TECHNICAL GUIDELINES ON DEVELOPMENT AND APPLICATION OF OPEN-SOURCE TOOLS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AA-CADI	Addis Ababa Cadastre Information System
ADR	Alternative Dispute Resolution
AI	Artificial Intelligence
AMANDA	Advanced Maryland Automatic Network Disk Archiver
Angular JS	Angular JavaScript
API	Application Programming Interface
ASP.NET	Active Server Pages Network
AU	African Union
AutoCAD	Automatic Computer-Aided Design
BMZ	Federal Ministry of Economic Cooperation and Development
C#	C-Sharp
CADASTA	Cadastre
CCO	Certificate of Customary Ownership
CELAIS	Central Land Administration Information System
CO	Certificate of Occupancy
COTS	Customer of the shelf software
CRISP	Cadastre Register Inventory Saving Paper
CRPRS	Cadaster and Real Property Registration System
CSS	Cascading Style Sheets
DB	Database
DFID	Department for International Development
DSDM	Dynamic Systems Development Method
EAC	East African Community
ECMA	European Computer Manufacturers Association
ELADM	Ethiopian Land Administration Domain Model
ESRI	Environmental Systems Research Institute
FAO	Food Agricultural Organisation
FDD	Frequency Division Duplexing
FIG	International Federation of Surveyors
FIG	International Federation of Surveyors
FLOSS	Free open-source software
FRF	Frequency Response Function

GDAL	Geospatial Data Abstraction Library
GEO ODK	Geographical Open Data Kit
GEOFIT	Donnons du pouvoir à vos données
GEWE	Gender Equality and Women Empowerment
GIMP	GNU Image Manipulation Program
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft für Internationale Zusam- menarbeit
GLTN	Global Land Tool Network
GNU	Gnu's Not Unix
GPS	Global Positioning System
GUI	Graphic User Interfaces
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
ICT	Information Communications Technology
ID	Identification Card
IEC	Information Education and Communication
IGAD	Intergovernmental Authority for Development
IGN FI	National Institute for Geographic and Forest Information
IIS	Internet Information Server
INSA	Information Network Security Agency
IOS	i-Phone operating system
ISO	International Organization for Standardization
IT	Information Technology
IT	Information Technology
ITC	Information Technology and Communication
ITC	International Institute for Geo-information Science and Earth Observation
JAVA	Just Another Virtual Accelerator
JPEG	Joint Photographic Experts Group
JRJ	Job Record Jacket
LADM	Land Administration Domain Model
LIDAR	Light Detection and Ranging
LIS	Land Information System
MASSREG	Mass Registration
MATLAB	Matlab Laboratory
MLHUD	Ministry of Lands Housing and Urban Development

MoLPP	Ministry of Land and Physical Planning
MOU	Memorandums of Understanding
MP3	MPEG Audio Layer 3
MPEG	Moving Picture Experts Group
MUDI	Ministry of Urban Development and Infrastructure
MVP	Minimum Valuable Product
MVP	Minimum Valuable Product
MySQL	My Structured Query Language
NGO	Non-governmental organizations
NLC	National Land Commission
NLIS	National Land Information System
Node.js	Node JavaScript
ntp	Network Time Protocol
NVU	New View Computing
OGC	Open Geospatial Consortium
OGR	OpenGIS Simple Features Reference Implementation
OpenPAM	Open Pluggable Authentication Module
OpenVPN	Open Virtual Private Network
OSG	Open-source GIS software
OSI	Open-Source Initiative
PDF	Portable Document Format
Perl	Practical Extraction and Report Language
PgAdmin	Program Administrator
PHP	Hypertext Preprocessor
PWDs	People with Disables
QGIS	Quantum GIS
RCMRD	Regional Centre for Mapping of Resources for Development
REGLAIS	Regional Land Administration Information System
RRR	Right, Restriction and Responsibility
RTK	Real Time Kinematic
SCA	Software Composition Analysis
SDLC	Software Development Life Cycle
SIDA	Swedish International Development Cooperation Agency
SLAAC	Systematic Land Adjudication and Certification
SLLC	Second-Level Land Certification

SOAP	Simple Object Access Protocol
SOLA	Software for Land Administration
SOW	Scope of Work
SOW	Scope of Work
SQL	Structured Query Language
STDM	Social Tenure Domain Model
TCL	Transaction Control Language
ToT	Trainers of Trainers
UgNLIS	Uganda National Land Information System
UML	Unified Modeling Language
UN	United Nations
UNHABITAT	United Nations Human Settlement Program
UTM	Universal Transverse Mercator
UX	User Experience
VGGT	Voluntary Guidelines for Responsible Governance of Tenure
VLC	VideoLAN (Local Area Network) Client
WCS	Windows Communication Foundation
WFS	Web Feature Service
WGS	World Geodetic System
WMS	Web Map Service
WORLAIS	Woreda Land Administration Information System
XML	Extensible Markup Language
XP	eXperience
ZOA	South East Asia
ZONLAIS	Zonal Land Administration Information System

FOREWORD

Different IGAD member states have had varying degrees of success in developing and deploying open-source tools for land administration. Some countries like Uganda and Ethiopia have had a lot of experience in the development and application of these tools as compared to newer countries like South Sudan. Other member states that are in the process of developing and applying such tools can learn a lot from the experiences of Uganda and Ethiopia. This technical guide is to assist such countries as it documents the experiences of these countries and details the practical steps and approaches for the development and application of open-source tools in land administration. It further provides an overview of good practices that exist in the IGAD region on the development and application of open-source tools in land administration.

EXECUTIVE SUMMARY

The use of Open-source software has gained a lot of attention in the world and is slowly replacing the use of proprietary software. There has been an advancement in the development of open-source software. Due to the development of spatial extensions, PostgreSQL and MySQL database solutions have become more capable of handling cadastral datasets. For a long time, open-source software was unable to compare with proprietary software in vector editing, a thing that has seen significant development in the recent past. The existing open-source products had majorly focussed on raster other than vector editing. Open-source software products are normally not known to normal GIS users but to developers because they are not marketed as proprietary software. In countries that are just developing their land administration systems, the license and maintenance costs of proprietary software are not sustainable. In addition, open-source software such as PostgreSQL and MySQL are easier and faster to install and require less hard disk space than Oracle.

It has been observed that innovations in land reform and land administration adapted to current conditions are being attempted in some countries in sub-Saharan Africa. However, insufficient innovative tools exist to deliver affordable security of tenure and property rights at scale for most of Africa's populations. It was proposed that new tools need to be developed, but these are not simple and easy to produce, or easily adapted to the diverse needs of various countries including those in the IGAD region.

There has been motivation to promote the use of open-source software and related tools for cadastre and land registration due to the fact that many systems and projects in developing countries struggle to provide appropriate and affordable services for tenure security. Reasons are related to governance but also technological and financial shortcomings. Information technology plays a crucial role in operating cadastres and land registration systems. In developing countries, the ongoing license costs of proprietary software often created serious constraints and have even stopped programs.

The main goal of the technical guide is to provide practical steps for the development and application of open-source tools in land administration. It is also hoped that with the use and improvement of open-source software and tools, cadastres can build local knowledge and contribute to the development of open-source projects.

Specifically, the guidelines are developed to;

1. Provide an overview of good practices that exist in the IGAD region on the development and application of open-source tools in land administration.
2. Facilitate a more informed approach to the development and application of open-source tools in land administration that can be used by Governments at various levels, the private sector, and Non-Governmental Organisations (NGOs).
3. Facilitate the adoption of appropriate Open-Source tools in the IGAD region.
4. Inform the sustainability of developed open-source tools in land administration over a long period at the country level.

The methodology adopted was majorly to run a successful hackathon on the development of these technical guide following the subsequent steps;

1. **Defining the Issue**. There was a clear definition of the issue and an agreement was made on the most appropriate solutions. This first step was done by a small number of people who took the initiative to think it through.
2. **Constituting Advancers' Team**. The Advancers' team provided initial ideas for the solutions to the problem/issue. These were internal and external teams with experience and expertise in the relevant area/issue. The document developed acted as the "Hacker's trigger" providing a roadmap for the hackathons to build on.
3. **Constituting the Hackathons Team**. The team had a good blend of diversity, member state representations, and professional and stakeholder diversity.
4. **Planning the Hackathon Meeting**. The hackathon was planned and held with the different experts in the field of development and application of open-source tools in land administration.
5. **Facilitation**. The hackathon meeting was guided by the facilitator who gave guidance during the meeting. Facilitation notes and questions were developed beforehand and were based on the key areas /components required to have the full draft document.
6. **Output**. A clear output was developed which has been improved into this final draft document.
7. **Validation**. The refined draft will be subjected to validation and developed into the final technical guide. It should, however, be noted that the final guide will be a living document which will continuously be updated with newer experiences in the IGAD region regarding the development and application of open-source tools in land administration.

The key lessons learned from the development and application of the open-source tool in land management include;

1. Mobilization and sensitization using various approaches are critical in the campaign to successfully develop and implement open-source tools in land administration. The political and technical have to be mobilized to support the implementation. Political leaders should be ready and willing to create a conducive environment for the implementation of open-source tools. They should approve or make provisions for the implementation of new provisions fast as they provide for legal reforms to support the implementation. The technology should be ready to relearn some aspects of land administration using open-source tools.
2. The technology used should be appropriate, customizable and suit the practices of different countries in relation to land. The technology is divided into two; the system of land administration and the data collection open-source tools. There should be compatibility especially when many open-source data collection tools are used. A standard of data collected should be developed such that the customization of the open-source tools is based on this standard to avoid conflict in collected data.
3. It is a good practice to involve key stakeholders in the development and application process. The different stakeholders provide the technical support required when developing and applying open-source tools.
4. Working groups should be established to support the development and application of open-source tools. These are dedicated teams which work long hours and are observed to increase productivity.
5. The processes should be transparent to encourage participation. The process should also be participatory to encourage ownership by the local leaders and communities.
6. It is encouraged to use the Agile development approach compared to the waterfall model. The Agile model is encouraged because it is faster as you are not required to first wait for a particular stage to be completed before one moves on to the next.
7. It is critical to building capacity internally during the development and implementation of open-source tools. This promotes the sustainability of the tool.
8. The development process should be done in the IGAD country. It has been observed on different projects for the development to be done out of the country. This limits the transfer of skills to the local stakeholders.
9. If possible, the development should be done in connection with local consulting firms in a country.
10. The development and application process should be backstopped by an international organization (s)

It is recommended that when the development and application of open-source tools is to be done, the following considerations should be completed.

