTR program?
3. To identify the sources of geospatial mismatches appearing in the process from field surveying to spatial data post processing stages.	Q4: What are the sources of geospatial mismatches from technical perspective at parcel demarcation and spatial data post processing stages?
	Q5: What are the sources of geospatial mismatches from social and other views due to no compliance with land regulations?
4. To propose legal and technical measures that can be adopted for overcoming geospatial mismatches under the maintenance phase.	Q6: What can be done legally and technically to avoid geospatial mismatches under the maintenance phase?

Table 1: Specific objectives and research questions

1.5. Research methodology

The methodology is a general approach to study research topics and reflect a main research strategy(silverman,2000).Based on the objective and research type which is a case study research, the research methodology adopted includes the following:

- literature review
- fieldwork for data collection through interviews, direct observations and documents collection and analysis

1.5.1. Research matrix

No	Research objective	Data required	Data source	Data collection technique	Data analysis method
1	Describe the policy, legal and institutional frameworks under which boundaries are adjudicated, demarcated, surveyed and recorded.	Relevant literature Views from all interviewees	Online sources; Secondary Primary	Literature review Interviews	Qualitative analysis
2	Determine the spatial nature, extent and number of geospatial mismatches in the boundary mapping under LTR program.	Landowners cases including objection letter, deed plans, cadastral maps; Orthophotos; Gasabo district and RNRA reports; Views from all interviewees	Primary Primary	Direct observations Interviews	Qualitative analysis
3	Identify the sources of geospatial mismatches appearing in the process from field surveying to spatial data post processing stages.	Landowners cases including objection letter, deed plans, cadastral maps; Orthophotos; Gasabo district and RNRA reports; Views from all interviewees	Secondary Primary data	Literature review Interviews Direct observations	Qualitative analysis of both primary data and secondary data
4	To propose legal and technical measures that can be adopted for overcoming geospatial mismatches under the maintenance phase.	Relevant literature Views from all interviewees	Secondary Primary	Literature review Interviews Direct observations	Qualitative analysis of primary and secondary data

Table 2: Research design matrix

1.6. Research design

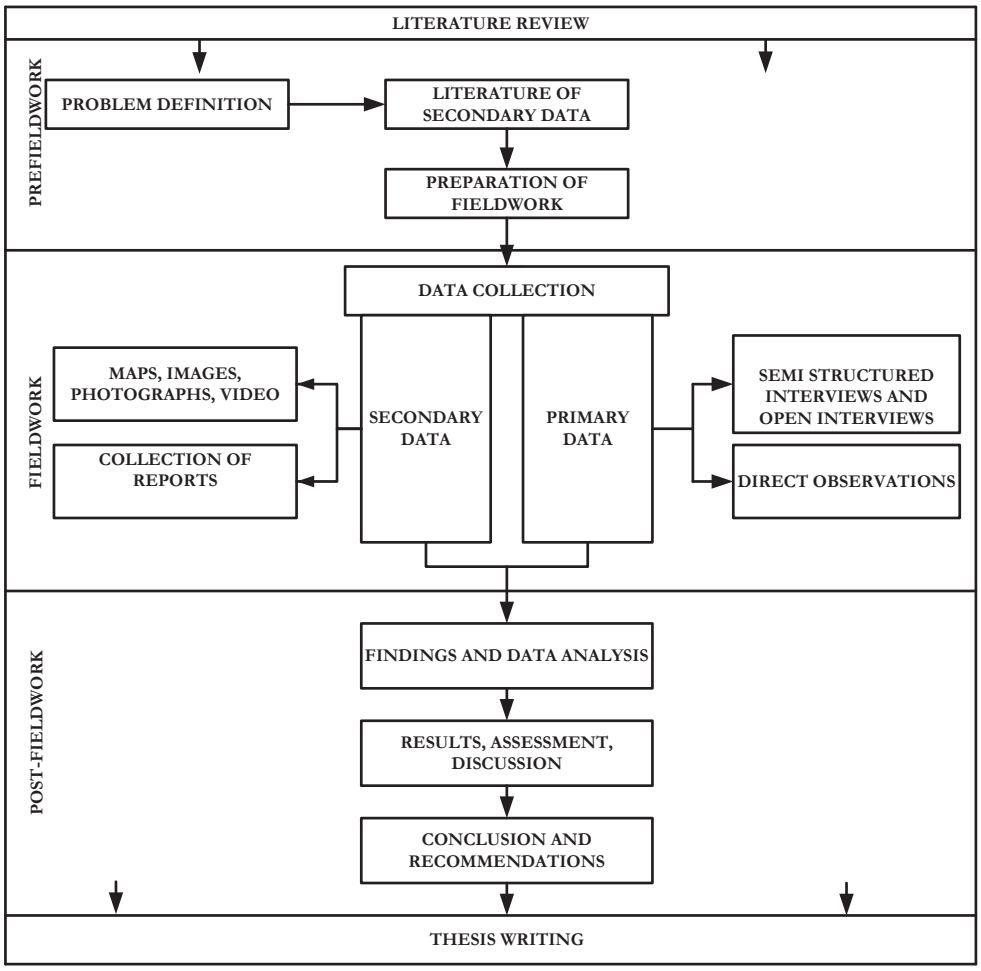

Figure 1: Research design

1.7. Benefits of research

Different individuals and organizations will benefit from the findings of this research:

- The findings will provide an insight on the nature, extent and number of mismatches in cadastral processes in land registration project in Kigali city.
- The findings could guide decision makers and land administrators to consider the issue of mismatches, so as to avoid unfair expropriation or inappropriate property taxes collection.
- In addition, this research will provide an opportunity to further research on how the problem could be fixed during maintenance phase.

1.8. Thesis structure design

Chapter 1: Introduction

This chapter provides an overview of the research: the background of the study, research problem, objectives, research questions and the thesis structure.

Chapter 2: Land administration concepts and projects

This chapter discusses key concepts of land administration, approaches to land administration, land administration processes and land administration projects in the form of land tenure regularization. This discussion aims at commenting and linking existing knowledge on land administration and land tenure

regularization projects. The body of knowledge provided in this chapter is a theoretical foundation to answer the research questions mentioned in the previous chapter.

Chapter 3: Land administration in Rwanda.
This chapter describes the procedures followed in LTR and the techniques used for spatial data collection. The focus is on orthophoto based land adjudication in parcel boundary registration referring to the general boundary principle. This description is important for spatial nature and sources of errors description in chapter 5.

Chapter 4: Study area and research methodology
This chapter explains the research approach. It presents in details the stages of the research including pre-field work, field work stages, post-fieldwork and the methodology to be used in data collection and analysis. It also describes the study area in which the field work was carried out.

Chapter 5: Fieldwork results
This discusses the main findings of this research. The results include the nature, extent, number and causes of geospatial mismatches in Rwanda in LTR program in the study area. The information came from the RNRA staff, district land officer, local readers, and landowners.

Chapter 6: Discussions
The chapter aims at presenting the analysis of results from fieldwork.

Chapter 7: Conclusion
This chapter presents conclusions on the research findings and discussions, and a summary of answers to the research questions.

2. LAND ADMINISTRATION CONCEPTS AND PROJECTS

2.1. Introduction

This chapter discusses key concepts of land administration, approaches to land administration, land administration processes and land administration projects in the form of land tenure regularization. The existing knowledge has been collected using literature review method.

2.2. Overview of land administration and land admnistartion projects

a) Land administration

Land administration is a millennium old activity aimed at securing land rights and stimulating good land management. This activity has been recognized by UN and other political worldwide organizations as important means to combat poverty. The United Nations Economic Commission for Europe defines land administration as the processes of determining, recording and disseminating information about ownership, value and use of land and its associated resources when implementing land management policies. Such processes include the determination(sometimes known as "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). In the context of this research, according to Henssen (2010), the word land administration is used to cover only land registration and cadaster.

For securing land and property rights, land administration systems are indispensable. They protect rights against unlawful actions. They are concerned with recording and storing land information to ensure its use and development. An effective land administration system should include some form of land registration and cadaster (Lemmens, 2011). The latter is a land information system when it is a land parcel-based and serves as multi-purpose cadaster(MINITERE, 2005). Land registration and cadaster usually complement each other, they operate as interactive systems. Land registration basically puts accent on the relation subject-right, whereas cadaster puts the accent on the relation right–object. This means that the land registration answers the questions as to who and how, the cadaster answers the question as to where and how much(Henssen, 1995). In order to secure land rights, Rwanda is building its land administration system through renewed land information system.

In securing land rights through land registration, one of the ways of registering land is involvement of local people in land registration process through PGIS. PGIS as an integration of many tools and methods often relies on the combination of expert skills with socially differentiated local knowledge(Rambaldi, Chambers, McCall, & Fox, 2006) . It is an effective tool in eliciting indigenous knowledge regarding the changes over time of landownership, use rights and land use(Lemmens, 2011)

This research studies the nature of geospatial mismatches in systematic LTR program which was done relying on general boundary principle under PGIS. In practice LTR is a set of procedures that systematically brings landowners to first registration of their land. It requires all land owners in a designated LTR area to participate. During this activity, the local spatial knowledge as a specific and on-going knowledge about the land and its resources and local people's management of them has to be taken into account (McCall, 2003) like in Rwanda case. For land rights recoding, the cadastral processes in LTR program include adjudication, demarcation, surveying, and recording(Government of Rwanda, 2012). According to Tuladhar (1996), under general boundary concept, the boundary between two parcels is undetermined, there is a strip of unspecified width and uncertain ownership is left between each parcel. Lemmens (2011) further states that the general boundary is less demanding standards but has a disadvantage of reduced level of confidence. In Rwanda context, the emphasis is on visible features on the ground and these are supposed to indicate the exact location of the boundary(Government of Rwanda,

2012). However though these features are visible on ground, they do not show exactly the legal boundaries due to the principle and techniques adopted in boundary mapping.

Land administration projects

Generally land administration projects (LAPs) are called the institutionalization of land administration systems capable of both reflecting and improving existing people-to-land relationships. This is the typical focus of many international aid and antipoverty initiatives(Williamson, Enemark, Wallace, & Rajabifard, 2010).

According to Williamson et al. (2010), LAPs are costly and range in cost from hundreds of thousands to billions of dollars. They can involve small grant to deliver tenure security in careful selected micromanagement areas, such as secure vegetable plots for the urban poor in Indonesia, or national programs for infrastructure to support tenures. Large scale and pilot titling programs are typical LAPs and have been undertaken in many parts of the World. These have been run in former Soviet and communist countries in Central and Eastern Europe. Southeast Asia has programs in Indonesia, Laos, Cambodia, Vietnam, Sri Lanka etc. Also, Africa and Latin America have long been the focus for large scale-projects(Williamson et al., 2010).

Today, LTR in Rwanda is one of those large scale land titling projects. Contrary to other projects, it was designed as a low cost titling project in Africa. In terms of time and outputs, this project has demarcated 10.3 million of parcels in three years (Nkurunziza, 2010).

2.3. Problems with conventional land administration approaches

Land administration requires many levels of technology, which have the capability to manage millions of parcels. The choice depends on the country needs, the work to be accomplished and financial means.

Nowadays because of the huge work, conventional land administration approaches are proven not to be successful in any case and fail to provide adequate support to societal development. These are inefficient and ineffective because of rigid and costly regulatory frameworks and poor land recording systems and centralized information systems (P van der Molen, 2006). In the conventional way of data acquisition, land registrars and surveyors usually consider as important to provide the registration of full titles to land and focus on accurately surveyed cadastral boundaries. This does not fit for the purpose of doing the work for the population who need immediate responses (Paul van der Molen & Lemmen, 2004). In addition, a lot of literature shows that in many parts of the World normal land administration procedures are time consuming, costly, frequently non-transparent, inaccessible for to many people in the rural areas, and handled in the languages that people do not understand. This may result in high transaction costs or other dealings leading to informal recording (P van der Molen, 2006).

The mentioned problems have been identified in Rwanda land administration before the creation of NLC which helps establish the new land administration. Old land administration was too bureaucratic characterized by a range of scattered land institutions and with difficult coordination(E. Rurangwa, 2004).

2.4. The new ways: Unconventional land administration approaches

According to P van der Molen (2006),in order to meet the need of poor, innovative approaches are necessary. Individuals and international organizations have proposed some new solutions comprising the following approaches: The UN/Habitat encourages innovative approach like the development of additional or alternative sustainable forms of tenure, decentralized and efficient systems of land administration including appropriate cadastral and land registration systems; arrangement for simplified

procedures that promote transparent, accessible, user friendly and accountable land administration; from the system perspective the UN/Habitat considers as innovative approaches like local land registers, effective-central local information and functional linkages, more inclusive registers, parallel land registration, digital access, better public awareness, privatized service and simplified recoding of representation; FAO states that for an innovative approach, efficient land administration procedures should allow transactions to be completed quickly, inexpensively and transparently. The World Bank is critical about land administrations that bring about high transaction costs and thus constitute a threat to the market activity and reduce the capacity of the poor to participate. The World Bank approves an approach for which land administration institutions should be transparent, accessible and cost effective with low cost registration and demarcation mechanisms (P van der Molen, 2006). According to (Augustinus, 2005) new approach should specifically take into account women land rights, no rigid boundaries in customary area and adaptation of conventional approach to new law.

Identification from less accurate photographs or satellite images is a well-known approach and understood by citizens. Therefore, accuracy and technology considered by surveyors in conventional ways should not be considered as panacea (P van der Molen, 2006). In this regard, with millions of parcels to record, Rwanda referred to these innovations in land administration and adopted to use orthophoto to complete this task. A part from orthophoto use in boundary surveying, other main features of LTR project include general boundary principle, and use of less skilled people called Para surveyors. Therefore the consideration of getting accurate surveyed boundaries by qualified surveyors was abandoned.

2.5. Examples of land administration projects under new ways

2.5.1. Lao land titling project (LLTP)

Lao land titling project was a Lao government initiative to accelerate the issue of land titles to increase efficient use of land for improved economic and social development. It was co-financed with the World Bank. The first phase of the project commenced on 1 July 1997, while the second phase started in October 2003.The project was a multipurpose to deliver tenure security, establishment of credit market, encouragement of private sector investment, and as a source of government revenue. This project has developed over a period of ten years from a low organizational, management, technical and educational base, to a functioning land administration system that has registered in excess of 328,000 parcels in nine of 18 provinces(Virachit & Lunnay, 2005).

The Department of Lands in the Ministry of Finance was responsible for implementing the project and the Provincial Lands Offices were responsible for the day-to-day operations of the systematic registration and land registration activities(Virachit & Lunnay, 2005).

The technical part was based on computerization of Land Parcel Registration System (LPRS).The first phase of this system was the development of computer based records software used by the systematic land adjudication teams. This enabled easy documents and reports exchange as well as direct transfer of data from the field to the land office(Virachit & Lunnay, 2005).

The success of the project's operations was largely attributed to innovative tools designed specifically for the project. These included the benefits of working together with the development partners, benefits from piloting proposed project activities before starting the main project, early introduction of supporting legislation, and the importance of establishing a sound education base from which capacity to support the project can grow(Virachit & Lunnay, 2005).

Though these innovative tools were helpful, some activities were not well implemented. Those were the development of appropriate institutional structures, the importance of accepting appropriate educational and community related programs to ensure that there was adequate dissemination of project information, delays in commencing key studies, and the importance of training to build capacity and ensure sustainability(Virachit & Lunnay, 2005).

Rwanda and Lao projects are both low technical and educational base. However Lao project has an advantage over Rwanda project. This is the use of computer software in data acquisition facilitating data exchange between office and adjudication teams. It is obvious that the number of mismatches in Lao project is minimal due to the technology applied and steps are reduced in data acquisition. The common lesson is that in both projects, they have been started before the clarification of key issues like REMA maps of wetlands in Rwanda. The use of those maps led to geospatial mismatches in output documents.

2.5.2. The Cambodia land registration project (LMAP)

The purpose of this project is to deliver land titles and develop a well-functioning digital land registration system through systematic land registration. It is a multi-development partner project which started in 2002. It is supported by Germany, Finnish and French governments. Pilot projects preceded this project and were carried out between1995-2002. During pilot projects 81,000 land parcels have been demarcated and thus constituted results of the basic information to design the project. In 2008, the project was working in 15 provinces of Cambodia where over 1 million of land parcels have been registered in 5 years. The project is supposed to cover the whole country in 15 years (Pieper, 2008).

The staff involved in the project consists of 26 teams including adjudicators, surveyors, demarcating staff, GIS and data entry officers. The total is 700 staff(Pieper, 2008).

The project is done following the common steps in land titling projects like opening meeting, field work, office work, public display of results, and title issuing. To the contrary from other land administration projects done under conventional ways, it is specifically a low-cost and local developed technology using orthophoto and total station when boundaries are not clear. In addition, data entry is in Khmer language(Sar, 2005).

As stated by Sar (2005) reasons of success include:

- Enough training of all land registration teams to improve effectiveness. Their staff comprises surveyors, other well trained staff and local representatives within 8 weeks including 4 weeks of theory and 4 weeks of field practice before they commence the work.
- The Cambodia government has established a fair and affordable registration fee structure. Fair means small landowners pay small and big pay big proportion to land size belonging to them. For instance in rural area, the fee is US$2.50 per hectare.

The success of this project results from enough training of the involved staff and reasonable registration fees.

2.5.3. Indonesia land titling project

The National Land Agency in Indonesia implemented the project which started in 1994.The objectives of the project were to improve efficiency and equity of Indonesian's land markets and to assist in further development of land management policies. Achievements of those objectives were to reduce land conflicts, increase tenure security and alleviate poverty. Those objectives were relatively tailored to Indonesian's rapid growth and institutional change(World Bank, 2002).

In the 2 first years, two pilot projects have been undertaken to test new methods, new process and procedures, especially for systematic registration and attendant procedures. The pilot projects were carried out in urban, semi-urban and rural areas. The first project covered 1200 parcels, while the other project covered 5000 parcels. The new methods and procedures introduced included: Adjudication team visited people going to door to door; the payment was collected after the submission of land certificate to the landowner instead of paying in advance; written documents to prove the ownership were not an absolute requirement in adjudication; low and uniform cost to the population; the private sector was introduced into the project to do cadastral survey while in the past the private sector was involved in establishing ground control only. Thereafter, the systematic land registration started since 1996.The target of this project was to record 1.2 million parcels under systematic registration and 4million parcels under sporadic registration in ten districts in Java(World Bank, 2002).

The project had 3 phases including phase A, phase B, and phase C. The first phases were successful with the main objectives accomplished.2 million of land certificates were issued. The project has achieved the target in land titling, cadastral mapping, record management, institutional development, and legal and policy studies. However, there was lack of transparency in systematic land registration. Part C of the project is rated not to be satisfactory because of following different reasons: It could not achieve its objective which was to develop land management policies; the main language used in the reports was English and there were problems of translation into Indonesian languages; new changes of political institutions and policies had impacts on this project phase(World Bank, 2002).

The technical approach adopted in surveying/mapping was utilization of new technology such as global positioning systems (GPS).They also established ground control points.

The successful factors of this project included the education and training programs, and the development of the private sector to undertake all aspects of surveying and mapping(World Bank, 2002).

2.6. Concluding remarks

It has been shown from literature review that land administration, cadastral processes, land administration projects are related each other. Innovative approaches to land administration such as low technology are nowadays being adopted when implementing land administration and carrying out land administration projects. This is the new tendency of land administration since the conventional approach is criticized being too slow and expensive. In land registration throughout all cadastral processes, when PGIS is used with local spatial knowledge, different factors should be taken into account for the success of the project. The next chapter presents land adjudication in Rwanda.

3. LAND ADMINISTRATION IN RWANDA

The aim of this chapter is to give a general overview of land administration in Rwanda including background to land tenure and land registration systems, government initiatives for securing land rights, and the details of the current title land registration process through LTR program. It addresses some of the issues needed to answer the research questions mentioned in chapter one.

3.1. Introduction

Rwanda is a unitary state whose legal and administrative structure is based on its constitution law. The National Constitution is the supreme law under an Executive Presidency and a Parliament. The country is divided into 5 provinces namely Western Province, Eastern Province, Northern Province, Southern Province and Kigali city. The administrative structure consists of provinces, districts, sectors, cells and villages (called "imidugudu")(D. Sagashya et al., 2010).

Before the enactment of the new constitution law in 2003, Rwanda has had unclear and improper law system. This led to a land administration lacking good foundation. During that period land administration in Rwanda could not presume an adequate population registration system. Most of land rights and land itself were not identified and registered. The land tenure system was governed under customary law before colonialism and by the duality between customary law and statutory law since colonialism(Official Gazette of Republic of Rwanda, 2007).

According to E. Rurangwa (2004), until the creation of NLC, Rwandan land administration was characterized by scattered land administration institutions in charge of keeping and maintaining land records and spatial data about land. For instance land records for rural areas and secondary cities were kept in the ministry of lands, environment, water and mines (MINITERE), Kigali city was autonomous in terms of land registration and taxation, cartography and mapping service was working as a standalone department in the ministry of infrastructures (MINIFRA), soil and geological data (maps) were in the ministry of agriculture (MINAGRI), and land taxation was under district/ city authority. Provinces and districts did not have any land administration structures. For rural lands, there was no formal land registration carried out at lower levels. The land administration system of Kigali city was totally independent from that operated by the ministry in charge of lands. The result was bad coordination of services and hard collaboration between institutions in case of land surveying and land allocation activities.

As stated in chapter one, with the aim of reforming its land administration in order to provide tenure security, Rwanda has undertaken important measures such as formulation of national land policy, OLL etc. Currently, Rwandan land administration system is initially being established in order to implement the national land policy and the OLL. The aim is to have the national wide coverage as soon as possible through the systematic land adjudication. This first land registration of all lands has been done under the program called Land Tenure Regularization (LTR) program(RNRA, 2007).

3.2. Key dates in land administration in Rwanda since 2003

The following are important dates in the improvement of land administration in Rwanda and the preparation and implementation of LTR(Government of Rwanda, 2012).

Adopted from LTR manual(2012)

Year	Activity
2003	The new constitution of Rwanda-**Article29:Every person has a right to private property**
2004	"**The National Land Policy**"-The first step in the new framework for land
2005	The Parliament passes the **Organic Land Law of 2005(OLL)**(15th Sept.2005).This sets out new arrangements for the land tenure and titling, for registering and administering land and land titles and for the guidance of the use and development of land
2008	**Strategic Road Map for Land Tenure Reform in Rwanda** is accepted by Cabinet (March 2008). Last revision dated April 2009.
2008	Development of the **Land Administration Information System (LAIS)** being covered.
2009	**Low Aerial Photography** is completed in Rwanda with 99% of the country being covered.
2009	Trials for **Land Tenure Regularization** are completed. The National implementation begins.
2010	**Development partners** provide the financial and technical support to RNRA. Implementation of LTR is intensified. Consultants appointed to support the LTR process.
2012 June	**Demarcation and adjudication** completed for the whole country(10.3 million parcels)
2012 June	**LAIS** operational and commencement of transfer of sectors with completed lease issuance from the LTR database to the Land administration system
2013 Dec-projected	**Leases printed and available** for all those who have registered with complete information and are eligible for title (anticipated to be 8 million).
2013 Dec-projected	All 10.3 million parcels **transferred to the LAIS**, thus establishing the Rwanda land registry

The current land administration after new land policy operates at national level through NLC, under MINERENA. Its coordinating board is chaired by the registrar of land titles. The NLC has also the responsibility of keeping the national registry consisting of digital database for land records and parcel maps. At district level, land surveying and registration should be carried out by district land bureaus. Land registration should be done on the ground in the presence of landowners and surveyors at district level.

3.3. Background to the land tenure in Rwnda

Land tenure system in the pre-colonial period

This was totally customary favoring land partitioning through the father to the son inheritance for long time(Eugène Rurangwa, 2002). It was recognized by the customary law and the administration of that time. Its main characteristics were the collective ownership and the harmonizing of links between agriculture and livestock.

Land rights were respected and transferred from generation to generation according to Rwandan tradition and institution. Those rights were accorded on behalf of the King who was the ultimate owner of the land and had the responsibility of caring for the population's welfare. The organization structure of the society in that period was such that families were grouped together under lineages, and these were in turn

clustered into clans. Each single clan was ruled by a chief. A clan was normally found on the national territory in different sizes according to regions. Land was given collectively not individually(Official Gazette of Republic of Rwanda, 2007). The King granted usufruct rights to the land through his local representatives (chiefs) in return for obligations and fees, payments, and labor. These rights could be withdrawn at any time and allegedly were also instruments for political means. The vast majority of the agrarian population had virtually no right over their land or their labor power. The profits from land use came from the territory occupied and the types of production (Wyss, 2006).

As stated in the Official Gazette of Republic of Rwanda (2007), under customary law, four systems regulated land access and land use. These systems were: "ubukonde", "igikingi", "inkungu", and "gukeba".

- "Ubukonde" was a clan right. Under this land law, the land belonged to the clan but the control and access to the land was held by the chief clan issued from the lineage-group which first cleared the forest. The chief could own vast tracts of land on which he would settle several families. These are called "abagererwa" and enjoyed some land rights subject to some customary conditions.
- "Igikingi" was right to grazing land and granted by the king or one of his chiefs known as "umutware w'umukenke", to any family that reared the livestock.
- "Inkungu" was custom. It was aimed at enabling and authorizing the local political leader, on his own or others behalf, to own abandoned or escheated land. These were the land reserves which the ruler of that time could grant to anybody who needed one.
- "Gukeba" referred to the process of settling families onto the grazing land or fallow land. Gukeba or kugaba as it was sometimes called was done at the province level under local authority.

Both, the chief in charge of land called "umutware w'ubutaka" and the chief in charge of livestock were responsible of good management of these resources. They were at the same level as the chief of army, "umutware w'ingabo".People enjoyed the mentioned rights above under the protection of the King with community-based landownership. This is the system that colonial rulers found in place.

Land tenure system in the colonization

As reported by (H Musahara, 2001), in the colonial rule until the independence in 1962, the customary land tenure system existed alongside codified land tenure rules for land owned by foreigners. The written was law very restrictive while the customary law was widely practiced, giving rise to insecurity, instability and precariousness of land tenure(Official Gazette of Republic of Rwanda, 2007). The customary law recognized land rights transferred through the following means: inheritance through the male line, from the chief in return for tribute, and by clearing new land to which no chief had laid claim. The most dominant system was clientship, by which the landless people were obliged to seek patronage and usufructuary land rights from political chiefs. The written law abolished forced labor in 1949 and cattle clientship 1954. Later in 1960, a Special Provisional Council suspended private rights to pastureland and its Commission for Enquiry drew up decrees related to cultivated land in the north and west. These evolved into the land issue act where customary law was generally upheld. The written law appearing in "coded and laws" of Rwanda was introduced in order to guarantee land tenure security for settlers and other foreigners wishing to invest in land in Rwanda(Official Gazette of Republic of Rwanda, 2007).

Land tenure system after independence

From 1962, the year of independence up to the eve 2004, land access, ownership, and control have been also governed by the dual system of land tenure as in the colonial period. In 1962, the Rwandan constitution (article 108) recognized Belgian land tenure regulations as binding, stating that lands held by original inhabitants were to remain in their possession, all unoccupied lands belonged to the state, all sales or gifts of land were to be approved by the ministry of agriculture and lands, and lands belonging to

foreigners had to be registered. Also, the law enacted in 1976 could not change very much the situation. It briefly said that all lands not appropriated according to the written law belonged to that state, and lands and rights of occupation granted legally could be sold under authorization of the minister responsible for lands. The customary law was predominant because around 90% were still governed under customary law. Only few lands were held under written law for few people, especially in urban areas and business communities. The land tenure of post-independence had three features: the shortage of land and increased fragmented holdings, internal population migration for new lands and "paysannats".