1. An assessment should be done of the existing open-source tools in a country before deciding whether develop their tool.
2. It should be noted that when a country has a national land information system, flexibility in the development of open-source tools is limited because the development is supposed to meet the data exchange format of the system.
3. Open-source tools developed should be consistent. A data exchange format should be determined on which the open-source tools should be based.
4. It is advised to develop the legal framework before the development of the conceptual, logical and physical models of the open-source tools. When a guide is available, the legal provisions can be done before development, however, provisions should be made to modify the law after the development of the open source.
5. An assessment should be done to determine which open-source tool is most suited for a particular country.
6. A financial assessment should be performed to determine whether to use a proprietary or open-source tool.
7. It is highly recommended that when the open-source tools are developed, a pilot phase important for testing efficiency.
8. The developed open-source tool should follow the standard requirements of cadastral mapping in the IGAD country as required by the mapping agency and the National Land Information System.
9. The development of the open-source tools should be customized to collect gender and sex land data provided for in the land regulations of the respective IGAD country, and in line with regional, continental and global frameworks

1.0 INTRODUCTION

The use of Open-source software has gained a lot of attention in the world and is slowly replacing the use of proprietary software (Bhatta, 2009; Pieper, 2008). There has been an advancement in the development of open-source software. Due to the development of spatial extensions, PostgreSQL and MySQL database solutions have become more capable of handling cadastral datasets. For a long time, open-source software was unable to compare with proprietary software in vector editing, a thing that has seen significant development in the recent past. The existing

open-source products had majorly focused on raster other than vector editing. Open-source software products are normally not known to normal GIS users but are well known among developers because they are not advertised as proprietary software. In countries that are still developing their land administration systems, the costs associated with licensing and maintaining proprietary software are not sustainable. In addition, open-source software e.g., PostgreSQL and MySQL are easier and faster to install and take up less hard drive space as compared to Oracle.

Different countries are developing and using open-source land administration software. The open-source tools have mostly been deployed in developing countries such as Nigeria, Namibia, Ethiopia, Uganda, Kenya, Mongolia, Philippines and Lao to mention but a few. These tools have essentially been funded by the world bank, BMZ, the European Union, the Ministry of foreign affairs of the Kingdom of Netherlands etc. The tools have been developed and deployed by international agencies which include the United Nations Food and Agriculture Organisation (UN-FAO), GIZ, ZOA, United Nations Human Settlement Program (UN-Habitat), Global Land Tool Network (GLTN) and the United States of America.Among the tools that have been developed include; Software for Land Administration (SOLA) Open Tenure, Social Tenure Domain Model (STDM), Cadastre Register Inventory Saving Paper (CRISP), Systematic Land Adjudication and Certification (SLAAC), CADASTA, Uganda National Land Information System (UgNLIS), 1.5.1.1, National Rural Land Administration Information System (NRLAIS), and Ardhisasa. These open-source tools have two major components: the data collection and a database for storing and editing land information. PostgreSQL and MySQL are the open-source databases on which most of these technologies are built.

1.1 Background

Land administration and cadastral systems are playing a crucial macro-economic role in the collection, documentation, management, and dissemination of information about land ownership, use and value (Apostolopoulos & Potsiou, 2022; Bhatta, 2009; Koeva et al., 2021; Pieper, 2008). Modern cadastral systems make extensive use of information technology (IT) supported by software systems. In developed countries, such systems were built over the past 20-30 years and have now become powerful tools in managing cadastral information. In developing and transitional countries especially those in the IGAD Region, the need for efficient cadastral systems and the use of IT to effectively manage their land records is as much a necessity as it is in developed countries, although there are substantial financial and operational constraints.

It has been observed that some Sub-Saharan African countries are attempting to implement innovations in land reform and land administration that are tailored to current conditions. However, there are insufficient innovative tools available to provide affordable security of tenure and property rights at scale to the majority of Africa's populations. It was proposed that new tools need to be developed however, these are not easy to make, adapt, or meet the unique needs of many nations, especially those in the IGAD Region.

There has been motivation to promote the use of open-source software and related tools for cadastre and land registration based on the observation that many systems and projects in developing countries struggle to provide appropriate and affordable services for tenure security (Bhatta, 2009; Enemark, S., Clifford Bell, K., Lemmen, C., & McLaren, 2014; Musinguzi et al., 2021; UNHABITAT, 2016). The causes include governance issues as well as financial and technological inadequacies. Information technology plays a crucial role in operating cadastres and land registration systems. In developing countries, the ongoing license costs of proprietary software have often created serious constraints, even leading to the cancellation of programs.

To improve the situation, innovative approaches, affordable and efficient tools tailored to the needs of Africa should be developed. However, experience has shown that developing such tools is not always an easy task since, in certain instances, ad hoc approaches based on the need for immediate results take precedence and system development is sometimes driven by suppliers rather than by customer needs.

The costs of proprietary software licenses and related tools have proved to be a constraint, but even more so, the lack of resources, models, and support for software development have stymied or terminated the initiatives (Bhatta, 2009; Pieper, 2008). Open-source software and related technologies have proved to be a credible substitute to proprietary software and related tools and are more flexible and adaptable to local conditions and languages. Cadastres can leverage local expertise and contribute to the creation of open-source initiatives that can subsequently help other cadastres in the IGAD Region.

It is important to explore and develop an understanding of open-source software and related technologies in general, as well as in the fields of cadastre and land registration in order to come up with recommendations on the use of open-source products(Bhatta, 2009; Musinguzi et al., 2021; Oput, 2019; Pieper, 2008).

It is necessary to have a balance between the different technological approaches for the innovative approaches to the system design. The use of different technologies such as different surveying

technology or approach to the system design (such as free open-source software (FLOSS) or customer-of-the-shelf software (COTS) etc.) should be carefully considered from the maintenance, license payment, system security and local capacity points of view to ensure the systems are operational. The information system maintenance for some period after the project end should ideally be part of any system design.

1.2 Objectives of the Technical Guide

The main objective of the technical guide is to provide practical steps for the development and application of open-source tools in land administration. It is also hoped that with the use and improvement of open-source software and tools, cadastres can build local knowledge and contribute to the development of open-source projects.

The specific objectives are;

1. To provide an overview of good practices that exist in the IGAD region on the development and application of open-source tools in land administration.
2. To facilitate a more informed approach for the development and application of open-source tools in land administration that can be used by Governments at various levels, the private sector, and Non-Governmental Organisations (NGOs).
3. To facilitate the adoption of appropriate Open-Source tools in the IGAD region.
4. To inform the sustainability of developed open-source tools in land administration over a long period at the country level.

1.3 Scope of the Technical Guide

The technical guide has been developed purposely for the development and application of open-source tools in land administration in IGAD Countries. It is designed to guide various stakeholders in different member states on how to develop and apply open-source tools in land administration. The guide is further designed to mitigate the challenges that are likely to be encountered and to enhance smooth implementation at all levels. Considering that many stakeholders from government, civil society and the private sector will be involved at various stages in different member states, the guide provides uniform standards to ensure harmony and consistency in the processes and products.

The information herein draws from the existing legal frameworks and previous experience in the development and application of open-source tools in the IGAD member states. In addition, benchmarking has been done in other countries with in the continent; Nigeria, Lesotho, Ethiopia, Rwanda and Internationally; Nepal, Cambodia, Samoa, Tonga, Laos and the Philippines to develop the best practices.

The primary audience for the technical guide includes IGAD member states, respective local governments, political leaders, civil society organizations, consulting firms, the beneficiary communities and the public at large. Users of this guide are expected to refer to its provisions for guidance and information. The information in the guide will be revised from time to time to incorporate pertinent lessons in the subsequent development and application of open-source tools in the different IGAD member states.

1.4 Open-source tools in land administration

1.4.1 The Concept of open-source tools

Open-source tool refers to any software program with accessible source code that anyone can modify, distribute, and use without any legal restrictions. Open-source software may be free or available at a small charge. For example, Apache is freely available but Apache 2.0 is at a small charge. Because the source code is available to anyone, users can suggest improvements, report bugs, and contribute code to the project. This collaborative approach can lead to rapid development and improvement of the software.

Open-source tools are often used in software development, where they can provide a cost-effective and customizable alternative to proprietary software. Examples of popular open-source tools include the Apache web server, and the MySQL database management system. There are also many open-source programming languages, such as Python, Java, and Ruby, which are widely used in software development.

Volunteers in the global community continue to develop these tools with charity funds driven by the desire to make the world a better place. The development of open-source tools has focused on improving accessibility, improving ease of use and advancing the required improved technology in handling land data. A deliberate effort has been made to make the open source-based databases to be secure such that land records are protected.

1.4.2 Comparison of open source and proprietary tools

Open-source tools are technologically agile with the ability to solve technical problems in several ways. These tools avoid a situation where project work stalls because a particular functionality is not available from a vendor. In a situation when proprietary software is used, waiting is done for the vendor to solve the technical problem and deliver the functionality(Bhatta, 2009). This slows down the project's progress because proprietary software developers are a small team which is most likely overwhelmed with requests for technical assistance from a global market. In addition, it is not uncommon to spend days or weeks negotiating the terms and conditions of provision of the support from the vendors. This support usually has to be financed yet funds may not be readily available, especially in developing countries. Furthermore, allowing troubleshooting the glitches in the software builds better the skills of the trained personnel when every technical issue is solved by the vendors.

Open-source tools provide speed in the delivery of solutions (Pieper, 2008). Speed is achieved by taking community versions of the solutions to technical glitches. These options can be reviewed and compared immediately and after comprehension applied to the problem, this enables getting a solution fast enough and hence delivery made right away. Also, professional support and services have become increasingly available for open-source tools. Open-source tools are generally more cost-effective than proprietary software. This enables us to start small given the budget challenges when developing such tools in Africa, a budget that may not be available as is with the large parastatals. With open-source tools, it is possible to start quickly with community versions, having the opportunity to try different alternatives or versions and pick the one that will work in a given context.

Even though proprietary or commercial software has very solid security of information, the open-source community and vendors have responded very well to security information problems. In dealing with open-source tools, the availability of the code to a larger community enables faster identification and fixing of problems compared to commercial software that conceals the code and hence the problems in the code take longer to get fixed. Open-source tools promote talent because developers are allowed to experiment and interact with other developers globally. Open-source tools also are based on shared maintenance costs due to heavy community involvement. Instead of writing an application yourself and supporting it alone, the costs of maintenance and sustenance are shared among multiple parties(Oput, 2019). Open-source is the future, web, mobile, and cloud solutions are being predominantly built based on open-source infrastructure.

Some data and analytic solutions are available only in the open-source environment. Therefore, open source is a very good investment in the future.

There are so many open-source alternatives for the existing proprietary software which are equivalent or more reliable, secure and flexible, see Table 1

Table 1: Common existing proprietary software and existing open-source equivalents

Software Category	Proprietary Software	Equivalent free open-source software or tools.
Operating system	Microsoft Windows	Linux Ubuntu
Browser	Internet Explorer	Mozilla Firefox
Office automation	Microsoft Office	Open Office
MathWorks	MATLAB	Sci Lab
Graphics Tool	Adobe Photoshop	GIMP (GNU Image Manipulation program)
Drafting tool	AutoCAD	Archimedes
Web Editors	Adobe Dreamweaver	NVU
Desktop Publishing	Adobe Acrobat	PDF Creator
Blogs	Blogger	WordPress
Mobile	IOS	Android
Media Player	Windows Media Player	VLC Player
Databases	Oracle, Microsoft SQL Server	My SQL. Mongo DB, HADOOP
Server	Microsoft Windows Server	Red Hat Server[1], Ubuntu Server
Web Server	IIS	Apache

1.4.3 Importance of open-source tools

The reasons why open-source technology would be preferred to proprietary software include;

1. Open-source software can be installed free of charge on many nodes as needed. This provides flexibility which may not be the case with proprietary software.
2. The costs incurred on Open-source software are minimum and users can modify the software to the required specifications.
3. In open-source technology, source code and translation tools are readily available.