The inheritance law has favored land fragmentation. This law provided that land would be subdivided among male inheritors. When subdivision became small, another plot had to be cleared or bought.

Internal migration followed due to land scarcity. People moved from overpopulated areas to under populated areas. Rural-urban migration took place for people looking for better living due to there were lack of land in rural areas. In this case some parts of the population went to neighboring countries such as Uganda and former Zaire(H Musahara, 2001).

"Paysannat" was introduced by Belgian 1952 as an arrangement to alleviate the situation of clients who had no security of tenure over the land they cultivated(H Musahara, 2001). In the period between 1970 and 1980, due to intensive migration from densely populated areas, the government also attempted to transform the existing human settlement system into one of grouped homesteads, known as the "paysannat". The aim was to make more rational the occupation and use of land that was becoming more and more scarce(Official Gazette of Republic of Rwanda, 2007).

There was little state intervention in Rwanda's land matters after independance. According to Blarel (2001), the exception was for 1976 land law and two decrees in the previous year, and for 1996 land regulations on the temporary management of abandoned land(Official Gazette of Republic of Rwanda, 2007). This dual system of land tenure existed until the start of systematic land registration in 2007.The government through National Land Centre has undertaken this activity with the aim of putting an end to all forms of informal land appropriation, tenancy and customary system(RNRA, 2012a).

3.4. Background to land registration in Rwanda

The reference of this subsection is based on the 2005 OLL and non-peer-reviewed reports of Rwandan government and attached organizations.

In the past, the land rights were secured under two types of land registration: informal land registration and formal land registration. The informal land registration was predominant in the rural areas while the formal land registration was done for few lands in urban and rural areas.

The informal registration of land rights transfer was practiced on the whole territory but was predominant in the rural areas during the post-independence period. The decrees and orders regarding land regulation could not stop such kind of registration. In fact land rights were not fully protected even if people had the written documents justifying how they accessed the land. Until the enactment of 2005 organic land law, land registration was dominated by private conveyance system. Almost all land transactions in Rwanda were informally registered since the country territory is mainly rural. By whatever means the land was acquired, people often wrote a paper as a proof of land ownership but did not go to register that land right transfer to the competent land authorities. This practice was common for almost all land rights transfer like inheritance, gift, buying land etc. For instance in the case of buying land, the land transaction was

completed by the written agreement intended to prove the land transaction. The agreement between the seller and the buyer was written, signed, and testified by the third part who was witnesses. These people were eligible to testify in the case of conflict of over this land.

The formal land registration was sporadic. It started with the colonial era. In 1885, the colonial administration established the decree concerning land occupation, stating that occupation of land should be accompanied by a title deed. Only colonialists and foreigners benefited from this new land registration system while the local population continued holding lands informally or unregistered lands. Also, another decree of 24/01/1943 allowed the Catholic and Protestant missions to register their lands in urban districts and trading centers. The land registry has been introduced in 1960s for keeping land values (owned plots), their owners and the layout of the territory. Between 1960s until 2005, the spatial data information in the registry was obtained through sporadic land registration which was a centralized activity in the ministry in charge of lands. Since 1994 MINITERE had the mandate and authority for land administration at national level. For registering the land elsewhere in the country except in Kigali city, landowner had to submit his/her documents to MINITERE. These included deeds prepared by provincial notary. After submission, his/her documents were checked and registered in the land registry. The deed was then delivered as provisional land right testimony. The title certificate of ownership was normally supposed to be issued after 10 years upon lease money payment. From 1998, Kigali city had its own land administration and was autonomous in terms of land registration. In Kigali city, the registration was done by addressing a letter to the mayor of Kigali city followed by the deed signed by the notary. The documents were registered. The Department of Urban and Planning prepared the plot survey and designed the cadaster map showing the plot location. After clearing all payments, the title certificate was delivered as stated previously.

This process of formal land registration was slow because of a too bureaucratic land administration and no land administration at district level for helping people(H Musahara & Huggins, 2005). Sometimes many people were forced to travel long distance for fulfilling administrative formalities to register their land. In that period people having small parcels had no interest in registering their lands, only those who wished to invest in land formally registered their lands. Consequently, until the enacting of 2005 OLL, only 10% of lands were officially registered under formal land registration.

In addition, the land registry at MINITERE was paper based format. Kigali city had the same registry but later it introduced a digital land registry in 2002 which was operational until 2006.

3.5. Governement initiatives for securing land rights

Important measures for securing land rights have been taken to solve different land problems. The latter included problems caused by inefficient customary system, land problems due to high land value resulting from high population pressure on a small territory, and imprecise boundary location generating conflicts between neighbors and families. All opted measures focused on systematic land registration as an effective response(Official Gazette of Republic of Rwanda, 2008).

This sub-section will talk about the following important government initiatives taken in order to provide land tenure security: The proposed institutional framework and legal frame work. The LTR program will be described in details in a separate section as a land administration project which is also a Rwandan government solution to tenure insecurity.

3.5.1. Institutional management framework

The current systematic land registration system has been done under the supervision of government land governance institutions. These have been redefined under the land tenure reform in the perspective of public sector and decentralization. The improved land tenure system is now structured around three separate functions in each sector: the ministerial sector responsible for policy making, coordination, budgeting and accountability to parliament; service delivery decentralized to districts; and specialized agencies to provide technical and professional functions.

The OLL sets out the institutional framework for LTR as follows:

- Ministry of Natural Resources

At the ministry level, there is the Ministry of Natural Resources (MINIRENA).It addresses the issues of policy, in particular through the ministerial decrees and/or orders that set out laws and procedures for administration, planning and allocation of land(D. Sagashya et al., 2010).It is responsible for all land matters including LTR implementation(Government of Rwanda, 2012).

- National Land Commission

The national land commission is the key land service delivery agency. This is responsible for the strategic direction of Department of Lands and Mapping. It also bears the principal responsibility for overseeing implementation of organic land law, the district land commissions, district land bureaus, and promoting public ownership policy by advocacy and consultation. Under article 8 of OLL, national land commission is established by presidential order, at national(D. Sagashya et al., 2010).

- Rwanda Natural Resources Authority and Office of Registrar of Lands Titles

This office started in 2007.It is responsible for government implementation policy in respect to the land sector including the implementation of LTR(Government of Rwanda, 2012).

- Department of Lands and Mapping(Former National Land Centre)

This office started being operational in 2008. It is the department of RNRA responsible for land matters and responsible for day to day supervision of implementation of LTR and management of central activities. (Government of Rwanda, 2012) This institution is defined under separate law.

- District Land Commissions

These are the key land service delivery agencies like National Land Commission, and have similar responsibility. However they work at district level. They are also established by presidential order,

- Zonal offices

These are Offices of deputy registrars of land title responsible for all day to day LTR implementation in their respective zones(Government of Rwanda, 2012).

- District Land bureaus

Districts land bureaus are available in all 30 districts. These are part of district administration though supervised technically by RNRA. They are responsible for all land administration matters at the district level and involved in the mobilization of claimants, supervision of cell and sector executives, and receipt of unclaimed leases from LTR. These bureaus are administratively answerable to the local authority. Normally a DLB is directed by the District Land officer (DLO). As public notary for land, the DLO certifies applications for land, maintains the cadastral index maps and records of all lands to be registered on behalf of the office of the land registrar.

- Cell and sector Land Committees.

These are formed by the districts. They are responsible for adjudication following demarcation, and during objection and corrections, and lease issuance(Government of Rwanda, 2012).These are the first point of contact for land registration and land use planning(D. Sagashya et al., 2010).

3.5.2. Legal framework

In an effort to address continuing insecurity regarding land rights, the 2005 OLL and its implementing decrees require registration of all land. The legal framework includes the new national constitution, land policy, the OLL and its related regulations.

National constitution

The constitution of the republic of Rwanda distinguishes state and private property and grants every citizen the right to private property, whether owned individually or collectively. The state has the authority to grant rights to land, and to establish laws governing land acquisition, transfer, and use(USAID, 2010).

Land policy

Rwanda did have neither a land policy nor a consolidated land law until 2004. This situation has enhanced the duality between the very restrictive written law and the largely practiced customary law, and has given rise to tenure insecurity. Only few scattered land regulations were used to deal with land matters and most of them dated back from the colonial period (Official Gazette of Republic of Rwanda, 2007). During Belgian colonization, Belgian land tenure regulations were followed for land governance. Later these were recognized as binding after independence by the Rwandan constitution of 1962 and 1976. They were complemented by a decree law no 21/79 of July 23 1979 determining the expropriation of property for public interests. They were applied until 2004 (H Musahara & Huggins, 2005).

In 2004, the government of Rwanda developed a national land policy aimed at directing, harmonizing land management and administration, and reducing land related conflicts as soon as they appear (Official Gazette of Republic of Rwanda, 2007). This will enable the population to enjoy a more secure form of land tenure and bring about proper land utilization. It is intended to develop modernized cadaster system by formal land registration and surveying of all lands in Rwanda as highlighted in articles 30 and 32 of the current organic land law.

Art.30 "Registration of land a person owns is obligatory. The order of the Minister having land in his or her attributions specifies the procedures through which land registration is carried out".
Art.32 "The following certificates shall accompany the letter of application to certify landlordship:
1º a detailed identity of the applicant, and of his or her spouse if married under the regime of community of property;
2º brief description of the land, indicating particularly the area, where the land is located with reference to well-known landmarks like roads, rivers, neighbors sharing boundaries ;…" (Official Gazette of Republic of Rwanda, 2007).

3.5.3. Land law (the OLL), decrees and orders

The enactment of the Organic law no 08/2005 of 14/07/2005 dealing with the use and management of land in Rwanda and other related legislation were proposed as the instruments for facilitating the implementation of, and having land users comply with, the National land policy. They results from efforts made for creating a statutory regime. The land law and related regulations aim to improve tenure security through land registration(D. Sagashya et al., 2010).

The land law, referred to as Organic Land Law (OLL), with effect from 15 September 2005, intended to improve tenure security, through land registration facilitates the development of an equitable land market, and sustainable use of land in Rwanda. Throughout its various articles the OLL anticipated various and essential reforms in land administration and planning. These constitute a main change in land legislation and administration in Rwanda and are the basis of current transformations(D. Sagashya et al., 2010)

This land law is complemented by a series of decrees and orders regarding the institutions in change of land administration, land registration and land use. The following legislations have been enacted:

- Presidential order nº 53/01 of 12/10/2006 determining the structure, the powers and the functioning of the Office of the Registrar of Land Titles.

- Presidential order nº 54/01 of 12/10/2006 determining the structure, the responsibilities, the functioning and the composition of land commissions.
- Ministerial order nº 001/2006 of 26/09/2006 determining the structure of land registers, the responsibilities and the functions of district land bureau
- Ministerial order nº 001/2008 of 01/04/2008 determining the requirements and procedures for land lease
- Ministerial order nº 002/2008 of 01/04/2008 determining the modalities of land registration
- Law nº 18/2007 of 19/04/2007 relating to expropriation in the public interest
- Law nº 20/2009 of 29/07/2009 establishing the National Land Centre (NLC), and determining its responsibilities, functions, organization and competence.

As stated previously, before the enactment of OLL, there was a clear division between the majority of unregistered land rights (held customarily or informally) and the minority of land rights held under written law introduced in the colonial period. The majority of land rights were less secured. When introducing the OLL, the first objective was to eliminate that division so that all Rwandans hold their land under one unified legal and administrative tenure system as defined in the OLL and its associated orders and laws.

In line with the implementation of OLL, the NLC and the Office of the Registrar of Land Titles started the Land Tenure Regularization in 2009. All land rights prescribed in land law and other land regulations in rural as well as urban areas have been established through LTR and certified by legal land titles.

3.6. Systematic land tenure regularization(LTR) in Rwanda

This section describes the procedures followed in LTR program for used for spatial data collection. It is useful for the description of the nature and causes of geospatial mismatches as described in chapter 5.

The trial phase of systematic land adjudication started in 2007. In this year, four cells of LTR trials were covered in four districts. Since June 2009 LTR program has been extended on the whole country.

In practice, LTR is a set of procedures that systematically brings land owners to first registration of their land. The objective is to record all existing land rights in land and clarify their status under the OLL. Valid rights can be then converted into a recognized form under the OLL and registered. As required by the law this applies to all land in Rwanda: private land, state land in the private domain, and state in the public domain(Government of Rwanda, 2012).
In the design and implementation of LTR, the focus has been on orthophoto based systematic land adjudication. This is a low technology compared to the one which is normally used in the conventional surveying. This activity has been done using high resolution orthophotos (0.25m) under Participatory GIS. For better execution of LTR activities, all land owners were legally required to participate in the designated area of LTR(RNRA, 2007).

The data acquisition techniques are based on "general boundaries" principles. They incorporate existing accepted parcel boundaries on the ground, which are mostly demarcated by walls, fences and vegetation, using simple methods of boundary demarcation on aerial photography and/or satellite imagery. The boundaries are taken as 'social' rather than 'technical' boundaries (D. Sagashya et al., 2010).

The documentation used here is the LTR manual. It is the new version of the "Draft Operations Manual for the Systematic Regularization of Land Tenure in Rwanda which was written during the design and trial phase of LTR. This document is a record of how the process has been implemented in Rwanda.

The systematic land adjudication processes include 6 main related processes:

- Notification of areas for the LTR program
- Local information campaign , and training of Para surveyors and adjudication committees
- Cadastral processes consisting of boundary demarcation, boundary surveying (marking of boundaries) on an image of photograph, adjudication of land rights, and recording of claims and parcel boundaries.
- Objections and corrections
- Mediation for land disputes
- Registration and titling embracing the following steps: parcel correction, lease preparation, extract generation, and lease issuance

The table below shows the LTR process flowchart.