[1] Open source but not free

4. Open-source software is developed and managed by a distributed community of developers. This makes support when faced with technical issues readily available.
5. Open-source software provides stable and community-driven development processes.
6. Open-source software has been observed to be high quality and economical (i.e., Speed and Stability).
7. Open-source software has been noted to be secure and has high modularity. The user is not locked to one shell or Graphical User Interface (GUI).
8. Many developers benefit by starting with open-source software and then tweaking it to suit their needs. Since the code is open, it's simply a matter of modifying it to add the functionality they want.
9. Users are empowered to fix and debug the software themselves instead of simply operating it.
10. The Free Software Foundation enables users to run the software as they want.
11. People in the open-source community come forward to find solutions, assist each other, and share extensions that would benefit the masses. This implies that the source code is available for anyone who wishes to study it, analyse it, and modify it in any way. Thanks to this feature people can easily extend the code and add specific functionalities as per their requirements.

1.4.4 Challenges or risks of open-source software

Open-source software and tools have all the strengths listed in section 1.4.3, but this does not mean they are without challenges or risks. Is open-source software and tools a security risk? There are still questions about how open-source software should be managed. A number of challenges and risks associated with open source include;

1. Open-source components are not created equal. Some are vulnerable from the start, while others go bad over time.
2. Usage has become more complex. With tens of billions of downloads, it’s increasingly difficult to manage libraries and direct dependencies.
3. Transitive dependencies: if you are using dependency management tools like Maven (Java), Bower (JavaScript), Bundler (Ruby), etc., then you are automatically pulling in third-party dependencies – a liability that you can’t afford. This will happen if the licensing of open-source software is not carefully examined.

4. In 2018, across billions of open-source component release downloads, 1 in 10 open-source components had known security vulnerabilities (10.3%). 51% of JavaScript package downloads contained known security vulnerabilities and a 71% increase in confirmed or suspected open source-related breaches since 2014.

1.4.5 Risk mitigation for Open-Source software

1. The licensing of open-source software should be carefully assessed. This is because some open-source software and tools may start as open source but they could become commercial.
2. Build internal capacity to support the operation and maintenance of open-source software.
3. Proper planning of execution of the tasks when open-source software or tools are used.

1.4.6 Challenges or risks of proprietary software

Discussed here are the challenges of proprietary software or tools which would cause recommendations for open-source software or tools. These include and are not limited to;

1. **Not many customization options**. Since this proprietary software is developed for a specific kind of industry and audience, it gets difficult to customize it to fit the exact needs of the people. Users are not building their system so it's obvious that they will have limited flexibility options.
2. **Portability is beyond the bounds of possibility**. Users don't have the option to extract data and files out of their system with a proprietary solution. They are quite restricted to performing certain functionalities.
3. **You don't have any option other than trusting the company blindly**. Since the company owns the platform and the storage space, you'll have to manifest a lot of trust in your vendor. They will have to continuously develop and refine their software, to handle their consumers' needs better. The vendor should also be within reach whenever you need assistance with the software. Several vendors don't upgrade their platforms, so it's better to do a bit of research first and then jump onto doing business with a vendor.
4. **You are just renting software.** Even if you have bought the proprietary software, you won't own the code it's built with. It is not yours and hence requires a monthly rent from you, to keep the software or tool running.
5. **The scale-up with proprietary software is a challenge.** The development of additional modules in the tool has a high-cost implication compared to when open-source software and tools are used.

1.5 Early efforts on open-source tools in land administration

Open-source tools in land administration are relatively new, and their adoption has been slow. However, there have been some early efforts to develop open-source tools in this area. One of the earliest examples is the Cadasta platform, which was launched in 2015. Cadasta is a platform for documenting and mapping land and resource rights. It is designed to be used by organizations that work on land tenure issues, such as NGOs and government agencies. Another early effort in open-source land administration tools is the Open Tenure project. Open Tenure is a suite of software tools designed to help communities and individuals document and manage their land and resource rights. It was launched in 2011 and has been used in several countries, including Tanzania and Colombia. More recently, the Global Land Tool Network (GLTN) has been promoting the use of open-source tools in land administration. GLTN is a network of organizations that work on land tenure issues, and it has developed a suite of tools that can be used by governments, NGOs, and other organizations to support land administration. The GLTN tools include software for land mapping, land valuation, and land use planning.

Open-source software or tools facilitate the implementation of Voluntary Guidelines for Responsible Governance of Tenure (VGGT). This is through addressing section 17 of the VGGTs – Records of Tenure Rights and supporting other sections. These tools improve transparency to tenure rights, and service delivery, can record land rights through a continuum of rights, support land administration processes, simplify processes and implement standards for example Land Administration Domain Model (LADM) – ISO 19152 (Lemmen et al., 2001).

The open-source tools in land administration are categorized into two;

1. A Land Information system that is used for managing land rights for example the Uganda National Land Information System (UgNLIS) and Ethiopia National Rural Land Administration Information System (NRLAIS), Ardhisasa. This system is where the spatial and textual data collected on land is stored and managed. Other open-source tools include Software for Land Administration (SOLA) Open Tenure, Social Tenure Domain Model (STDM), Cadastre Register Inventory Saving Paper (CRISP) and CADATSTA also have a land management system though are well known for their data collection capability.
2. Data collection tools are used to collect spatial and textual data on land for importation into a Land Information System. These include Systematic Land Adjudication and Certification (SLAAC), Mass registration (MASSREG), Software for Land Administration

(SOLA) Open Tenure, Social Tenure Domain Model (STDM), Cadastre Register Saving Paper (CRISP) and CADASTA.

The following sections discuss the different open-source tools that have been applied in the different IGAD countries.

1.5.1 Ethiopia

a) National Rural Land Administration Information System (NRLAIS)

NRLAIS is a web-distributed and computerized rural cadastre software system designed for handling systematic land registration (mass registration) and the maintenance of the land register through subsequent transactions with a capability to aggregate the cadastre data from woreda to federal levels(Luftbild, 2020). For each administration level, it has different functional features which is one of the central requirements of the sustainability and effectiveness of the rural land administration system with the existence of a comprehensive, transparent, participatory and up-to-date land registry which records the land rights in respect of each parcel within a Woreda contains spatial and textual components integrated each other.

NRLAIS is flexible to be customized to local needs and conditions and framed on a common model and data standards to allow sharing of the rural cadastre data between regions and the federal government. It has five modules; Mass Registration (MASSREG), Woreda Land Administration Information System (WORLAIS), Zonal Land Administration Information System (ZONLAIS), Regional Land Administration Information System (REGLAIS) and Central Land Administration Information System (CENLAIS) and the system was designed in a way that additional Zones, Woreda and Kebele can be brought on line progressively.

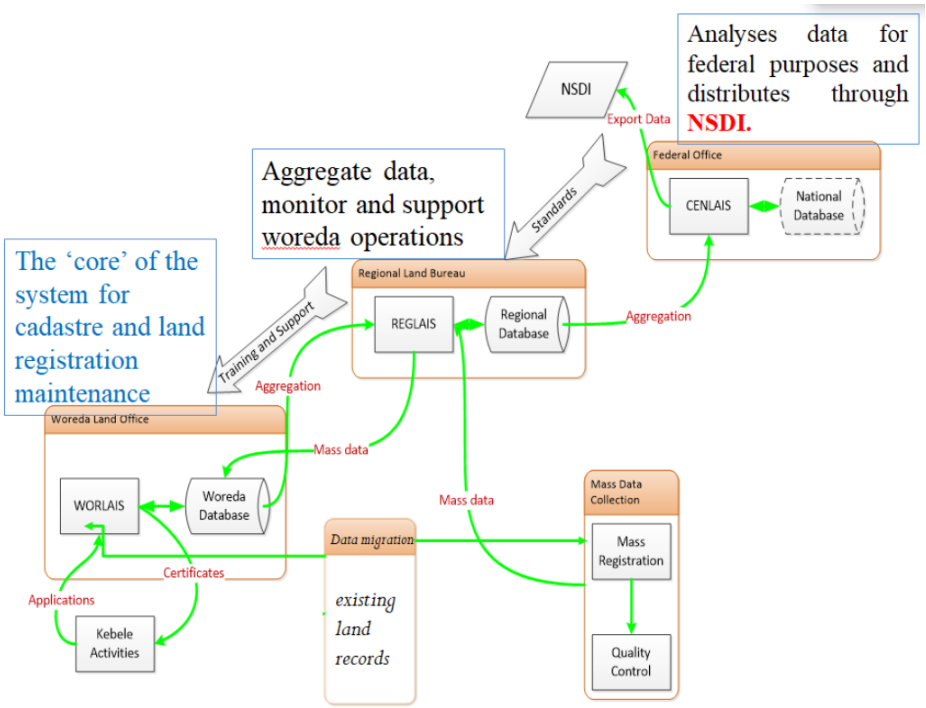

Figure 1: The conceptual design of the NRLAIS

NRLAIS created an excellent foundation for rural land management in Ethiopia. It is the key strategic development within the land administration sector and will provide the required functionality to manage the land administration datasets and provide administration services. The overview of NRLAIS components is shown schematically in Figure 1 and Figure 2.

The development of NRLAIS is entirely based on open-source software technologies approved by the Open-Source Initiative (OSI), applied tool-kit approach development and its conceptual design framework of the system was based on ISO standard 19152, "Land Administration Domain Model (LADM)". It was used as the basis for the specification of the NRLAIS conceptual data model and adapted to the requirements of the rural land administration sector of Ethiopia. The NRLAIS LADM packages were structured into four main packages plus one support package. The structure of the conceptual model follows the general structure of the LADM. The NRLAIS LADM adopted 4 main packages and one auxiliary class package. The five packages are:

1. **Party:** Containing all the classes necessary for modelling all aspects of natural and non-natural persons with a direct or indirect interest in land.
2. **Administration:** Containing all elements of the conceptual model with relation to legal aspects. The core of the package is the implementation of the Right, Restriction and Responsibility (RRR) concept of LADM.

3. **Source:** Containing all the elements of the conceptual model that are related to documents. A source is evidence for a fact in NRLAIS.
4. **Spatial**: Containing all the classes necessary for the modelling of the spatial aspects of NRLAIS and representing the cadaster.
5. **Auxiliary classes:** models common structures such as code lists or common attribute sets.

It also applied international standards and a best practices approach which was applied in the design and development of the NRLAIS. These standards were;

- Standard web architecture
- Standard programming languages such as JavaScript (ECMAScript 5) or Python
- SQL
- Web standards such as HTML, HTTP, XML, SOAP
- UML

The main system components and subsystems were developed based on system requirements and the system design which are physically independent but logically dependent on each other and are connected at the database level. Each subsystem has its purpose and specialized graphical user interface to handle different types of data and fulfil the corresponding tasks. Figure 2 below shows the relationship between the components of NRLAIS.

NRLAIS has excellent data migration capabilities to migrate data from the existing interim systems that can store and process in NRLAIS database. NRLAIS provides a legal cadastre system that includes non-redundant, accurate and consistent parcel geometry as well as a land use right records. Forthcoming there is only one system and institution responsible for the registration and maintenance of rural land records in each regional state.

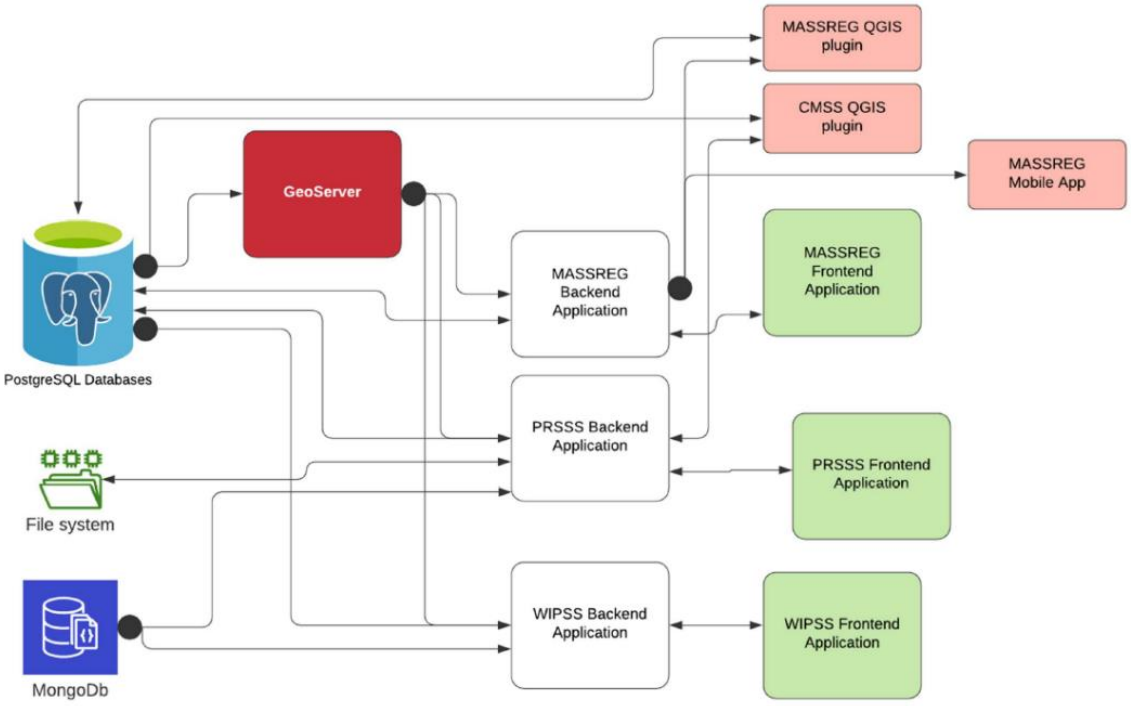

Figure 2: The relationship between NRLAIS components

b) **Mass Registration (MASSREG)**

The MASREG is an open-source data collection tool which was developed by Ethiopia to be used for the collection of spatial data that would be uploaded into the NRLAIS(MANR, 2018). The development of this tool had substantial input from Ethiopia whose stakeholders were involved from the development stage. The tool has also supported and integrated the mobile application however still under development and further piloting because the existing mobile application has only the capability of collecting spatial and not textual data. Allowing for automated collection of textual data poses a legal challenge because existing legal provisions do not support electronic signature and confirmation via mobile applications.

MASSREG is one of the five functional components of NRLAIS. The purpose of dividing the NRLAIS system into different levels was to provide different functionalities in line with the different tasks of the Administrative Levels. MASSREG is an application designed to be used as an important data and workflow management tool for Second Level Land Certification (SLLC) processes. It provides the following functions that facilitate an SLLC work:

1. Data entry
2. SLLC workflow management
3. Certificate preparation
4. Data migration from old systems

5. Transferring certified parcel records to WORLAIS

MASSREG maintains consistently structured SLLC data obtained from field registration forms, spatial adjudication data and supporting documents converted to electronic formats. MASSREG provides streamlined web-based user interfaces for entering data from registration forms and uploading supporting documents. The data entry process implements the double entry approach, in which field registration form data is encoded and crosschecked twice by two different data encoders.

The entire access to MASSREG is controlled by access privileges, which are based on user roles. Table 2 shows access privileges for modifications and changing the status of applications with respective rights. it also explains the stages that data will follow in the MASSREG system.

Table 2: Access privileges for modifications and changing the status of applications with respective rights

Stage Number	**Stage**	**Name Description**
0.	None Existent Stage	The parcel is not part of the textual database of MASSREG yet
1.	First Entry Stage	The first copy of the data from the filed registration form (FRF) is entered
2.	Second Entry Stage	The second copy of the data from FRF is entered
3.	Sent to Supervisor	The parcel record is forwarded to the data entry Supervisor for verification. This happens when the first and the second copy of the data entered from the FRF are different
4.	Data Entry Confirmed	The data has passed the double data entry verification process.
5.	Sent for Minor Correction	The data has been found to have minor errors. It needs to be rectified.
6.	Sent to Major Correction	The data has been found to have major errors. The parcel record needs to be revised fully.
7.	Major Correction First Entry	The first copy of the data from FRF for a major correction is entered
8.	Major Correction Second Entry	The second copy of the data from FRF for major correction is entered

9.	Sent Major Correction Supervisor	The parcel record is sent to the major correction data entry supervisor. This happens when the first and the second copy of the major correction entries are different
10.	Data Entry Confirmed by Public Display	The data is published for landholders to check and the landholder is considered to have accepted the land record.
11.	Checked	Experts make a final check of the data
12.	Approved	A Woreda authority has approved the parcel record for certification
13.	Certificate Printed	The certificate is printed but not issued to the land holder
14.	Certificate Issued	The land certificate is issued to the landholder

For spatial adjudication data, which is the core aspect of SLLC, MASSREG provides two data entry possibilities. The first option is the use of QGIS application, which is a customized plugin that runs on desktop computers; the second option is to use a special-purpose mobile application that runs on portable computers. The portable computer option allows adjudication teams to directly enter spatial data onto portable computers while the QGIS option allows GIS technicians to scan field maps that are produced by adjudication teams and use them for screen digitization. In both cases, the data is fed into the same MASSREG database, where MASSREG filters all spatial data entries to ensure consistency with the rest of the database. This document addresses aspects of the MASSREG's administration.

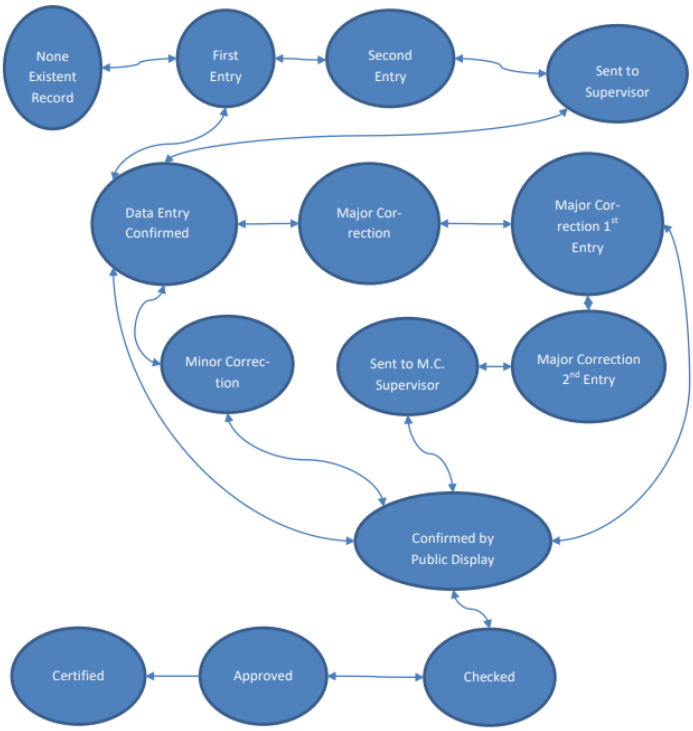

Figure 3: The application process of the MASSREG tool applied in Ethiopia

c) Cadastre and Real Property Registration System (CRPRS)

The Cadastre and Real Property Registration System (CRPRS) was developed to serve as an integrated and unified platform across the country, as well as the legal cadastre in the states of the Federal Republic of Ethiopia. CRPRS is intended to be the urban counterpart of a relatively successful endeavor on the rural side: National Rural Land Administration Information System (NRLAIS)

During the project preparation, CRPRS was expected to be developed with components for city, regional and federal entities. However, the regional and federal components are not developed as of yet and as it stands only the component for city-level registration is in operation. However, the regional and federal components have not yet been developed, and as of now, only the component for city-level registration is currently operational.

i. Technical Details

CRPRS data model adheres to the standards set by Ethiopian Land Administration Domain Model (ELADM). It implements a one-window principle and, therefore, every customer's application for a service is registered. Required documents such as ID, Passport, etc., are scanned and stored in the database. The system implements only the first and subsequent registration system; and like AA-CADIS, the system only implements the registration process without regard for adjudication.

CRPRS is implemented to be three-tiered with Web, Service and data tiers. Two components, that is., web and desktop components, make up the client end layer. The web application developed using Angular JS and OpenLayers web mapping library is composed of a registration client and an admin client. The desktop client is a customized QGIS through a plugin developed using python.

The service layer consists of a registration web application, an admin web application, and business logic, all of which are written in ASP.NET and C#. A map server based on GeoServer serves map data layers to the web and QGIS client through standard web map service. The data layer is built with PostgreSQL with PostGIS extension that implements ELADM.

Aside from the data layer, much of CRPRS' architecture and tools are similar to AA-CADIS. The adoption of PostgreSQL over Oracle is a positive development because of its open-source permissive license. However, the service layer is still dependent on proprietary technology.

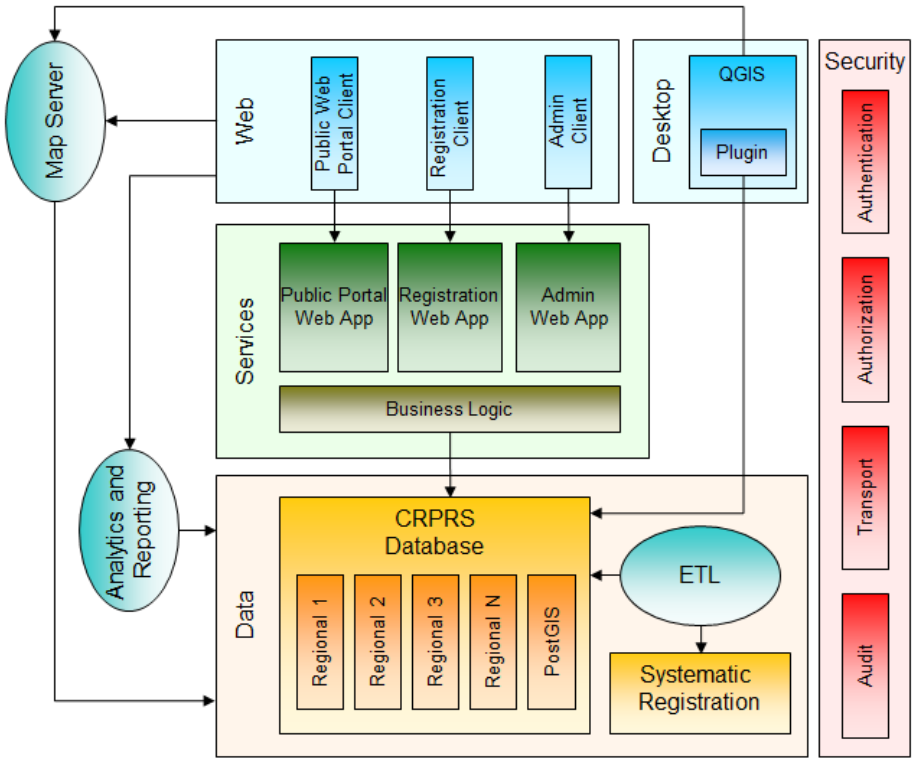

Figure 4: CRPRS Architecture

ii. Features

CRPRS handles the recording of customer applications, cadastre data and registration data along with their related documents. The following are the data handled by CRPRS as specified in the E-LADM.