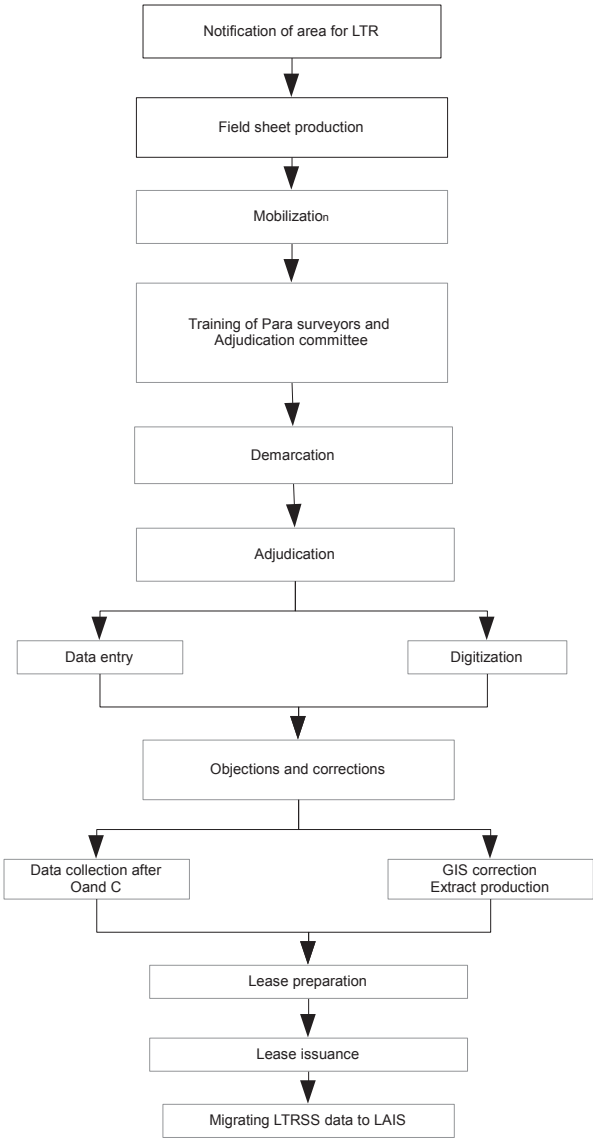

Figure 1: LTR process flowchart

3.6.1. Notification of areas for the LTR program

According to Government of Rwanda (2012), different meetings and activities take place before the start of LTR activities. The deputy registrar of titles meets with each district land officer and sector land committees in their zone to agree which sector will commence LTR activities in the next three months. The deputy registrar of titles meets with the zonal operations manager to prepare a three sector months plan in the zone which will start in LTR activities. The concerned sectors will neighbor those which just have finished at least one of the LTR activities. In the meeting at sector level, the deputy registrar of titles and zonal operations manager will inform the sector executive secretary and the representative of cell land committees in the sector, the date of the start of LTR activities. The cell land committee then publishes the notice for the commencement of LTR activities. The notices are prepared by RNRA and handed to the cell land committee by the field manager. This is done two weeks before LTR in the cell. Also public meetings are held to inform the landowners about this activity. After the plan is confirmed, the zonal operations manager sends it to the map production for the preparation of cell index map and designs the field manager for each activity.

3.6.2. Local information campaign and training

The local information campaign is an activity that consists of disseminating the information about LTR at local level. It is done in the public meeting to ensure all public is aware of the nature and objectives of LTR, legal responsibility and rights of landholders, implications of registration of land, various events in LTR, and mechanisms available to the public for advice and complaint (Government of Rwanda, 2012).

Reference made to the three month plan, zonal operations manager inform field manager when the public meeting will take place. Before and during LTR activities, various media are used to inform the public on LTR. Before the start of LTR in any sector, the field manager with village leaders and cell land committees advertise the public meeting using posters, announcements in churches and common activities. In the meeting the field manager explains LTR procedures using guidelines set out by RNRA. If required, he demonstrates how demarcation and adjudication will be done, and distributes fliers and booklets for those who can read. He also introduces claims receipt, lease documents, field sheets and registers. The public include land cell committees, villages' leaders, and the general public. Sometimes sector land committees and district land bureau are in the meeting. The population asks questions for better clarifications of the issues that will affect them during the process(Government of Rwanda, 2012).

The Para surveyor trainer from a cell that has completed demarcation carries out the training of the new Para surveyor applicants. These are trained how to read and interpret an orthophoto, identify and clearly how to mark a parcel. The applicants are tested by the well being employed. For each cell, eight Para surveyors are required. The field manager and adjudication committee trainer (if available) conduct the training of the adjudication committee. The training is practical based. During the training session, the adjudication committee is introduced to the claims register, the disputes register, the claims receipt, the objections receipt, the fees receipt, and the demarcation activities(Government of Rwanda, 2012).

After the training of both Para surveyors and land adjudication committee, the field manager informs the zonal operations manager that the demarcation and the adjudication can commence.

3.6.3. Cadastral processes in boundary mapping

Boundary demarcation, boundary surveying, and adjudication of land rights

The field manager meets with cell executive leader to decide when the demarcation will start in the village. It is required for the village to be bordering each other. The Para surveyors are divided in cells and teams. The Para surveyors discuss their plans and check if any of them are working on the field sheets which overlap with another that has been already demarcated. If this is the case they mark on the new sheet where the overlap ends to avoid duplication. In each cell, the Para surveyor trainer work with Para surveyors to support them. The field manager gives each Para surveyor the following materials: index map to identify where the Para surveyor currently is, parcel identification numbers, and other necessary field equipment(Government of Rwanda, 2012).

In the boundary demarcation, the landholder should be present on his land. The land committee and the Para surveyor request the landowner to show the existing physical boundary in the presence of the landowners of the neighboring parcels. He/she walks along the entire boundary, and indicates the boundary of his plot to the Para surveyor. When the neighbors and claimant are not present, the village leader indicates the boundary to the best of their knowledge. This can be confirmed during the time of objection and corrections. The Para surveyor uses the physical feature to locate the position of the field sheet. During this exercise physical features can be used but these are necessary when the boundaries are unclear. Normally no markers are placed on the land of someone (Government of Rwanda, 2012).

In boundary surveying, two principles are applied: General and fixed boundary. In the case of general boundary village leader, Para surveyor, claimant, and neighbors walk around the parcel. The Para surveyor plots the boundary on the orthophoto in the presence of the landholder, the neighbors and the village leader if they can all be present and gives a unique parcel identifier (UPI). When present, they check if the boundary is correctly drawn. He marks the UPI inside the parcel on the map. When the physical boundary cannot be seen clearly on orthophoto, the fixed boundary will be established by a qualified land surveyor. In some circumstances, the Para surveyor uses a measuring tape to measure the length of the boundary. He will then use a ruler on the image to measure the boundary according to the scale on the image. The verification is done as above. In the event of a dispute, the Para surveyor is required to record a boundary around the disputed plots to the satisfaction of the disputing claimants. The village leader guides the dispute resolution. The field manager and the Para surveyor trainers do spot checks on the work being done by the field teams to see if they are following the process suitably. At the end of every day, the Para surveyors record the number of parcels they have demarcated. As soon as the entire cell is completed, the Para surveyors check if there are no parcel duplications on a cell sheet and no duplications of unique parcel identifiers(Government of Rwanda, 2012).

Adjudication directly follows the demarcation and surveying of the parcel boundary. After, the Para surveyor writes a demarcation receipt. He/she hands the claimant the receipt to take it immediately to the adjudication committees for registering the land rights. The information on the receipt includes the parcel ID, the land claimant names, parcels IDs of neighboring parcels, status of servitude, land use, remark, names and signature of Para surveyor, administrative location of that parcel, and date of demarcation. The claimants provide the details of their ownership to the adjudication committee who is based at cell office. The adjudication committee members carefully write the names and other details of landowners in the register. They verify if all legally interests of landowners are recorded. If there are more than one landowner parcel, they establish the shares that one landowner holds in the parcel. If there is unsolved claim during demarcation and adjudication process, the land committee enters the details of the claimants and the reason for the dispute into the dispute register. The adjudication committee gives the claimant that claim receipt after filling the detailed information in the land claims register. The adjudication committee remains in the cell for at least two weeks after the demarcation has completed to allow for any further claimants to provide their information(Government of Rwanda, 2012).

Recording

This comprises data entry and digitization. The input data include claim registers, dispute registers, field sheets, claim receipt books, fee receipt books, and dispute books. All these are deposited by the zonal operations manager.

Three month sector plan indicates which sector should be entered and when. The whole sector is entered at the same time. All information in the registers is entered in the LTRSS database. After that, the cell register for that cell is checked to make sure all disputes are recorded in the LTRSS. The worksheets are printed on A4 paper presenting the data from each cell. The team of checkers checks the data against the claims register to see if it matches. If there is a difference the sheet is subject to correction. The checker then submits the correction lists to data entry staff members who enter the corrections into the LTRSS database. They give back the checker the lists for filing. The zonal data technician sends a village list to the relevant regional GIS coordinator .This list includes all unique parcel identifiers and village LTRSS documents in the cell. The regional GIS coordinator joins this list to the spatial parcel data to produce a map showing parcels colored according to the village. The parcels identified as being in incorrect village or recorded without village are then corrected. The area of each parcel is computed in square meters. An excel spreadsheet of parcel ID, village, and parcel area is sent by regional GIS coordinator to the zonal data technician who updates the LTRSS accordingly(Government of Rwanda, 2012).

The digitization of parcels is done referring to the three month sector plan. All available cells are digitized concurrently. The field sheets are scanned cell by cell using high resolution sheet feed scanner and NextImage software. Scanned field sheets are then geo-referenced using geo-referencing tools in QGIS software. At the beginning, parcel digitization was to vectorise parcels boundaries directly looking at the pencil marks of the sheets as collected from the field. Technicians then proceeded with the digitization on the computer screen. In this method, digitizing technician spent much time reading the field sheets. This method was used from June 2009 to end October 2010. There was loss of time. The pencil was sometimes not visible by GIS operator, then Para surveyors started redrawing the boundaries with the normal pen after field work and before they sent the field sheets to the NLC. The digitization process was still the same. Since November 2010, a new way for digitization was introduced. GIS unit staff digitizes parcels using on screen digitization of the scanned field maps and according to parcel digitization manual. The digitization technicians digitize parcel as polygon features with a yellow boundary and no fill. They add parcel number recorded on field sheet to the attribute record associated with each parcel. Once a parcel has been digitized, the digitization technician performs systematic checks for two types of errors: digitization errors which are corrected before the step of objections and corrections, and field demarcation errors which are returned to the cell for correction on the ground in objections and corrections period. The digitizing technician reports all parcels that need field correction. Thereafter he joins the list of all parcel numbers recorded in the register and their corresponding villages to the spatial parcel data. Any parcels which are in incorrect villages or recorded without village name are then corrected. Parcels are numbered with their parcel ID and a cell map is printed out (Government of Rwanda, 2012).

3.6.4. Objections and corrections

This step allows the public to check and, if necessary, make corrections to spatial or textual data related to their claim, and also to raise any objections to the existing claims they have made.

One week before the objections and corrections starts, the public is informed by village leaders that this activity will occur in their respective village. Different means to inform the public are used. They include posters, leaflets and more mass media tools if necessary. This activity lasts for two weeks. The data sheets are displayed in a place where they can be seen so that claimants can make objections for correction.

When change is required, the Para surveyor marks the change on the field sheet and in red pen and reports the case to the GIS unit. Village leaders are employed for a maximum period of three days and encourage landowners to the objection and corrections office. Land transactions that have occurred between end of adjudication and objection and corrections period are also recorded when both parties present the evidence of that transaction. The original claimants details are crossed out and a new claimant's details are entered in the claim register(Government of Rwanda, 2012).

3.6.5. Mediation for land disputes

In case of disagreement during demarcation and adjudication process, the adjudication committee and any available witnesses try to resolve it within a period no more than 30 minutes. If the claim cannot be solved in that time, the land committee enters the details of the claimants and the reason for the dispute into the dispute register. They advise the two parties to look for legal redress from Abunzi (local arbitration) for properties being worth a maximum value of 3 million Rwf. Where the value is more than this they are advised to go to courts(Government of Rwanda, 2012).

3.6.6. Registration and titling

This comes after objection and correction and consists of parcel correction, lease preparation, extract generation and lease issuance. The digitizing technician applies corrections to the digital parcel map and check topology between parcels and adjacent cells. He/she reports the corrections made .He/she also uses the DS Map Book tool for Arc GIS software to generate the cadastral extracts in jpg format for all parcels. He/she prepares an excel spreadsheet including all unique parcel identifiers and associated area. Scanning technician scans the corrected sheets for archiving. The output is the corrected parcel dataset, cadastral extracts and corrected areas for certificates of emphyteutic lease. One week before lease issuance, the field manager holds a meeting with the cell land committee. The public is informed that there will be lease issuance and they can provide further information if necessary. Lease issuance starts and lasts for 4 weeks. A lease document includes 4 documents: original and duplicate lease contract, certificates of emphyteutic lease, and parcel cadastral extract(Government of Rwanda, 2012).

3.7. Migaration of LTR data to LAIS

All data present in LTRSS will be transferred to LAIS. Both are digital databases:

- LTRSS(Land Tenure Regularization Support System) is a database created for large scale recording of LTR claims data and high volume production
- LAIS (Land Administration Information System) is a database for maintaining the land administration records and processing transactions.

The migrating cell data will be then removed from LTRSS. The maintenance team will undertake all future land transactions in LAIS(Government of Rwanda, 2012).

3.8. Conclusion

The background of land tenure and land registration systems, government initiatives to solve the problem of tenure insecurity, and LTR program were discussed in this chapter. The land tenure system in Rwanda was first of all customary and dual system including customary and statutory since the colonization era until 2009. The current land registration was preceded by informal registration of many land transactions and formal land registration for few lands. The LTR has been implemented by NLC under the MIRENA. The NLC was in charge of carrying out the cadastral processes and record the data in a digital database called LTRSS. The overview of land administration in Rwanda is the basis for understanding why LTR program was undertaken and how it was carried out. It is used to answer some of the research questions. The next chapter talks about methodology and data collection.