- Cadastre: Parcel, Building, Administrative boundary, Cadastral block, Easement (right of way)
- Registration: Party, Right, BAUnit, Restriction (including the specialized types such as a mortgage), Responsibility
- Document: Administrative document, Field survey document
- Application: Applicant, Application details, Application tasks, Task assignee

iii. Deployment, Capacity and Status

As of July 2022, CRPRS was deployed in 14 cities across three countries and none of the cities nor MUDI had data centres for CRPRS.

While situations greatly vary across cities, there are roughly two system admins per city who perform all ICT tasks including network, database, and system administration.

iv. Strengths & Gaps

- CRPRS is an attempt to create a national standard for Urban Land Adjudication and Registration.
- Even though the CRPRS was intended to automate more than 40 processes, as it stands the original design goals have not been met. Only a few work procedures can be supported by the current implementation. For example, users must handle geographical data using third-party applications like ESRI ArcMap.
- Because of the hardcoded features used in the existing implementation and business operations, it is quite challenging to modify the program. The need for reengineering the architecture to incorporate new work processes and software components is dictated by the numerous dependencies between components.
- Compared to LIS systems in the country, deploying CRPRS has higher hardware requirements. This has an impact on scalability cost, which was one of the reasons, for example, Oromia regional cadaster office mentioned preferring SOLA over CRPRS.
- During the assessment, MUDI or any of the registration offices developed the human capacity to operationalize, maintain and upgrade CRPRS. Hence, they had to rely on

support from INSA. Given the absence of a clear plan for the future CRPRS from INSA's end, it puts the prospects in jeopardy.

- CRPRS is well documented and all technical documentation is updated to upkeep the current state of the system
- There is still a dependency on proprietary technology on the service layer.

A standard certificate template has been established nationwide averting the need to create a custom template per jurisdiction as observed in NRLAIS.

1.5.2 Uganda

a) **Uganda National Land Information System (UgNLIS)**

The UgNLIS was developed by National Institute for Geographic and Forest Information (IGN Fl's) partners for software development, Innola Solutions Inc. and GEOFIT (Fr)(Oput et al., 2018; Toko et al., 2022). This system provides an integrated cadastral management functionality and data model to handle cadastral surveying, land valuation and physical planning tasks as required in land registration. The UgNLIS was configured around an Open-Source and full web global land and property management solution based on HTML5, CSS3/Javascript. This system has different modules with external systems supported by an open API. It has exchange file formats that incorporate land valuation and physical planning modules.

National Land Information System (NLIS) has already made a profound contribution to the improvement of service delivery across the land sector with a substantial reduction in the time required for land transactions, minimization of opportunities for corruption, increase in accountability and strengthening of tenure security(Burke, 2020; MLHUD, 2015c). The results registered since the implementation of the NLIS include;

1. Increase in the number of land transactions.
2. Decentralization of the cadastral and registration services,
3. Securing land records and maps,
4. Establishment of audit trail of land transactions,
5. Improvement in the quality of records and their management,
6. Instant retrieval of land-related information,
7. Better service delivery to the stakeholders,
8. Improvement in public perceptions of land service delivery,
9. Increased sustainability of land governance.

b) **Systematic Land Adjudication and Certification (SLAAC)**

SLAAC is a tool developed by the Ministry of Lands, Housing and Urban Development, named after the World Bank-funded Systematic Land Adjudication and Certification programme. The tool has been piloted to support adjudication on Customary and Freehold land(Chimhowu et al., 2013; MLHUD, 2015a, 2015c). The tool follows the standard requirements of cadastral mapping as required by the Department of Surveys and the Uganda Land Information Systems. It is focused on the recordation of individual customary ownership and freehold ownership through procedures stated in the land regulation. The SLAAC tool aimed to bring customary land records to the Uganda National Land Information system hence providing exclusive security of tenure. The tool has the following key features;

1. The tool only registers the ownership rights of individuals or groups of people. It assumes that all people have equal rights.
2. It focuses on only two tenure systems in Uganda, that is customary and freehold tenure systems.
3. To map customary land, the tool uses handheld GPS devices that are connected to tablets using a cable.
4. On freehold land, the tool uses a geodetic GPS in Real Time Kinematic (RTK) that is connected to tablets to map the parcel of land use for a given parcel for example.
5. The tool can capture the type of land use for a given parcel for example; agriculture, civic, commercial, conservation, environmental protection, and farming among others.
6. The tool uses 40cm spatial resolution for the rural areas and 25cm for peri-urban areas as a base map for the maps.
7. The projected coordinate system used is WGS84_UTM 36N.
8. The tool can scan a Job Record Jacket (JRJ) and links it to the spatial information of a landowner.
9. It establishes a bar code which is a parcel identifier that is linked to the attribute information to the spatial unit.
10. SLAAC currently collects data using QGIS and a local host database (PostgreSQL) and it is managed through two data processing centres before it is transferred into LIS.
11. Data processing centre for quality assurance before data migration to the national Land Information System.
12. The tool requires a National Identification Number.

The SLAAC application is based on the use of mobile tablets installed with either windows operating systems or Android operating systems based on open-source software running on Postgres/PostGIS database, Alfresco and QGIS software for mapping. Orthorectified imagery or orthophotos are used as a base map while carrying out the demarcation of boundaries and other land rights data. This tool has been used in Uganda for data processing, associated quality control, monitoring and evaluation, production of reports and final reports required in the titling process. This tool supported the availability of data in a digital format more reliably, efficiently and transparent when compared to paper-based manual processes. This has reduced the cumbersomeness, and inefficiency of land registration reducing the number of mistakes made in the processes.

Figure 5: Systematic Land Adjudication and Certification (SLAAC) tool operation

The use of SLAAC in Uganda aimed at an increased rate of land registration and certification, securing land rights for vulnerable groups, increased productivity and use of documented rights in contribution to the social and economic development of Uganda. This tool was designed to support the processing and issuance of Certificates of Customary Ownership, Communal Land Associations and Freehold Titles.

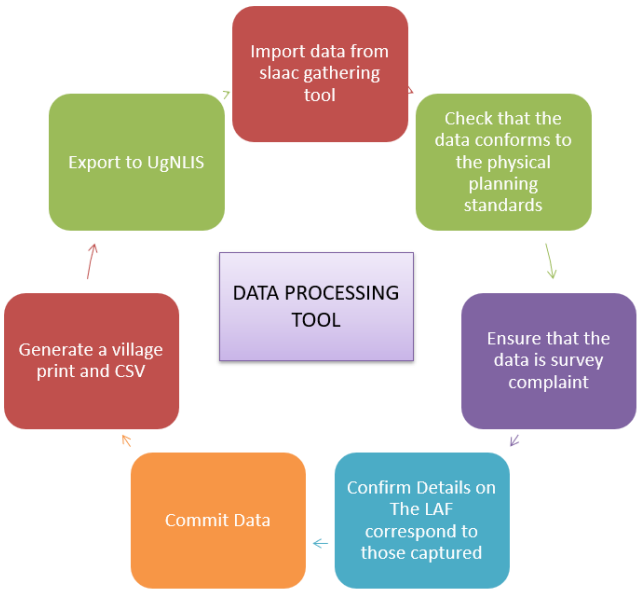

Figure 6: Systematic Land Adjudication and Certification (SLAAC) tool process

The MLHUD focuses on the use of SLAAC data capture and mapping tool as not only a Land Administration data collection tool but a spatial data collection tool that can be used for data collection and mapping in the areas of Forestry, Valuation, Physical Planning, Housing, Informal Settlements and Agriculture.

Mapping of Customary Land Rights should now focus on the different classes of mapping for specific areas for example Towns, urban centres and for the peri-urban areas, a more precise and accurate methodology of mapping should be used but ensure the adoption of the Fit for purpose' Land Administration approach for rural Areas(MLHUD, 2015c, 2015b). The adoption of the Goal Driven Workflow Generation with Artificial Intelligence Planning in SLAAC.

1.5.3 Kenya

Attempts to set up a land management system in Kenya started as early as 1984 with main aspects including the scanning of land records for storage in the system but this was not fully successful. In 1991, supported by the Swedish International Development Agency (SIDA) another attempt was done but it neither achieved the results that were planned until 2004 when digital records were developed with small aspects of registration. From 2013 to 2018, online services became a reality through the system was hampered by the challenge of being based on proprietary software which required high maintenance costs. Later on, three systems were developed; Land Information System (LIM), share point and Ardhisasa (https://ardhisasa.lands.go.ke/home). LIM was based on proprietary software – ArcGIS but has been redeveloped to open-source technology. The same

applied to share point. Ardhisasa was developed later in the house solely based on open-source technology and incorporates LIM and share point.

Ardhisasa is an online platform that allows Citizens, other stakeholders and interested parties to interact with land information held and processes undertaken by Government. It has been developed jointly by the Ministry of Land and Physical Planning (MoLPP) and the National Land Commission (NLC) and key partners in Government. It allows the lodgement of applications for various services offered by the Ministry and the Commission. The applications are handled through the platform and responses are presented through it.

The successful set-up and operation of Ardhisasa is attributed to support from the political sphere, adequate funding from the national government and involvement of all government agencies in the development and deployment. However, it has also been faced with its share of challenges which include Political engagement and frequent change in government, change management issues, sustainability issues due to the use of proprietary tools at the beginning, Legal framework bottlenecks, limited human capacity and ICT infrastructure.

1.5.4 Others

a) **Software for Land Administration (SOLA) Open Tenure**

SOLA was initially developed through a Food Agriculture Organisation (FAO) managed project funded by the Ministry for Foreign Affairs of Finland (FAO, 2012, 2021). The project goals were; the development of an open-source enterprise software application that supports core cadastre and registration functions, support for the customization of the initial SOLA software in pilot countries and its implementation, and establish an open-source community of users and developers around SOLA software.

The SOLA open-source software has about six (6) applications which include;

1. A registry – which has integrated registration and cadastral functions that happen in the day-to-day operations at the land offices,
2. Systematic registration – this application supports the first registration of land rights in a systematic manner supporting public display of cadastral maps and generation of land rights certificates,
3. Admin – this provides system administrations functionality,
4. State land – this supports the administration of state land through processing leases, acquisition, disposal and management of land owned by the state,

5. Community server – this stores and enables access to land rights data collected for the community at different levels, and
6. Open tenure – this enables the field capture of tenure rights using mobile devices.

The software architecture is of three tiers;

1. Java web start – for presentation,
2. Web services – for the services, and
3. PostgreSQL with PostGIS extension for the data layer.

SOLA is based on open-source components and non-proprietary industry standards (International Standard Operation (ISO) 19152 – Land Administration Domain Model (LADM)) and WMS for the ability to use either orthophotos or satellite imagery. In addition, it uses the modular loosely coupled components – Service-oriented Architecture and the Enterprise Application Framework. SOLA supports cadastre and registration functions and services provided by a typical land office. The system incorporates international best practices and standards and can be further customized to meet the specific needs of a country.

SOLA has been used in different countries; Lesotho implemented a lease management system to support cadastral registration processes, and prepare and manage leases. Samoa was used by the Ministry of Natural resources and Environment to integrate land registration and mapping and support condominium registration, Nigeria in the presidential technical committee on land reform systematic registration pilots which were scaled up in many other states, Uganda to register customary land issuing Customary Certificates of ownership to the rural poor by the Ministry of Lands Housing and Urban Development, the other countries where SOLA has been piloted include Nepal, Cambodia, and Tonga(FAO, 2012).

SOLA has made it affordable, sustainable and fit for purpose computerisation of the cadastre and registration systems to countries. Open tenure supports a crowd-sourcing approach in collecting tenure rights by communities. Communities use tablets or smartphones loaded with open-tenure mobile applications to record tenure rights. These recorded details are then transferred to a community server where data can be accessed through the internet with the moderation of the data in charge.

b) **Social Tenure Domain Model (STDM)**

STDM is a multi-partner software that was developed to support pro-poor land administration. This tool is based solely on open-source software development principles (GLTN, n.d., 2015;

Lemmen, 2010). This tool can broaden the scope of land administration to integrate formal and informal land rights. It is a specialization of the Land Administration Domain Model (LADM) which was previously known as the Core Cadastral Domain Model.

STDM describes relationships between people and land unconventionally compared to the traditional land administration systems. It provides means of relating people to their property in informal settlements and areas under customary land ownership. It has supported registration in areas where regular or formal registration of land rights is not the rule for example in slums.

STDM supports the development and maintenance of records in areas where regular or formal registration of land is not the rule. It focuses on land and property rights which are neither registered nor registerable, as well as overlapping claims that may all have to be adjudicated. STDM focuses on social tenure relationships as embedded in the continuum of land rights concept that has been promoted by GLTN and UN-HABITAT. The STDM-embedded land administration system can support informal land rights for example occupancy, adverse possession, tenancy, use rights, customary rights, and indigenous tenure in addition to formal ones. The tool can also accommodate a range of spatial units ranging from points, lines, polygons and volumes. Additionally, the land rights recorded are of all types that are individuals, couples, groups, groups of groups, companies, municipalities or government departments etc.

Data collected in STDM, both spatial and non-spatial, comes from a variety of sources based on local needs and capabilities. STDM can innovatively handle all this data to ensure that all the data needs are fulfilled. It incorporates high-resolution satellite imagery, which is an emerging and very promising source of spatial data for land administration. To support and determine the viability of this concept, the World Bank with funding from GLTN tested the feasibility of mapping using high-resolution satellite imagery in Ethiopia in the year 2008. In addition, this technique has been successfully applied to the whole country of Rwanda.

STDM prototype was developed at the International Institute for Geo-information Science and Earth Observation (ITC) in close cooperation with Global Land Tool Network/UN-Habitat and the International Federation of Surveyors (FIG). Conceptual, functional, and technical designs and prototypes were developed and tested in different countries with slums, customary tenure, and overlapping claims. STDM has been successfully developed and piloted in Uganda, Ethiopia, Kenya, Saint Lucia, St. Vincent and the Grenadines.

c) **Cadastre Register Inventory Saving Paper (CRISP)**

The CRISP tool has been piloted in Uganda to record the informal rights on customary land and the overlapping rights on the Mailo Tenure system. This tool attempted to use satellite imagery and orthophotos in conjunction with low-cost single-frequency receivers to map parcels of land. On customary land, the rights of all family members were recorded and Certificates of Customary Ownership (CCOs) were issued, while, where overlapping rights existed, Land Inventory Protocols (LIPS) were given as intermediate documents and then Certificates of Occupancy there later issued.

The tool was piloted on Mailo tenure to record multiple ownership rights that exist on this tenure (Burke, 2020; Musinguzi et al., 2021; Oryema, 2016). The overall project was backed by the fact that subsequent updates had not been done under the Mailo tenure to interlink the landlords and the tenants in the registries hence implying insecurity of possession rights by these smallholder farmers. This tool was piloted in Mubende and Mityana for Mailo and Soroti and Katakwi for customary land. The tool has been designed to capture the formal and informal settlers' interest in land. The features of this tool are;

1. The tool relies on open-source software for data collection and management. It uses a local host database (PostgreSQL) and Quantum GIS (QGIS) for topology and overall data management.
2. It applies the differential positioning technique in Real Kinematic Mode (RTK) while doing data collection in the field. CRISP establishes a single frequency base receiver GPS (EMLID REACH RS) connecting with data loggers to generate information at an improved accuracy.
3. The tool works with predefined misclosure that must be set before data collection, however, has got several coordinate geometry techniques that supplement the GPS technique. These include triangulation and LiDAR technology that has not been experimented with yet.
4. It also uses functions like offsets to capture the width of the corridors (roads, utility lines).
5. The tool allows the recordation of all the necessary authentic documents of ownership or restrictions for example the National ID, mortgages and loan agreements.
6. The tool possesses all the packages of the Land Administration Domain Model (LADM) and is thus semantically ready to contribute to the mapping of user rights and ownership.
7. It only captures tenancy/occupancy rights on Mailo tenure hence one major class focused on claimants.
8. The tool captures the type of land use for a given parcel, for example, agriculture, civic, commercial, conservation, environmental protection, and farming among others.

9. The tool also captures the type of structures on the land i.e., permanent, or temporary structures to help ascertain the land value.
10. It interplays 40cm orthophotos, OpenStreetMap and google earth as base maps for the identification of visible boundaries.

d) **CADASTA**

This is a flexible suite of mobile and web-based tools designed to collect, manage, store and analyse land and resource rights. It collects data using GPS embedded in smartphones or tablets and online satellite imagery. It is designed to access different web maps for example open street, Digital Globe, Esri etc. It supports multiple languages and real-time updates can be made of the data, graphs and statistics. It enables customization of data reports to suit the client's need and a comprehensive quick search through large amounts of land data. Additionally, it has measurement tools which can be used during the mapping process.

The Cadasta Platform is a secure, Esri ArcGIS-supported suite of mobile and web-based tools designed to help users collect, analyze, store, and share data on land and resource rights. The platform can be used to capture multi-layered information about people's relationship to land and resources, including spatial dimensions, footage from drones, digital maps, video or audio interviews, photographs, paper attestations, tax receipts, and other supporting documentation (Frank & Madaleine, 2018). It can store data that has been previously collected through traditional paper-based surveys and maps and can be paired with a wide variety of other digital data collection tools.

Cadasta's fit-for-purpose digital data collection forms allow partners to collect data quickly based on their specific needs. The flexibility of the platform allows for data collection in a variety of ways. By building flexible, cost-effective, and user-friendly technology for land rights documentation, Cadasta works to overcome surveyor shortages and the problems faced with traditional systems(Frank & Madaleine, 2018).

In this context, Cadasta works as a technical service provider of land expertise and technology for individuals, communities, organizations, governments, and businesses looking to strengthen land security and build stronger, more sustainable communities. Cadasta offers its partners affordable and open-access tools and technical assistance to support efforts to document and secure land and resource rights.

Cadasta's approach is informed by years of experience working with formal land administration processes and national-level land information systems, as well as working with volunteered

geographic information to develop robust and up-to-date datasets. The services are participatory, demand-driven, and tailored to local project needs. Partners are supported in identifying and mitigating conflict, ensuring gender-sensitive approaches, and building knowledge of land systems(Frank & Madaleine, 2018).

The training materials and sessions are adapted to local use and focus on the training of trainers. The goal is to strengthen the community's capacity for data collection and mapping which will lead to strengthened rights. The tool aligns with national-level land data standards and systems wherever possible and collaborates with other stakeholders, such as land administration officials and the private sector. Through the tools, technology, services, and partnerships individuals, organizations, communities, and governments are empowered with the information they need to make data-driven decisions to secure their land and resource rights to build stronger, more sustainable communities.

1.5.5 Comparison of different open-source tools in land administration

It is noted that most of the open-source tools in land administration applied in the IGAD region are developed internationally and piloted in the region. These have been customized to collect land data as per the legal framework in each IGAD member state. Uganda has had the most open-source tools piloted in the country due to the flexible legal framework that allows for this. It was observed that the tools have data collection and storage components both being used in the different pilots in the IGAD member states. The application of the tools has remained at a pilot stage apart from Uganda and Ethiopia where the deployment of SLAAC and MASSREG is being attempted for the whole country. Apart from SLAAC and MASSREG, the sustainability of the other tools has not been possible when the projects close. This is either due to the limited support from the donors or limited accessibility to the tools. In the region, it is only Uganda and Ethiopia with fully developed national land information systems, UgNLIS and NRLAIS which are used to store the collected land information. These are based on open-source technology. There has been an attempt in Kenya to develop such a system but it is still at a young stage. The other capabilities of the different tools in land administration are shown in *Table 3*.

Table 3: The comparison of Open-source tools in land administration

Comparison aspect	CADASTA	CRISP	STDM	SOLA	MASSREG	NRLAIS	SLAAC	UgNLIS
Open-Source	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

technology used								
Best on Land Administration Domain Model (LADM)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Accessibility for use	limited	limited	available	limited	limited	Not available	limited	Not available
Capability	Data collection and land management system	Data collection and land management system	Data collection and land management system	Data collection and land management system	Data collection and land management system	Land management system	Data collection and land management system	Land management system
Development	International	International	International	International	Local	Local	Local	Local
Implementation range	Global	Global	Global	Global	Ethiopia	Ethiopia	Uganda	Uganda
Storage	local	local	local	cloud	local	local	local	local

1.6 Open-Source tools in Land Administration

Land administration involves the management of land records, property rights, land use planning, and land taxation, among other things. Improved land administration is critical for effective land management and the protection of property rights. Improved land administration requires the existence of a cadastre system and a register of rights on the land (Abbay, 2001; Luftbild, 2007; Oryema, 2016; USAID, 2016). Previously, proprietary tools have been easy to implement in land administration, but their support was only available for a limited time and came at a considerable

cost (Pieper, 2008). After the support period ended, these tools often ceased to function as governments could not afford the ongoing maintenance costs.

Open-source tools can play an important role in improving land administration by providing affordable, accessible, and customizable software solutions. They have the potential to democratize land administration and provide greater access to land information for individuals and communities, particularly in developing countries where traditional land administration systems may be inadequate or non-existent. Additionally, because they are open-source, they can be customized and adapted to meet the specific needs of different land administration contexts. Although numerous open-source tools are available worldwide, the following open-source tools are commonly utilized in land administration.

Table 4: Examples of Open-Source tools applied in Land Administration

No	Name	Usage
1	PostgreSQL	Database management system - used at all levels for storage of structured and semi-structured data
2	PostGIS	An open-source extension to the PostgreSQL database that adds support for spatial data. It provides a wide range of spatial functions and allows users to store and manipulate spatial data in a relational database.
3	QGIS	An open-source Geographic Information System (GIS) software that provides tools for data visualization, analysis, and editing. It supports a wide range of spatial data formats and can be used for tasks such as mapping, geocoding, and geoprocessing.
4	GDAL/OGR	Converting different GIS formats
5	Geoserver	Used at all levels for OGC-compliant services such as WMS, WCS, WFS etc. It allows users to share and edit geospatial data through standard protocols.
6	MapProxy	MapProxy is used as a proxy to encapsulate WMS requests for performance and security reasons
7	Open Data Kit (ODK)	Platform for mobile data collection. It allows users to design custom surveys and collect data using smartphones or tablets.