4. STUDY AREA AND RESEARCH METHODOLOGY

In the previous chapter, land administration in Rwanda is introduced. The main objective of this chapter is to introduce the case study area and describe the approach followed for data collection and analysis. It discusses in details the sampling method, pre-field work, field work activities carried out for primary and secondary data collection, and data analysis. The materials used in data collection, and the ethical consideration are also mentioned here. The challenges encountered during data collection are the last section of this chapter.

4.1. Background to the study area

Kigali city is the capital of Rwanda and one of its five provinces. It is located almost in the centre of the country, and its geographical position is on Latitude 1^0 57' South and on Longitude 30^0 04' Est(Kigali City, 2012a).It started in 1907 under the order of the first resident of Rwanda called Dr. Richard Kandt. At the beginning, it was a small Germany colonial outpost with little link to the outside world. During the First World War, Germans lost the war and left the country. They were replaced by Belgians troops who entered Kigali and declared victory over them on 6 May 1916(Kigali City, 2012b).

Under Belgian authority, the expansion of Kigali was slow and this city was mainly located on the top of Nyarugenge hill. At the independence date on first July 1962, Kigali remained a small village aimed at administrative functions. In 1962 its population was around 6,000 over an urban area of 3sqkm.From 1962 to 1984, the population has increased at high rate, while the urban area expanded rapidly. The population grew at 16% and reached nearly 150,000 people, the built up area has also expanded to 12 sqkm(Kigali City, 2012b).In 2002, the total area of Kigali city was around 349sqkm.The current Kigali city area is around 730sqkm, consisting of 25% for urban area and 75% for rural area. This resulted from land reform that occurred in 2005 with the new national administrative boundaries (Kigali City, 2002).

Today, Kigali city consists of three districts, namely Nyarugenge, Gasabo and Kicukiro. These are also divided into sectors, which in return are divided into cells which are further subdivided into Imidugudu also called villages. Thereby, Kigali city encompasses 35 sectors, 161 cells and 1061 villages. It is a city that has grown into a modern metropolis as heart of emerging Rwandan economy which accommodates around 1,000,000 people over 730kmsq(Kigali City, 2012c).

4.2. Selection of Kigali City

The case study was carried out in Gasabo district in Kigali city. This is the biggest district in Kigali city (429.3kmsq) with 426, 2999 inhabitants over 1million inhabitants of Kigali city. Gasabo is composed of 15 sectors with rural and urban areas. The rural area embraces 8 sectors: Bumbogo, Gikomero, Jabana, Jali, Ndera, Nduba, Rusororo, Rutunga. The urban area consists of 7 sectors including Gatsata, Gisozi, Kacyiru, Kimihurura, Kimironko, Kinyinya, and Remera, (Kigali City, 2012a).

The selection of Gasabo district in Kigali city has been motivated by the following criteria: Gasabo has already finished the systematic land registration and is in the maintenance phase; availability of spatial and administrative data; easy access to essential basic information including land laws, digital maps, the

database and archives of its land department; some landowners have the deed plans which help to understand their objection case (some deed plans were done by KCC project, others by private surveyors)

The total number of all parcels in Gasabo is 191, 445 over 332,073 in Kigali city. Between 26March and 11 September 2012 the number of parcels having known land problems at Gasabo land department is 2921 including 700 land objections reported to RNRA. These are found to share similarities in the study area, so I decided to collect data in Gasabo district even if it was possible to collect data in the three districts. This is due to in the same area the principle of general boundary and use of land adjudication orthophoto-based were adopted; and due to the previous mentioned criteria. Therefore, we could understand that the aim was to examine the nature and the causes of geospatial mismatches that occurred in the land adjudication process. The table below gives an indication on land adjudication in the study area:

Situation of parcels demarcated in August 2012 in Kigali city

District	Measured land	Complete information on land	Incomplete information on land	Conflict cases registered
Gasabo	191,445	144,527	46,918	140
Nyarugenge	67,334	54,839	12,495	154
Kicukiro	73,294	60,211	13,083	27
Total	**332,073**	**259,577**	**72,496**	**321**

Table 3 : Demarcated parcels in Kigali city in 2012; Source: RNRA

Figure 4 shows the visited sectors in the study area:

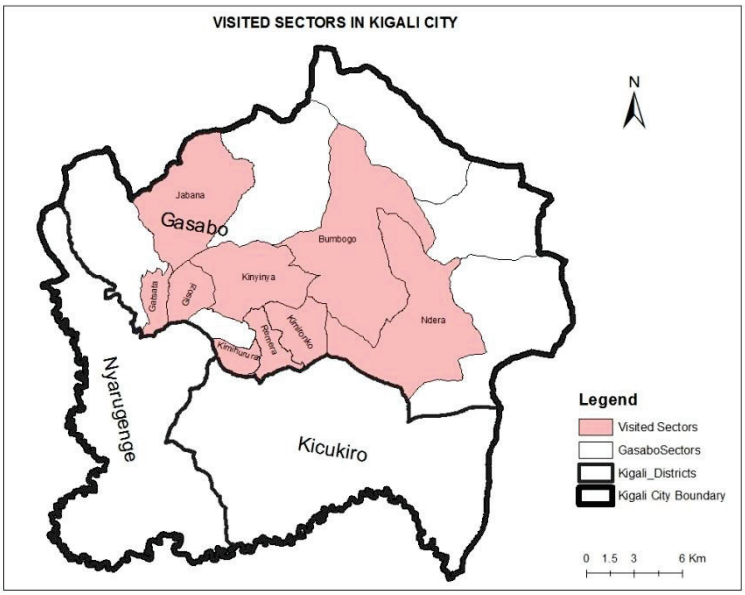

Figure 2: Visited sectors in Gasabo

4.3. Research methodology

The methodology of this research is mainly based on the approach of case study method. The research is carried out according to the research design in section 1.6 considering the objectives of the study.

A research methodological plan was designed consisting of three parts, namely called pre-fieldwork, fieldwork, and post-fieldwork. The first two parts describe the data collection methods, while the post-field work concerns data analysis and will be detailed in discussions chapter.

Both primary data and secondary data were collected in this research. The primary data help understand the existing situation of land adjudication and the geospatial mismatches in the process that occurred at different stages. The secondary data provide relevant up to date information on the current process.

4.3.1. Pre-fieldwork stage

This stage consisted of defining the research problem and objectives to be achieved using the literature review as the main tool. The researcher did also other activities relevant to the field work for getting data as described below.

This stage consists of identifying the data required and the material needed based on literature review, so as to perform the survey. After identifying the data required, a research methodology was done to facilitate the data collection during the limited fieldwork period. The materials included scientific articles, conference papers, official government web portals, and government reports published on the LTR program.

Before going to the fieldwork, preliminary arrangement was done by contacting at least one key informant at each institution which was intended to be visited. The communication was done via telephone and emails. The identification of these organizations and their staff was important because they have the list of all people who reported their land objections after titles issuance in Kigali city. The cases needed for the research were obtained during field work because the information is kept confidential. Having access to this needs personal explanations in the presence of authority.

At this stage, the necessary documents were prepared such as questionnaire interviews, a pre-test and translation of these in Kinyarwanda. Also, the support letter from ITC was prepared to request necessary help from any individuals and organizations in Kigali city for field work. The consent form was prepared to maintain ethical aspect of research.

4.3.2. Fieldwork stage

Sampling

The survey was carried out from 26September to 26October 2012 .It was designed to collect the information on spatial mismatches and their causes in Rwandan land adjudication process. The primary data were collected from RNRA staff and Gasabo district authorities' interviews, household interviews and direct observations. Two types of interviews were conducted: Open and semi-structured interviews. The respondents to open interviews were RNRA staff and Gasabo district authorities. They were selected based on their position and role in local government entities. 15 key informants were selected and interviewed (refer to table 7).

Organization	Authority position	Number
RNRA	Deputy Director General of RNRA and Head Land and Mapping Department	1
	Ag. Director Land Administration RNRA unit	1
	LTR GIS Manager	1
	Chief of GIS unit in Western province and former GIS staff in Gasabo district	1
	GIS staff	2
	Para surveyors	2
Gasabo District	Director of lands	1
	Engineers in land department	2
	Land sector engineer in Remera sector	1
	Local leaders in land committees	3
Total		**15**

Figure 3: Government official informants

The selection of landholders was done randomly due to the availability of respondents, and the limited time allocated to the fieldwork. The database of land requests of Gasabo district was used to call the landowners by telephone and the respondents who agreed to be visited were selected. In total 30 landholders who had land objections were interviewed (refer to table 6). The household survey consisted of semi-structured interviews for landholders.

District	Sector	Number
Gasabo	Bumbogo	1
	Gatsata	3
	Gisozi	4
	Jabana	1
	Kimihurura	1
	Kimironko	10
	Kinyinya	6
	Ndera	2
	Remera	2
Total		**30**

Table 4: Number of interviewed landowners

Primary data collection

In this research, the selection of the target groups is in line with the purpose of this research and the groups include all actors who were involved in the systematic land registration. The interviews and direct observations were applied to collect primary data. The process of gathering information is described below:

- **Interviews with local government officers and RNRA staff**

This was done through open interviews. They were conducted with local administrative authorities and the concerned RNRA staff. Interviews with RNRA staff were digitally recorded. Only one interview with Deputy Director General was conducted in English. Others were done in Kinyarwanda, transcribed and translated into English. From this group, the interview was used to get information about the current LTR program, policy, legal, and institutional frameworks under which boundaries are adjudicated, demarcated, surveyed and recorded, geospatial mismatches and their sources, and strategic measures. The information collected from interviews was used to answer research questions.

- **Interviews with landholders**

This was done through semi-structured interview. This is also the main source of primary data collection in this study. All interviews were conducted through the medium of the local language, Kinyarwanda, summarized and transcribed on the questionnaire paper, and translated into English. The results were used to answer research questions. All respondents have provided important information, so all questionnaires collected from them were used for analysis.

- **Field Observations**

In addition to interviews, the fieldwork consisted of approaching the landholders, observing their parcels and discussing with them about land demarcation process. 3 documents were used to identify the boundary of parcels and check the discrepancy between the registered parcel in the database at RNRA and the parcel on the ground. Those included extract of cadastral plan issued by RNRA, deed plan (fiche cadastrale) made by a licensed private surveyor and an orthophoto of the same area. During this activity, we talked about the geospatial mismatches and their causes.

It was assumed that not all the enquiries answers would be given.Therefore personal observation was used to come up with sensible answers depending on the comments that were made by the landowners interacted with. The visit of the parcel was the means for justifying the existence of the parcel boundary with mismatches in addition to the legal document of landowner

Secondary data collected:

The secondary data supplied by the government officials contributed to provide secondary data. The collected data included spatial and non-spatial data. Non spatial data including documents, web portal link and videos were collected. The spatial data included digitized parcels in Kigali city, Kigali city boundaries, and aerial images of Kigali city.

The data collected from the secondary sources are described in the table below:

No.	Data	Format	Source	Comment
1	Orthophoto images of Kigali city taken in 2009	Orthophoto image of 25cm resolution	Gasabo district	-
2	Digitized parcels	Shapefile	Gasabo district	-
3	Kigali cell's boundaries	shapefile	Gasabo district	-
4	Registry of land related requests including land objections	Soft copy of Excel document	Gasabo district	-
5	Land laws	PDF document	Gasabo district	Some of these documents are in Kinyarwanda, French and English
6	Letter of acceptance for doing research in Gasabo district	Signed hard copy	Gasabo district	-
7	Applications of land objections	Hard copies	2 Land owners	These mainly include deed plan and extract of cadastral plan
8	Survey manual	Word document	RNRA	-

9	Films	CD and soft copy on flash disk	RNRA	One film is on LTR program and another is on Land reform
10	Link of new web portal	-	RNRA	-

Table 5: Secondary data sources

4.3.3. Data analysis

The data analysis was done using:

- The nature of geospatial mismatches was analyzed using AutoCAD software, the layers of digitized parcel by RNRA and deed plan by private surveyor were overlaid with the same scale and assessed to see if the boundaries differed from or matched each other. The difference in the extent was seen by comparison of both layers.
- The assessment tool adopted from Hensen who states that during establishment of cadaster the operational component consists of 4 cadastral processes including adjudication, demarcation, surveying and recording(Henssen, 2010). In this framework, from technical view, spatial and textual aspects were taken into account for analysis of causes of geospatial mismatches. From social, legal and time views social and other factors were considered. The interviews with spatial data were synthesized in this framework by qualitative analysis and showed the causes of geospatial mismatches in LTR program.

The table below shows the assessment framework for geospatial mismatches in the 4 cadastral processes:

	Spatial aspect	Textual aspect
Adjudication	None applicable	Blunders errors Systematic errors Random errors
Demarcation	Blunders errors Systematic errors Random errors	Blunders errors Systematic errors Random errors
Surveying	Blunders errors Systematic errors Random errors	None applicable
Recording	Blunders errors Systematic errors Random errors	Blunders errors Systematic errors Random errors

Table 6 : Causes in cadastral processes

4.4. Materials used, ethical consideration, and problems encountered

The material used included:

- Extract of cadastral plan issued by RNRA to landholders
- Deed plans (fiche cadastrale) made by a licensed private surveyor
- Orthophotos of the areas including visited parcels.
- Audio recorders
- Interviews questionnaires

With regards to informants, ethical consideration concerns the collecting information, looking for agreement, maintaining confidentiality etc.; On the side of the researcher, areas of ethical concern include introducing bias, inaccurate reporting etc.(Kumar, 2005). Some interviewees gave the permission to use

the recorder materials for the purpose of this research. Those who refused were not recorded. Also, informants expressed themselves in the language they wanted and speak fluently.

The problems encountered include:

- Availability of informants

The timetable for meeting officials and landholders was subject to changes. Some informants were not available according to the time they agreed upon with the researcher. Opinions of INGO/ONGO are not incorporated in the research because their involvement was not found at the time of visit to the case study site.