8	Land Administration Domain Model (LADM)	Model for describing land administration workflows and data structures. It provides a standard framework for land administration systems and can be used to develop custom solutions.
9	Cadasta	Platform for managing land and resource rights. It provides tools for data collection, analysis, and visualization, and allows users to collaborate on land-related projects.
10	ExperMaps	The basis for web-based geospatial clients
11	Node.js	Application environment
12	Python	Used for customization of QGIS

1.7 Lessons learnt from past efforts in open-source tools

The key lessons learned from the development and application of the open-source tool in section 1.3 are;

1. Mobilization and sensitization using various approaches are critical in the campaign to successfully develop and implement open-source tools in land administration. The political and technical have to be mobilized to support the implementation. Political leaders should be ready and willing to create a conducive environment for the implementation of open-source tools. They should approve or make provisions for the implementation of new provisions fast as they provide for legal reforms to support the implementation. The technology should be ready to relearn some aspects of land administration using open-source tools.
2. The technology used should be appropriate, customizable and suit the practices of different countries in relation to land. The technology is divided into two; the system of land administration and the data collection open-source tools. There should be compatibility especially when many open-source data collection tools are used. A standard of data collected should be developed such that the customization of the open-source tools is based on this standard to avoid conflict in collected data.
3. It is a good practice to involve key stakeholders in the development and application process. The different stakeholders provide the technical support required when developing and applying open-source tools.

4. Working groups should be established to support the development and application of open-source tools. These are dedicated teams which work long hours and are observed to increase productivity.
5. The processes should be transparent to encourage participation. The process should also be participatory to encourage ownership by the local leaders and communities.
6. It is encouraged to use the Agile development approach compared to the waterfall model. The Agile model is encouraged because it is faster as you are not required to first wait for a particular stage to be completed before one moves on to the next.
7. It is critical to build capacity internally during the development and implementation of open-source tools. This promotes the sustainability of the tool.
8. The development process should be done in the IGAD country. It has been observed on different projects for the development to be done out of the country. This limits the transfer of skills to the local stakeholders.
9. If possible, the development should be done in connection with local consulting firms in a country.
10. The development and application process should be backstopped by an international organization (s).

1.8 Guidelines and recommendations on the development and application of open-source tools

1. An assessment should be done of the existing open-source tools in a country before deciding whether develop their tool.
2. It should be noted that when a country has a national land information system, flexibility in the development of open-source tools is limited because the development is supposed to meet the data exchange format of the system.
3. Open-source tools developed should be consistent. A data exchange format should be determined on which the open-source tools should be based.
4. It is advised to develop the legal framework before the development of the conceptual, logical and physical models of the open-source tools. When a guide is available, the legal provisions can be done before development, however, provisions should be made to modify the law after the development of the open source.
5. An assessment should be done to determine which open-source tool is most suited for a particular country.

6. A financial assessment should be performed to determine whether to use a proprietary or open-source tool.
7. It is highly recommended that when the open-source tools are developed, a pilot phase important for testing efficiency.
8. The developed open-source tool should follow the standard requirements of cadastral mapping in the IGAD member state as required by the mapping agency and the National Land Information System.
9. The development of the open-source tools should be customized to collect gender disaggregated data on land provided for in the land regulations of the respective IGAD country, and in line with regional, continental and global frameworks.
10. IGAD to provide technical support to member countries in the development (business and system requirement) of Open-source tools in land administration.
11. Include skill transfer in the contracts during the development of open-source tools in land administration. Capacity building should be tagged to the project deliverable. The contracts should include the number of people to be trained and these will be assessed if the skill transfer is successful before the contract closure.

1.9 The organisation of the Guide

This guide is organised in sections and subsections to ease its readability. Section one gives a background to the guide; the objectives of the guide and its scope. It introduces the concept of open-source tools in land administration, how they compare with proprietary tools and the importance of using open-source tools. Furthermore, the section provides a history of the development and application of a sample of open-source tools in the IGAD region and globally. It mentions the common open-source tools in land administration, lessons learned from the development and application of open-source tools in land administration globally and the IGAD region, the guidelines and recommendations on the development and application of open-source tools and the organisation of the guide.

Section two presents the key actors in the development and application of open-source tools in land administration with their mandates, roles and responsibilities, while section three discusses the process of the development of open-source tools. Section four presents the application of open-source tools and section five discusses the sustainability of open-source tools.

2.0 KEY ACTORS IN THE DEVELOPMENT AND APPLICATION OF OPEN-SOURCE TOOLS

The development and application of open-source tools is a collaborative effort involving a wide range of actors at different levels (international, regional and national) who work together to create high-quality, reliable software that can be used by everyone. The key actors involved in the development and application of open-source tools are: developers, governments, local governments, open-source foundations, Non-profit organisations, civil society, consultancy firms and academia. Their roles and responsibilities are described in the sections below

2.1 International level Actors

The international and regional level actors include the donors and facilitators. Their roles, mandates and responsibilities are:

Table 5: Mandate, Roles and Responsibilities of International-Level Actors

Institution	Mandate	Roles and Responsibilities
Open-Source foundations such as the Apache Software Foundation, the Linux Foundation, Python Software Foundation and the Mozilla Foundation	Support growth and sustainability of open-source software	▪ Provide infrastructure and resources to support the development of open-source software
Donors e.g., World Bank, European Union the Netherlands Embassy, Finnish government, UK-DFID, BMZ etc	Provide funds for the program	▪ Guidance and support towards strategic decision-making. ▪ Fund different activities on the project.
Facilitators e.g., GIZ, UNhabitat, IGNFrance if, Hansa Luftbild, SIDA etc	Provide equipment and technical personnel to coordinate activities.	▪ Purchase equipment and software. ▪ Spearhead development of tools. ▪ Provide technical support. ▪ Monitor project implementation.
International Consultants	Provide technical support	▪ Development of tools

		▪ Capacity building ▪ Tool testing and quality assurance ▪ Tool maintenance

2.2 Regional level actors

Table 6: Mandate, Roles and Responsibilities of Regional-Level Actors

Institution	Mandate	Roles and Responsibilities
Intergovernmental Authority for Development (IGAD), African Union (AU), East African Community (EAC), Regional Centre for Mapping of Resources for Development (RCMRD)	To set guidelines and standards at a regional level	▪ Capacity building in the region. ▪ Facilitating exchange visits.

2.3 National level actors

The national actors include the ministries responsible for land, civil society organisations (including organisations representing the different socially vulnerable groups such as women, youth, People with Disabilities (PWDs), and the elderly, among others) professional bodies, academia, political leaders, communities, traditional, religious and cultural institutions. Their roles, mandates and responsibilities are summarised in table below:

Table 7: Mandate, Roles and Responsibilities of National-Level Actors

Institution	Mandate	Role and Responsibility
Governments of IGAD member states	Provide funds for the program	▪ Guidance and support towards strategic decision-making. ▪ Fund different activities on the project.
Ministries and government agencies working on land	Coordination of project implementation. Provide technical support in planning, implementation and monitoring	▪ Review and provide comments and approve reports from consultants procured to provide technical services

	To set guidelines and standards	▪ Coordinate to ensure desired outcomes or impacts are obtained. ▪ Procure, engage and supervise consultants. ▪ Commit staff at the national level to participate. ▪ Ensure various departments are functional and provide respective services. ▪ Process logistics. ▪ Organise training programs to build the capacity of stakeholders at national and local governments and community levels. ▪ Develop Information Education and Communication (IEC) materials for the public.
Consultants	Provide technical support.	▪ Coordinate with key stakeholders to ensure effective program implementation. ▪ Develop and apply tools ▪ Review and advise on methodological and technological issues
Civil Society Organisations	To coordinate the rollout of mobilization and sensitization	▪ Review and advise on methodological and technological issues. ▪ Ensure the rights of the poor, women, youth, children and the vulnerable are considered. ▪ Identify messages and channels to be used to deliver messages. ▪ Develop and produce IEC materials for different audiences.
Religious, traditional and cultural institutions	Mobilize, Sensitize and promote the program	▪ Create awareness about the program. ▪ Educate the communities. ▪ Mobilize the communities.
Professional bodies e.g. – lawyer societies, surveyor institutions, National Information Technology institutes, land	Review program documents and activities and provide advice on matters of	▪ Provide professional advice on specific matters. ▪ Uphold professional standards among their members that may be engaged in the program activities.

administration associations etc.	professional standards and ethics	
Academia - Universities	Conduct research and publication (e.g., policy reviews)	▪ Integrate lessons learned into their curriculum. ▪ Encourage research development and implementation of open-source tools in land administration. ▪ Share information to inform the development and application of open-source tools. ▪ Provide technical support in the development and application of open-source tools in land administration.
Political leaders and communities (beneficiaries)	Cooperate with the project implementers.	▪ Mobilize and sensitize communities. ▪ Participate in the project application
The technical team	Participate in program activities	▪ Participate in mobilization and sensitization. ▪ Expeditiously execute their roles and responsibilities concerning the program. ▪ Provide technical advice
Local technocrats	Participate in field activities.	▪ Mobilize, sensitize local communities and verify land rights. ▪ Expeditiously execute their roles and responsibilities concerning the program. ▪ Participate in the adjudication, demarcation and mediation processes.

3.0 DEVELOPMENT OF OPEN-SOURCE TOOLS

3.1 Introduction

The development of open-source tools in land administration should be divided into two phases; the preparation phase and the development phase. The preparation phase is important because it prepares the country for the development phase. The activities which should be involved in the preparation phase are; analysis of the existing situation, making exposure visits to countries with developed open-source land administration tools, development of technical specifications and requirements for the land tool, assessment of the national capacity, identification of the open-

source tool development expert(s), assessment of the funding availability, and identification and development of local capacity.

The success of the development phase depends on how well the preparation phase was carried out, and it entails the following key steps: analysis and planning for the development, analysis of the software requirements, designing and prototyping of the software, software development, testing, and deployment, as well as maintenance and updating of the developed tool. In addition, gender problems highlighted in section 3.4 should be taken into account while developing open-source tools for land administration.

3.2 Preparation phase

3.2.1 Existing situation analysis

A study should be conducted to determine the existing land administration and management issues in a country including gender and vulnerability issues therein. The land administration and management issues could include but may not be limited to; access, data quality, storage, land use planning, registration, cost of land transactions, legal framework, mapping methodologies, institutional capacities, human capacity, land tenure, land disputes, gender, marginalized and funding. A report on these should form the basis for exposure visits.

3.2.2 Conduct exposure visits

Exposure visits to carefully selected countries should be done. The countries selected should have similar or close land administration and management structures or issues. These countries, however, should have a land information system developed to tackle these issues, preferably based on Open-source tools. International and regional countries should be considered due to the learning lessons that can be obtained. If the country's financial resources permit, it is advised that the exposure trips should also be separated into political and technical categories. Political leaders in underdeveloped nations do not value these systems highly, necessitating the need for such exposure trips. The visit for the political category should be brief and focused on demonstrating the system's high level of competence. This should be attended by ministers, commissioners, directors, and other political decision-makers.