- Household interviews

Since land problems are serious issues, the researcher spent more time to convince the landholders the purpose of the research

- Insufficient time

Because of the limited time, the researcher investigated the current land objections available at Gasabo district only. The staff in charge of archives at RNRA and Gasabo could not provide the corrected parcels after landholder objections. It was hard and time consuming to get those corrected parcels. These may have served for better understanding of the existing situation of land objections and their corrections.

4.5. Summary

This chapter dealt with study area, data collection and analysis methodology description. For primary data collection, open interviews for government officials and structured interviews were designed. Various methods of primary and secondary data collection such as interviews, field observations, and documents collection were used to collect spatial and non-spatial data. Aerial images, ownership data were used for field verification. An ethical aspect to be maintained during interviews was respected by the researcher. Various types of challenges were also faced by the researcher such as availability of key informants, and lack of time. Other challenges were encountered throughout household interviews. The next chapter will talk about the Fieldwork results.

5. FIELDWORK RESULTS

The previous chapter describes the research methodology and the research area. This chapter focuses on the fieldwork results description. All visited sectors in Kigali city in Gasabo district are at the same level of the now being implemented systematic land registration program. During the time of fieldwork, all sectors had the registration under the maintenance phase. It might be expected that there are geospatial mismatches at different stages of the systematic land registration program. Three important aspects are discussed in this chapter: General issues of LTR program, geospatial mismatches in LTR program, causes of the geospatial mismatches in LTR processes, and improvement in the maintenance phase. The nature, extent and number of geospatial mismatches will be described with the help of collected data to answer the research questions mentioned in the section 1.4 of chapter one.

5.1. General issues of LTR program

The objective of this section is to provide an understanding of general issues of LTR program by landowners in the study area. The general issues discussed include: the understanding of policy, legal, and institutional frameworks under which the boundaries are demarcated, surveyed, and recorded; and the understanding of objective, principles and stages of LTR. The understanding of these affects land registration and its outcomes.

5.1.1. Understanding policy, legal and institutional frameworks

a) Policy and legal framework

The LTR program with the target of registering all lands under systematic land registration is built upon both the national land policy and the OLL. The understanding of provisions of these about land registration is a success factor for people participation in the LTR program.

Landowners' response

Most of interviewed landowners indicated that they do not know land laws.

Officials' response

The local leaders also do not understand the land laws. They reported they have limited knowledge of land legislation and the only thing they know is that each landowner should register he/her land. According to district staff and 2 RNRA staff, the community fear to lose their land rights because they think land laws will not protect their rights, and they are not sure to get fair payment in case of expropriate.

Two local leaders said: "People say the customary law was good and known by all. However the new laws force them to pay land taxes and are not known." Though under this tenure system landowners did not have legal documents they enjoyed their land rights and still think new land laws have threat to their land rights.

b) LTR management framework

The LTR management framework for land registration consists of Ministry of Natural Resources, National Land Commission, Rwanda Natural Resources Authority and Office of Registrar of Lands Titles, Department of Lands and Mapping(Former National Land Centre), District Land Commissions, Zonal offices, District Land offices, and Cell and sector Land Committees. RNRA and district staff knows

these institutions are important to carry out systematic registration but people do not know what they do except to tell them to register the land. This is explained by the fact that 18 of landowners struggled to know where to submit their request for parcel correction. One landowner gave the following reflection on that: *"When I wanted to request for the correction of my parcel I did not know where to go and to whom to ask. I asked the local leader who said I had to go to RNRA land agency, finally another person gave me guidance"*.

5.1.2. Understanding objective, principles and stages of LTR

All landowners interviewed have a general idea of LTR objective which is to record all existing rights in land and clarify their status under the OLL. They said that the rights have been recorded but they are not sure if these have been clearly clarified because they have pending claims for correction.

The understanding of principles of LTR has been investigated as follows:

- public and open process

In order to be a fair and transparent process, the information dissemination about LTR process should be advertised through the media and public meeting. This principle supposes that everyone in the community should have equal access to the information and full understanding of it. The response from interviewees indicated that 15 have heard about systematic land registration in the public meeting and through the media. Other 15 remaining did not participate in the preparatory meeting got information from neighbors.

- establishing rights to land

This principle does not aimed at creating new rights but to legally confirm the existing rights(MINITERE, 2005). The research revealed that most of respondents did not have the official documentation except the ones they got informally under private conveyance. The RNRA and district officials declared that during land right establishment, some people ignored the importance of their rights and combined their parcels together. They registered joint parcels as one in order to reduce registration cost perceived to be costly and avoid future land taxes payment. Knowing the risk of this act, some landowners reported their cases which have been corrected in the database.

- just administration

As stated by RNRA (2007), the LTR process will not grab any person right over land, and no occupant of land will be treated in a discriminatory manner. Reflections have been made on just administration in LTR process. *"During the demarcation of my parcel, I was with the Para surveyor, local leader, and neighbors. I did everything they asked me. However, they recorded my parcel wrongly. I do not understand why the neighboring parcels have been recorded nicely except mine."* All landowners said that they did get just administration since their cases are still pending. The RNRA staff said that all Para surveyors who were corrupted during parcel demarcation or refusing to demarcate the land due to different reasons were dismissed.

- a transparent mechanism for resolving disputes,

The majority of landowners and all officials interviewed believe that land registration can put an end to the disputes over boundaries between neighbors and members of families.

- security of tenure in urban and rural areas, and

20 landowners and all officials agreed that land rights will be secured through systematic registration. *"I can understand that my rights are secured since you explain me but RNRA field staff did not tell me that. They only came and asked me to show them the boundary of my parcel"*. This was a reflection of landowner in Gatsata sector.

- A replicable program

The LTR is a simple routine set of administrative and legal procedures.

- Speed and accuracy

The landowners agreed that the LTR has been fast but disagreed about accuracy of their parcels. RNRA staff, district officials and local leaders said that there were errors in the process so that some issued documents had incorrect cadastral maps.

Half of interviewed landowners confirmed they knew all stages of LTR procedures before parcel demarcation. Others followed and relied on information from neighbors.

5.2. Geospatial mismatches in the LTR processes

Nature of geospatial mismatches

The type of geospatial mismatch discussed in this research refers to the spatial difference between the recorded boundary and the reality on the ground as defined in the glossary of terms.

According to landowners, the extent in the parcel on the ground does not match with the extent specified in the cadastral map. That is the extent found after fieldwork for all 30 cases. According to (Government of Rwanda, 2012) they should match each other or the difference should be very small. However, during fieldwork, there were no specifications about this difference. The surveying law was not applied yet.

According to all interviewees geospatial mismatches are seen when you compare the RNRA outputs called extract cadastral plans and the deed plans which are done by Para surveyors. The deed plan is considered to represent the reality on the ground according to RNRA and landowners perceptions. Geospatial mismatches are illustrated by two cases: one is the recorded boundary with big area compared to the reality on the ground; another is the recorded boundary with small area compared to the reality on the ground. The landowner statement below indicated one of these cases: *"I was surprised to see that in the title issuance, the parcel area in my document was half of the real area."* These cases are found in appendix 1.

During the fieldwork, the landowners said that if they wanted the correction of parcel, the rule is that they have to hire a licensed private surveyor who does a deed plan of their boundaries using a GPS. At the beginning they paid €75 but at the time of fieldwork the cost was reduced and they paid €50. They took that document with the old RNRA cadastral plan and application letter to the district which sent these to RNRA on their behalf. The comparison of both plans was useful for both the RNRA and the landowner to show the geospatial mismatch. The RNRA checked if the deed plan was correct. When it was correct then RNRA corrects parcels otherwise the landowner was advised to bring an accurate deed plan. For this research, all 30 landowners used deed plans to request the parcel correction.

The figure below showed one of the forms of geospatial mismatches in the LTR process:

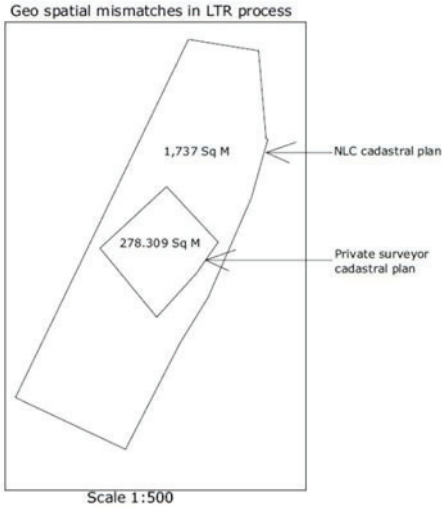

Figure 4: Geospatial mismatches illustration in LTR

Spatial extent and number of geospatial mismatches in the study area

District officials declared that geospatial mismatches are too many in the non-planned and overpopulated areas where it is not easy to distinguish the boundaries between parcels on orthophoto. This is the case of Gisozi, Gatsata and Kimironko. Their number decreases significantly in the planned area like Kimihurura sector and less populated areas like Ndera, Jabana and Bumbogo sectors. The situation is summarized in the table 8. Four RNRA staff, two local leaders also supported the information above and affirmed that most of the known cases are in urban sectors where people previously had deed plans, are well educated and can distinguish the difference between the new documents issued by RNRA and the others they got before LTR program.

The RNRA staff confirmed that many problems of geospatial mismatching occurred in the areas declared by REMA as wetlands while they are not. At the beginning, in GIS unit, they were using the maps of REMA showing the limit of wetlands. Those maps had too many imperfections. For instance the layer of wetlands had an expansion over the populated areas and cut the landowner parcels. That situation led to the reduction of parcel areas and postponement of titles issuance for many landowners. Later, RNRA worked together with REMA which created new maps for that situation. Certain of those cases caused by REMA wetlands policy have been resolved. However the solution was not satisfactorily for all parcels having such kind of problems. They were again imprecisions in the new maps sent to the RNRA for correction of parcel maps. Some parcels with geospatial mismatching due to REMA maps of wetlands still exist.

According to the deputy director general at RNRA, the number of geospatial mismatches is not significant compared to the current reported cases over all recorded parcels.

This table showed the number of investigated cases in the study area.

District	Rural sector	Number	Urban sector	Number
Gasabo	Bumbogo	1	Gatsata	3
	Jabana	1	Gisozi	4
	Ndera	2	Kimihurura	1
			Kimironko	10
			Kinyinya	6
			Remera	2
Total	**30**			

Table 7: Cases of geospatial mismatches in the study area

All cases having geospatial mismatches in Gasabo district are found in appendix 2.

5.3. Causes of geospatial mismatches in the LTR processes

a) Adjudication process

Landowners' response

According to landowners, some of them could not participate in the adjudication and demarcation of their parcels because of different reasons. These included: The landowners had personal problems that prevented them to participate; other landowners were not informed about the demarcation of their parcels. For all those who delegated someone to respond on their behalf, their parcels have been adjudicated and demarcated correctly. However, for those who did not have information and could not

delegate any person, they did not know how their parcels were demarcated. Later, they knew that their parcels have been adjudicated and demarcated. This information is summarized in the table below:

They also said that some landowners gave wrong information during boundary adjudication

Governemnt officials' responses

RNRA staff, district officials and local leaders reported that information on some parcels in Kigali city was given by local leaders because their landowners were not present and the information was sometimes incomplete. They also said, some landowners gave wrong information on the real landowners and land rights. According to this scenario, the following cases have been reported: the case of men having two wives who registered the land on the wrong owner name; the people who registered the land of owners living abroad; the powerful men who took the land of other people; and people who took the land of minor orphans. In addition, local leaders reported that some landowners did not participate in the adjudication stage because they valued their activities rather than land registration. One made the following reflection: *"Many people did not understand and see the benefits of the land registration; they always said the first beneficiary will be the state to collect land taxes. During adjudication we could not see some of them though we informed them"*. They further explained that landowners considered land registration as time consuming, preventing them to complete their daily activities for nothing.

b) Demarcation process

Landowners' response

Landowners confirmed that in some cases Para surveyors partly did the demarcation: They did not go to bushes or wet places to see the exact boundary on the ground. They marked some parts of the boundaries as they saw them and others by guessing.

In another case, they simply skipped the demarcation step: They stood up in one parcel and marked the boundaries of its surrounding parcels referring to orthophoto without checking the boundary location with landowners; they also came and asked the landowners if they were real owners, after landowners approved being owners, the Para surveyors continued marking the boundaries on orthophoto without asking them to show the boundaries.

For the case of absent landowners, the local leaders helped in the demarcation exercise and showed the boundary. In some cases he/she could not show the exact boundary.

Government officials

RNRA staff, district staff, and local leaders confirmed the information on parcel demarcation given by landowners. They also reported some landowners did not show their real boundaries and the result is that the Para surveyor marked the wrong boundary. Under this cause, the following cases have been identified: the cases of orphans of the 1994 genocide who were children during the tragedy and did not know their boundaries during parcel demarcation; some wives when their demarcated the land on behalf of their husbands they could not show exactly the boundaries; and some landowners feared to pay land registration fees, they combined their parcels together and delegated one person to register for them for all combined parcels in one. Also, some influential men took the land of other people who kept quiet due to fear or did not get just from mediators (Abunzi. Those people showed wrong boundaries.

In other cases, Para surveyors also assigned wrong cell name, number and owner name to parcel.

c) Surveying

Landowners' response

Para surveyors were normally supposed to show the marked boundary on orthophoto to the landowners according to the LTR manual principles. However, they failed to do so. This was a serious issue in the demarcation process. A landowner made a reflection on that: *"They did not show me how they marked my parcel boundary. At least, they may have allowed me to see the boundary of my parcel on those beautiful photos they were carrying"*. In this research, 20 respondents were not shown the boundary mark on orthophoto by the Para surveyors.

Landowners said that Para surveyors added an offset road to their parcels, thus the result was a big recorded boundary compared to the reality on ground.

In reading orthophoto, some Para surveyors had difficulties to distinguish the boundaries because these were not on orthophoto or were not well visible.

There was also a parcel which was not surveyed correctly because of the conflict between Para surveyor and landowner

RNRA staff response

RNRA staff supported the landowners' response. They also confirmed that Para surveyors made errors in surveying by giving an offset road to some land owners because they did not know that was a problem. Later, the problem was corrected in GIS unit for planned areas while it was not in unplanned and rural areas.

They said in the case of wet orthophoto by the rain, the thickness of the pencil was increased on orthophoto, thus leading to imprecise boundary. The weather has introduced random errors in the field sheets.

RNRA staff mentioned blunders errors in boundary surveying. For instance Para surveyors made errors during the marking of the boundaries on orthophoto. In some cases they could not draw the boundaries as they appeared on orthophoto. After parcel boundary demarcation, the Para surveyor drew the boundary on the orthophoto using a pencil. In some cases the marked line with the pencil did not match the boundary as it appeared on the orthophoto due to human imperfections in drawing with free hand, fatigue and carelessness of Para surveyors, and insufficient time to complete their assigned daily work. At the end of the daily work he redrew again on the orthophoto using the normal pen over the pencil in order to make visible the boundary. Here it was difficult to redraw exactly the same line as it was at the first time. Redrawing has repeated same errors or introduced the new ones. Drawing twice on the same boundary probably led to the shift of the line away the exact boundary, consequently the result was geospatial mismatch in cadastral output.

Another category of causes they mentioned in surveying refers to inaccurate orthophoto that introduced systematic errors. Most of the orthophoto used in LTR were taken in 2008 and at the time of parcels demarcation they were 3 years old. Those orthophoto showed the reality on the ground for some parcels but failed to do so for others. This was caused by the fact that after 2008, a lot transformation in the land use occurred in Kigali city. They were many new buildings, new roads and other physical changes on the ground. During demarcation in some places, it was difficult to know the boundaries referring to orthophoto because of those changes. Also some orthophoto were not clear enough to show the exact boundary as identified above by landowners.

As reported by 4 RNRA staff, the training of Para surveyors was not enough. Their skills were critical. One staff has reflected this: *"If you deploy not well trained people on the ground, you get a lot of quantity of data but the quality of data is low."* They said most of errors made by Para surveyors in boundary surveying are due to insufficient training. Some of the Para surveyors were trained by their colleagues at the time of boundary surveying. At the beginning they did not take care of their role in LTR program and made errors. As the process went on they became aware of their tasks and role in LTR and try to avoid errors.

They also reported there were parcels which were not surveyed correctly because of the corruption. Some Para surveyors were corrupted by landowners to illegally demarcate the land for their specific purposes. All known cases of corruption led to immediate dismissal of the staff involved.

d) Recording

Landowners' response

The landowners said that they participated in the adjudication and demarcation of their parcels. They saw the boundaries of their parcels were well marked on orthophoto but the boundary recording of their parcels was wrongly done. 11 over 30 cases investigated suffered from geospatial mismatches. Their owners confirmed that those errors were made by GIS unit team. They could not specify the types of causes of geospatial mismatches in GIS unit because they said they did know how data post processing was done.

Government officials' response

According to RNRA staff, geospatial mismatches were due to spatial errors in incorrect field sheets from boundary surveying. When they were detected in GIS unit, the correction was to go again to the field and work with the Para surveyor for checking and correction. Also the correction was done for the detected errors but for unknown cases the errors propagated from surveying to the printing out of the parcel maps. Those errors resulted in geospatial mismatches showing parcels having either big area or small area compared to the reality on the ground. There was always the control of errors but it was not possible to know and fix all errors.

As spatial data entry was done using scanned field sheets, inaccurate scanned field sheets were also the source of geospatial mismatches. Other blunders errors were introduced by digitizing technicians when doing hands up digitization or onscreen digitization by carelessness. During post-processing digitization, overlaps and gaps between neighboring parcels happened when digitization was not done carefully. Those errors were checked automatically using ArcGIS topology error inspector and corrected manually. As the correction was done manually, some errors have been corrected but others were not.

When using the maps of REMA showing the limit of wetlands, GIS technicians made spatial errors by cutting the parcels of landowners in GIS overlay operation.

e) Objection and correction period

Landowners' response

They mentioned the issue of time constraint. For instance, in 5 cases, landowners reported that they were not received during objection and correction period. When they arrived at the office in charge of corrections they were told that they delayed to come on time. The period for corrections and objections was two weeks. It was a very short time and they could not see the land committees for reporting their cases after this period.

Other said that they neither participated nor delegated any person in this period for correction because of their personal reasons. This is indicated by the table below.

Participation in objection and correction	Number
Neither attended nor delegated any person	11
Attended	19
Total	**30**

Table 8: Participation in objection and correction period

Government officials

According to their response, all cases with geospatial mismatches which were not reported in that period had these at title issuance date.

f) Specific causes to officials in all stages

Landowners' response

They reported that the local leaders were present during parcel demarcation. The reason for that was because they were paid.

Government officials

Except top RNRA managers, other RNRA staff said that there was insufficient time to complete their daily tasks. They said they made some errors in all stages because of time constraint. They did the work in a hurry so that by carelessness, fatigue and stress they made errors.

5.4. Identification of improvement in maintenance phase

5.4.1. Legal improvement

According to landowners' responses, the land laws in Rwanda are good but the government should emphasize on giving more explanations so that people could know what the provisions about land registration from these laws are. Also, there should be enforcement of the present applied laws. The local leaders at sector and cell level gave similar response.

According to RNRA and district staff, the absence of surveying law in Rwanda had significant impact on land registration and its results. The land laws applied in the course of demarcation lacked some precisions about standards to be applied in cadastral surveys such as accuracies tolerance, equipment to be used etc. These are in the new enacted surveying law. Their conclusion is that the surveying law should be used, and other land laws should be clearly explained to the landowners. These land laws should be always updated with time and provide enough time for the parcel corrections process.

5.4.2. Technical improvement

Almost all landowners have proposed the following measures for technical improvement in the maintenance phase:

- Introduce new technology that will avoid errors.
- Use qualified and experienced Para surveyors who will be assisted by the qualified surveyors.
- NLC could correct the parcels without referring to deed plans made by private surveyors (Fiche Cadastrale). This is a main constraint for people to request for parcel correction. Its cost is at the moment 42,000RwF (€50) Most of the population cannot afford it. In this case, NLC could put in all sectors a land committee for recording all requests for correction and report to NLC.
- Follow all cadastral processes correctly during parcel correction.

- The parcel correction should be done under PGIS. Specifically, the recorded boundary on orthophoto should be agreed upon by all including landowner, landowners of neighbouring parcels Para surveyor, and local leader.

2 landowners mentioned that private companies could do boundary surveying in lieu of RNRA surveying and mapping department.

The Deputy Director General of RNRA said they will correct parcels when new land transactions occur or all landowners having parcels with problems come and report their cases at RNRA. He said they will use fixed boundary principle as an effective means to avoid the problem of geospatial mismatches. Other RNRA and district staff has suggested the following: the first measure could be the use of new technology that will reduce the steps in boundary mapping process. It should be also affordable, allow local people to participate in the process, and enable the spatial data entry from field when the Para surveyor walks along the parcel boundary. They also suggested the use of well skilled Para surveyors.

5.5. Remarks

Insufficient information about LTR program and understanding of policy, legal and institutional frameworks under which the boundaries are recorded led to minimal participation in the process. The geospatial mismatches were observed as many in overpopulated and unplanned areas while they significantly decreased in the less populated and planned areas of Kigali city. The proposed measure of using fixed boundary seemed to be very interesting as it reflects the opinion of top manager at RNRA department for mapping.

6. DISCUSSIONS

The focus of this section is on 4 issues including understanding of general issues, geospatial mismatches, and causes of geospatial mismatches, improvement measures.

After the results of trial project there were doubts that quick LTR could introduce errors (D. Sagashya et al., 2010).

6.1. General issues of LTR program

This research reveals the majority of landowners do not have the knowledge on policy, laws and other land related regulations. The population indicated that an explanation on these is insufficient.

In public meeting organized by RNRA with local leaders for local people sensitization, the community got explanations on the nature, principles and procedures of land registration. However, the research reveals that half of respondents participated in the public meetings and were informed on the LTR program while another part was not informed. The participation in public meeting in Kigali city for investigated cases was not as expected. These two scenarios are confirmed by the research done by Singirankabo (2011) on land registration in Rwanda who states that the community does not have enough knowledge on LTR program that could encourage them to participate.

According to the findings, there is a fact that systematic land registration did not give tenure security to all landowners because some of them had wrong recorded parcels. This is contrary to its main objective. The figure below shows the difference between the objective of LTR and the results of the program for investigated cases.

In this research, it has been found that 8 over 30 landowners neither attended nor delegated someone to respond on their behalf in parcel demarcation, and 12 over 30 did the same in objections and corrections period. Insufficient knowledge about general issues of LTR is an indirect cause of geospatial mismatches in the process as it affects landowners' participation.

6.2. Geospatial mismatches in the LTR processes

From the results it has been found that all interviewees agreed that geospatial mismatches were in the LTR process. All 30 cases showed geospatial mismatches in the legal documents they had. These indicated that for 17 cases the recorded boundary had a big extent compared to the boundary on the ground (ground reality) and for 13 cases the recorded boundary had a small extent compared to the boundary on ground. It was impossible for GIS unit to discover all geospatial mismatches introduced in boundary surveying. This is highlighted by Lemmens (2011) who states that if errors are in input data they will be in the output data in some form due to error propagation. Most of errors from boundary surveying were not corrected and they appeared in parcel map outputs. The results showed that 11 cases having errors introduced in GIS unit during spatial data post-processing were not corrected because landowners did not report the cases during objections and corrections period.

The research revealed that geospatial mismatches were frequent in the non-planned and overpopulated areas where it was not easy to distinguish the boundaries between parcels on orthophoto. They were few in the planned and rural areas.

6.3. Causes of geospatial mismatches in the LTR processes

a) Technical view of causes of geospatial mismatches in cadastral processes

	Spatial aspect	Textual aspect
Adjudication	• None applicable	Blunders introduced by landowners led to inaccurate identification of attributes of rights holders and types of rights: • Inaccurate identification of name of landholder by landowners in two cases: those who usurped land and those who responded on behalf of others • inaccurate identification of the land rights by landowners like in the previous case
Demarcation	Blunders introduced by: • Para surveyors skipped the boundary demarcation step • Para surveyors partly did boundary demarcation • Local leaders wrongly showed the boundary of absent people • Influential men, orphans who were kids during the 1994 genocide, respondents of absent people, and the people who combined their parcels in one showed wrong boundaries	Blunders introduced by: • Para surveyor assigned wrong number to survey marker
Surveying	Blunders introduced by Parasurveyors: • Inaccurate boundary marking on orthophoto by Para surveyors who give an offset road to landowner • Inaccurate boundary marking by Para surveyors due to carelessness, fatigue, and stress when drawing with pencil and redrawing with pen over the pencil. Random errors due to atmospheric conditions: • Random errors from rain :wet orthophoto caused the shift of line vertex of the boundary Systematic errors introduced by orthophoto: • Inaccurate boundary marking due to difficulties to read the unclear boundary on orthophoto • Inaccurate boundary marking by	• None applicable

	Parasurveyors due to absence of boundary on orthophoto because of changes in the built up environment after orthophoto acquisition in 2008.	
Recording	Blunders errors: • during hands up and onscreen digitization by GIS teams Systematic errors by: • Inaccurate scanned field sheets • Spatial errors introduced by field sheets having errors made in boundary surveying • Wrong digitization introduced by wetlands maps of REMA	• Blunders errors resulting from entering names, numerical calculations and other attribute details

Table 9: Spatial and textual causes of geospatial mismatches

b) Social and other views of causes of geospatial mismatches in cadastral processes

	Social	**Other**
Adjudication	• Minimal participation by land owner due to insufficient or no information on parcel demarcation in their village, and lack of motivation to participate in LTR program	• Insufficient time for recording land rights by land adjudication committee
Demarcation	• Minimal participation by land owner	
surveying	• Insufficient training of some Para surveyors • Minimal awareness of land registration LTR program by some Para surveyors • No compliance with LTR manual by Para surveyors who failed to show the marked boundary to landowners • Corruption by landowners • Conflicts between landowners and Para surveyors • Fatigue, stress because of no balance between work load and time	• Insufficient time for marking boundaries by Para surveyors
Recording	• Fatigue, stress because of no balance between work load and time	• Insufficient time for boundaries digital records by GIS technicians teams

Table 10: Social, time and other causes of geospatial mismatches

From the results, it has been found that geospatial mismatches had three causes from technical view to social and other views: Spatial errors(spatial aspect) and textual error(textual aspect) in the 4 cadastral processes were caused by blunders errors, systematic errors, and random errors.

During spatial data acquisition and processing, Lemmens (2011) affirms that errors come from three sources including systematic errors (imperfections of measuring instrument), random errors(observing procedures or the environment in which the measurement instrument operates), and blunders(the

surveyor). In the study area, the scenario above confirms the same: According the results there were cases of geospatial mismatches caused the Para surveyors who did not mark the boundary on orthophoto correctly; cases caused by unclear boundary on orthophoto and Para surveyors could not distinguish the boundaries; cases caused by carelessness and human imperfections, and cases caused by atmospheric conditions as reported by RNRA staff. All errors in GIS unit were caused by operators' carelessness. Also most of errors made in surveying propagated in output maps without being detected. About the data acquisition method, Lemmens (2011) states that analogue data acquisition using map, pen and paper in the field are becoming obsolete while Milindi Rugema (2011) in his research said that many steps lead to errors. The use of orthophoto in Rwanda was an innovation but the applied techniques provided analogue data in boundary surveying. Referring to LTR activities, they were also many steps in the process. Though one part of the process was done under analogue method and the other digitally, the technical sources of errors as mentioned here are partly caused by this analogue method and many steps.

Other causes are discussed as follows:
The research mentioned the local government as the provider of project information (Section5.1.2). It has been found that the information did not reach the population as much as possible and elucidated their role in the project. Considering people participation in the program, some landowners neither participated in the parcel demarcation nor delegated someone to respond for them. The same problem was observed in objections and corrections period.

The RNRA staff reported that the time was short for Para surveyors and staff in GIS unit to complete their daily assigned tasks. Also, the time was short for objections when the first results were published. 5 landowners reported they were not received within this period.

There was also the problem of Para surveyors who were not enough trained. Because of that issue, at the beginning they did not take care of their role in LTR program and made errors. As the process went on they become aware of their tasks and role in LTR. It is not easy to say the exact number of parcels that have been demarcated by less skilled Para surveyors but this issue was mentioned by all interviewees.

The Government of Rwanda (2012) in LTR operations manual states that the Para surveyor should show the marked boundary on othophoto to all people present in parcel demarcation of any landowner but this rule has been violated. 20 landowners said that they were not shown the surveyed parcel on orthophoto. Normally this rule is intended to avoid spatial mismatching in the process.

There was only one case reported about conflict between the Para surveyor and the landowner in which the boundary was not recorded properly. No case of corruption in parcel demarcation was reported though it was mentioned that it took place in other parts of Kigali city at the beginning of LTR program.

6.4. Legal and technical measures for improvement

Landowners and local leaders suggested that the government should give more explanations about land legislation in Rwanda. In addition, RNRA and district staff said existing land legislation should be updated for clarifying land issues like land registration. They also said surveying law should be applied to help in maintenance phase. All respondents confirmed that the time for the LTR process was short and they advised that the time for correction in maintenance phase could be provided by the law and be enough.

In cadastral maps upgrading, the technology to be used should reduce time and cost of cadastral data acquisition(Ali, Tuladhar, & Zevenbergen, 2012). Today advances in technology allows efficiency and cost cutting in data acquisition. There exist methods such as mobile GIS for getting and transmitting digital

data directly to a laptop, tablet PC or smartphone via internet. Office and field workers can then view, use and update the data(Lemmens, 2011). In line with the statements above, this research has also suggested the use of a modern and affordable technology which will allow spatial data entry electronically and reduce errors and steps of the process. Other technical measures for overcoming geospatial mismatches from all interviewees include: use of skilled staff; doing this activity under PGIS by following correctly all cadastral processes in spatial data acquisition. Another important suggestion from the deputy director general is the adoption of fixed boundary principle during maintenance phase. Also 2 landowners gave the idea of giving surveying activities to private surveyors which will be supervised by RNRA staff.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. conclusions

7.1.1. Sub objective 1

The first sub objective is to describe the policy, legal and institutional frameworks under which boundaries are adjudicated, demarcated, surveyed and recorded. To achieve this objective, 2 research questions were formulated.

Q1: What is the policy and legal institutional frameworks under which boundaries are adjudicated, demarcated, surveyed and recorded?

The policy and legal framework includes: The 2005 land policy, the 2004 land law and its associated land regulations (decrees and orders). The details are given in sections 3.5.2

The organizational framework consists of Ministry of Natural Resources, National Land Commission, Rwanda Natural Resources Authority and Office of Registrar of Lands Titles, Department of Lands and Mapping(Former National Land Centre), District Land Commissions, Zonal offices, District Land offices, and Cell and sector Land Committees. The details are in 3.5.1

Q2: What are the objectives, guiding principles and stages of systematic land adjudication in Rwanda?

The LTR was launched to conduct the systematic land registration in Rwanda. Its main objective is to clarify the existing land rights over land and, where required, convert those rights into legally recognized rights. The guiding principles consist of the public and open process, establishing rights to land, a transparent mechanism for resolving disputes, land tenure security in urban areas and rural area as well, just administration, and replicable program, speed and accuracy. All these principles were designed for the success of the systematic land registration program. The stages of the process include the following: notification of areas for the LTR program, local information campaign, training of Para surveyors and adjudication committees, 4 cadastral processes (demarcation, surveying, adjudication, and recording), objections and corrections, mediation for land disputes, registration and titling.

7.1.2. Sub objective 2

The second sub objective is to determine the spatial nature of geospatial mismatches in the boundary mapping under LTR program. Question 3 was posed to identify the nature, extent and number of geospatial mismatches in the process.

Q3: What are the spatial nature, extent and number of geospatial mismatches in boundary surveying and recording in LTR program?

This is the spatial difference between the reality on the ground and the recorded boundary. Details are in section 6.2

In terms of space and number, they are frequent in non-planned and densely populated areas of Kigali city. Their number decreases significantly in planned and less inhabited areas. The details are in section 6.2

7.1.3. Sub objective 3

Identify the sources of geospatial mismatches appearing in the process from field surveying to spatial data post processing stages. This sub objective is achieved through research questions 4 and 5.

Q4: What are the sources of geospatial mismatches from technical perspective at parcel demarcation and spatial data post processing stages?

In the study area, the types of errors observed included blunders introduced by staff, systematic errors introduced by inaccurate orthophoto, and random errors introduced by the environment. Those errors led to geospatial mismatches in the process. Details are in section 6.3

Q5: What are the sources of geospatial mismatches from social and other views due to no compliance with land regulations (land law, decrees)?
The identified causes comprise inadequate knowledge about LTR by landowners leading to minimal motivation to participate, minimal landowner participation in boundary demarcation and objections and corrections period, insufficient skills of Para surveyors, violation of LTR regulations by Para surveyors in parcel demarcation and insufficient time to finish the daily tasks assigned to technicians and Para surveyors. The details are given in section 6.3

7.1.4. Sub objective 4

The fourth sub objective is to propose legal and technical measures that can be adopted for overcoming geospatial mismatches under the maintenance phase. Research questions 6 helped to achieve this sub objective.

Q6: What can be done legally and technically to avoid geospatial mismatches under the maintenance phase?
The respondents confirmed that the time for the LTR process was short and they suggested that the time for correction in maintenance phase could be provided by the law and be enough.

They suggested technical measures including use of new and affordable technology which will avoid errors use of skilled staff, and adoption of fixed boundary for parcel correction. The details are in section 6.4

7.1.5. Main conclusion

With the establishment of land administration in Rwanda, the conventional way of spatial data acquisition was not adopted. Rwanda decided to use an innovative approach for boundary mapping. The parcel boundaries were surveyed with orthophotos. The program was faster, low-cost but has introduced a series of geospatial mismatches having impact on landowners' tenure security and its related benefits.

The overall objective was to examine the nature, extent, number and causes of geospatial mismatches in land adjudication process in Kigali city. Using the case study to do the research, this object has been achieved.

The results showed that geospatial mismatch is the difference between the ground reality and the recorded boundary. It has been found that geospatial mismatches are many in dense and unplanned areas in which land use changes appeared after orthophoto acquisition. Their number decreases significantly in less populated and planned areas where it was easy to distinguish the boundary on orthophoto and where a lot changes in the land use did not occur after orthophoto acquisition in 2008.

According to this research, the causes of geospatial mismatches in LTR processes included blunders errors, systematic errors and random errors.

7.2. Recommendations

Further studies could be done to see how to fix the problem of geospatial mismatches at lowest cost with improved accuracy of the recorded boundary.

Since some landowners fear to lose their land rights, Gasabo district could consider geospatial mismatches as a serious issue during land expropriation and pay fair land costs in order to keep landowners trust in the state.

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LIST OF APPENDICES

APPENDIX 1

Geospatial mismatches of investigated cases

Extent / Parcel ID	Ground Sqm	RNRA map Sqm	Spatial difference= Ground- RNRA	Sector
3453	156	480	324	Gisozi
1263	229.807	1,247	1,017	Gisozi
2027	2,000	2,647	647	Gisozi
394	425	279	-146	Gatsata
651	278.309	1,737	1,458.7	Gatsata
2381	2,500	3684	1,184	Gisozi
570	866.962	972	105	Kimironko
949	888.081	936	48	yes
476	1,676.114	1,767	91	Kimihurura
498	750	450	300	Kimironko
143	813	1,102	289	Kimironko
1423	894.853	847	-47.8	Kimironko
1671	652	2429	1777	Gatsata
3700	786.649	601	-185.65	Kimironko
2926	700	1500	800	Kimironko
1160	3,200	2,900	300	Ndera
2166	4216	1216	-3000	Kinyinya
117	689	1,020	331	Bumbogo
330	195.585	275	79.42	Remera
831	797.740	873	75.3	Kimironko
3285	357.206	363	5.8	Kimironko
2950	841.598	858	16.41	Kimironko
3915	883.690	945	61.31	Kimironko
267	831.335	718	-113.3	Kinyinya
4336	603	532	-71	Kinyinya
4068	8736			Kinyinya
2655	3,107.493	3,048	-59.5	Kinyinya
2656	786.033	768	-18	Kinyinya
628	524	410	-114	Remera
2321	628.57	645	-16.43	Ndera

APPENDIX 2

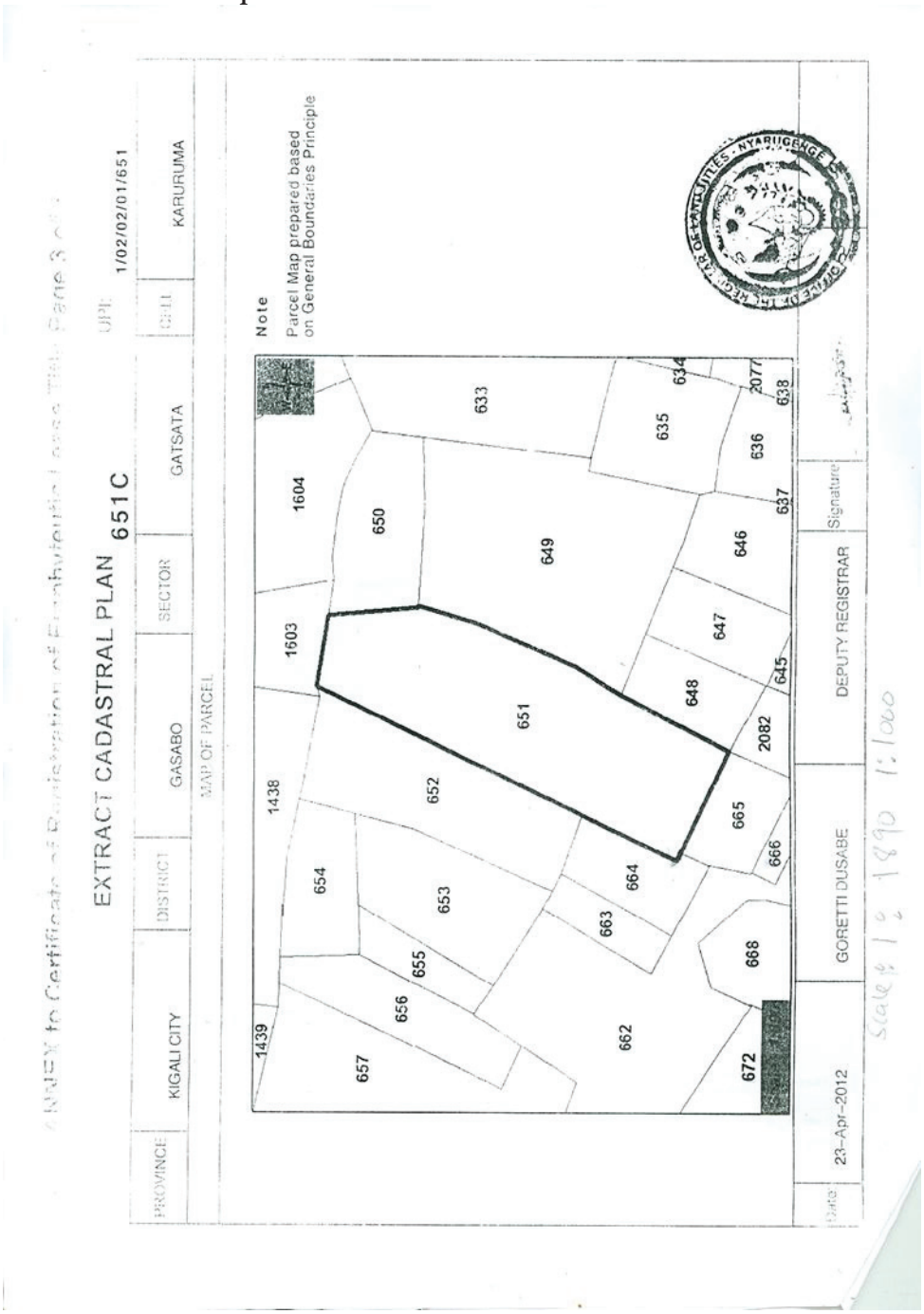
Report on parcels with geospatial mismatches in Gasabo district by October 2012

District	Rural sector	Number	Urban sector	Number
Gasabo	Bumbogo	9	Gisozi	28
	Gikomero	0	Gatsata	25
	Jabana	7	Kacyiru	5
	Jari	1	Kimihurura	6
	Ndera	12	Kimironko	20
	Nduba	1	Kinyinya	15
	Rutunga	0	Remera	13
	Rusororo	16		
Sub total	46		112	
Total	**158**			

Table 11: Parcels with geospatial mismatches

APPENDIX 3

Extract of cadastral plan



APPENDIX 4

Authorization for doing research

REPUBLIC OF RWANDA

Gasabo, 24/10/2012
Réf. N°...3560/07.02/2012

CITY OF KIGALI
GASABO DISTRICT
www.gasabo.gov.rw
E-mail: info@gasabo.gov.rw
B.P: 7066 KIGALI

Mr HAGUMA Jean de Dieu
C/o KIST
Tel: 0783592889

Re: Response regarding to your request

Dear Sir,

With reference to your letter dated on 10th October 2012 which ask autorisation of doing your reseach in Gasabo District,

After considering your request, we would like to inform you that we agree to help you to conduct your reseach, we will facilitate you in order to achieve your gools.

We also ensure you that after conducting your reseach the out put will be helpfull.

Yours sincerely

NDIZEYE K.Willy
Mayor of Gasabo District