On the other hand, the second category should be the technical personnel who will directly be involved in the development of the system. These should comprise software developers, computer scientists, information technology experts, land surveyors, Geographical Information Scientists, sociologists/ gender experts and land officers working in Ministry responsible for land management in the implementing country. For this category, it is recommended that the exposure

visit lasts between 2 and 4 weeks. These should be briefed on the technical specifications and requirements that such a system requires. These will compile a report on return to their countries. For the exposure visits, it's important to have a fair gender-balanced team.

3.2.3 Development of technical specifications and requirements

The technical team in the Ministry responsible for land management in the implementing country with support from any international or regional experts will develop technical specifications and requirements to set up a land information system in a country based on open-source tools. This activity will be informed by the reports from the analysis of the existing situation and the exposure or study visits conducted. The country will then be able to have a picture of what is required to develop such a system.

3.2.4 Assessment of national capacity

A national capacity assessment should be conducted to determine the infrastructure and human capacity to fully develop and implement such a system. In addition, a financial feasibility analysis of the investment in the system's development and deployment should be performed. This analysis should include determining how much money is required to fully create the system, where this money may be obtained, and its financial viability. At this level, the country should draw plans when the development and implementation are feasible. How much international and local funds will be required, and how many experts will be required

3.2.5 Identification of open-source development tool expert(s) and team

Open-source development tool experts and teams should be identified both nationally and internationally. The identified national experts and teams should work with international experts to support the development and later sustainability of open-source tools.

3.2.6 Development of local capacity

Local teams that will participate in the development of open-source tools should be trained. These are individuals responsible for managing and implementing the newly built tool once contracts for international experts expire

3.3 Development phase

3.3.1 Analysis and planning

When developing an open-source tool, it's crucial to first take the land administration mission and goals of country into consideration. You should also make sure that the entire development process and product are gender-sensitive in accordance with local, regional, and international

commitments on gender. For example, a country may be interested in capturing the entire spectrum of land rights as was the goal when GLTN was developing STDM,open-source tool for land administration. It should be noted that even within IGAD member states, the missions and goals may differ from state to another. Since not all land rights are formally recognized, it is a good thing to have rights on a continuum that can be protected.

It is also important to assess the resources available for the tool's development. Is the funding locally created or coming from donors? Knowing whether the funding is coming from donors or locally generated is crucial since projects with locally supported funding have far more flexibility. When the development is funded locally, strategic planning is primarily focused on the country rather than the donors However in some instances when its donor funded and the goals and missions of the donors do not coincide with those of the countries actually doing the implementing, the implementing nations may be compelled to stray from their top priorities. In addition, an evaluation of the existing personnel to support the development should be done. The required personnel include; IT officers, land officers, land valuers, physical/land use planners, surveyors, policy analysts, Sociologists/gender experts, civil society, local community representatives, cartographers etc.

In addition to a local development team, support internationally may be required and this has to be determined earlier due to the resource consequence. Furthermore, an assessment should be done to ensure all the tools required for development are readily available and accessible. These include all programs that will be leveraged to develop, maintain or test other applications. It is recommended to focus on the free ones rather than the paid-up development tools. The development tools that may be considered are;

1. GitHub is the most used and is a web-based Git repository hosting solution where developers can access code.
2. Gleek is similar to GitHub but is a data modelling tool and is free to use.
3. Codepen is used by front-end developers to find great ideas. Developers share issues in development to get support.
4. Buddy is another development tool that can be used for development, deployment and testing. This is an easy and fast-to-use tool as the configuration is easier.
5. Cloud9 IDE is an online integrated environment where developers can find answers to development problems.

Scheduling is also crucial since a nation's land administration can affect its short- and long-term development goals. The development goals that go with a pre-developed tool may be the most appropriate, and only customization is done, however, these may have a significant impact on the timeline for the development of these tools.

Planning will ensure that the development starts on the right foot. Therefore, it is important to include all the ministries and departments which will be impacted by the developed tool. These ministries or departments may have the ability to provide either financial or technical support during the development process instead of only waiting to use the application. Some of the ministries or departments may financially benefit from the data collected by these tools and therefore it is reasonable to lobby for support from such. The ministries and departments which usually benefit from developed open-source tools in land administration for the case of Uganda include;

1. Ministry of Land, housing and urban development. This ministry with its departments benefits the most from the development and implementation of open-source tools in land administration. They have the capacity in the departments to support the development and application of the tools. They work in partnership with development partners to fund the development and application processes.
2. Ministry of finance, planning and Economic Development. Is at the receiving end of the funds generated from the registration of land using open-source tools. They should therefore be at the forefront to support the development of these tools. The tools also collect information on the households which information can be used for planning of communities. Some of the tools also collect land use data which data is critical in planning for communities.
3. Ministry of information and communication. This ministry providing leadership, coordination, support and advocacy in the formulation of policy, laws, regulations and strategy for the ICT sector is critical in the development and application of open-source tools. These tools need to be developed following the ICT policy prevailing in a particular country on top of the international ICT policy.
4. Ministry of science, technology and innovation. This ministry and its respective departments' plan, coordinate and implement government efforts to encourage scientific and technological innovations. Open-source tools are technological innovations in which a country could vest resources because security on land is an essential part of the country’s development.

5. Ministry of local government. The local government in the case of Uganda collect local revenue which revenue is mostly from the fees charged on the registration of land. The registration of land has stalled for a long time till the introduction of fit-for-purpose land administration. The developed tools have been observed to increase the registration rate which comes with increased local revenue to support the development of the local governments. In addition, the local governments are at the forefront of the implementation of the tools in land administration and the structures of the local government have to be involved in the implementation process.
6. Ministry of justice and constitutional affairs. This ministry and departments are related to the development and application of open-source tools in land administration as most disputes in the courts are land related. The fast and efficient registration of land rights greatly reduces these cases which in turn reduces the case backlogs. The information collected by the tools in registration is used in court cases. In addition, open-source tools developed in land administration have included mediation tools to resolve land disputes.
7. Ministry for agriculture, animal industry and fisheries. The effect of tenure insecurity has the largest impact on agriculture production. The high number of land disputes associated with tenure insecurity and low land documentation affect investment in agriculture. The ministry and the different departments are therefore interested in the developed tool which will record the rights on the land of farmers at an affordable rate. These tools have also been observed to collect data on household production for example the STDM tool developed by UN-Habitat.
8. Ministry of gender, Labour and Social Development require gender and sex-disaggregated data to advise the government on appropriate gender intervention but also for reporting on the Gender Equality and Women Empowerment (GEWE) progress at the continental level and on the Beijing Platform of Action which all have specific Land data required.

The above ministries and departments may not be the same as those of other countries in the IGAD region but we have related ministries and departments which should be part of the development process of the open-source tools.

At the end of the planning, you should have enough information, which information could be from a baseline study. The baseline study done before the development of open-source tools should determine the following information in the intended application areas;

1. Land tenure situation. The types of tenure systems in the country should be assessed to critique the strengths and weaknesses of each type. The legal provisions and

characteristics of each tenure system should be well comprehended to feed into the development of the tools. In addition, existing interventions especially the tools that are being used in the country should be evaluated to determine their strengths and weakness.

2. Land disputes. A study should be done on the existing land disputes in the country. The nature of the disputes, categories and age of social groups affected, locations with majority land disputes, characteristics and the existing land dispute resolution mechanisms should be determined. This information is important because a good tool for land administration should be used to collect data which can be used in dispute resolution. The developers should be able to design the tool to collect the required information on disputes.
3. Environmental management. This will be done to determine the status of protected areas and fragile ecosystems in a country and the existing structures that have been put in place to manage the environment. Tools in Land administration should also be able to collect information on land that can be used in the management of the environment. This makes it important to assess the environmental management systems before a land tool is designed.
4. Gender situation. Gender dynamics differ across the IGAD member states. Within a state, the dynamics of the gender situation vary as well. Even though some IGAD states have begun the process of protecting women's land rights, more work remains to be done in other states. Land tools must be developed to encourage women's participation in land rights registration. The tools should record gender information, and women should be able to participate in the data collection process.
5. Stakeholder mapping. Stakeholders working in the land sector should be mapped and analysed in the country. Such stakeholders, with varying experiences in the land sector, can be involved in the development of the land tool. To ensure that the tools are gender-responsive, key stakeholders in the process should include institutions with gender expertise. These can be involved in the review and testing of the tools.
6. Capacity needs assessment. The capacity of different government structures should be assessed to determine the skills of different workers in applying technology in land administration. This assessment will be used to determine the kind of support which will be given after the development stage. Deliberate actions should be taken to ensure that both male and female officers are capacitated to promote gender-balanced technical teams.
7. Data and infrastructure availability. The data and infrastructure to support the developed land tool should be assessed. Some of the land tools use the internet to access satellite

imagery, store data on the cloud and need continuous online updates. These have to be given thought before, during and after the design and deployment of the land tool. The availability of data and infrastructure varies significantly across the IGAD region, affecting the development of open-source tools for land administration.

8. Political situation. The political situation is also relevant to the development of land tools. The makers of the land policy and laws decide which tools should be used in the country. A tool should be developed in consideration of the plans they have set out for the country. This information will enable the development of a high-level schedule of work detailing exactly what is being built, why it is being built, and how it all comes together.

3.3.2 Requirements Analysis

The next step is to understand the technical requirements of developing open-source tools. These should be based on solving a particular problem in land administration. Here, we have to look at the capabilities a tool should have to be able to collect required data accurately and reliably. At the requirements stage, one would want to ask questions such as;

1. What problem is being solved in land administration? Land administration challenges to be solved include; social problems due to pollution pressure on the limited resources, cultural norms and practices, rampant land disputes, land grabbing, land use planning challenges etc. The most dominant problem will influence the features which will be included in the tool.
2. Who is going to use the tool and why? The question of who is going to use the tool is very important. This originates from the land policy and law of the country which specifies the personnel that will interact with the tool during land registration, administration and management. The personnel are different, this could begin with the team collecting the data, analysing it and presenting it. The tool, for example, will be designed differently if the data is going to be collected by trained professionals compared to when the data is to be collected in the communities by the beneficiaries. In the latter case, the tool should be made simple but still provide for all the data to be collected reliably. The why aspect of the question is related to the purpose that the data is going to be used for by the personnel at the station.
3. What sort of land data is going to be input and output? The data collected by the tool on land is based on the land policy, laws and regulations of a country that specifies what should be collected on a piece of land to determine land rights. The predominant land data type collected includes descriptive, coordinates and imagery. Specifications could be

on the type of descriptive data, coordinates and imagery to be used. On the descriptive data, the focus should be on the names of people, their sex, ages, date of birth, household information, location (rural/urban), passport photographs, scans of identity cards etc. The type of coordinates system, datum and the respective significant figures should be considered. The imagery used could be satellite or orthophotos, however, the resolution range acceptable should be discussed. The output from the land tools could be maps, tables, images or graphs, prior knowledge of these requirements should be clear such that they are successfully incorporated into the tools.

4. Will the tool being developed be integrated with other tools? Due to the diverse data collected for land administration and management today, one tool may not be sufficient to accomplish all tasks. It is therefore not uncommon to have more than one tool incorporated. In addition, it is easier and good practice to customize the existing tools other than inventing the wheel unless it is necessary. This is evident with most open-source tools in land administration that have been developed so far, that is SOLA open tenure, STDM, CRISP, CADASTA etc. These tools work in connection with other open-source tools; Postgres, PostGIS, KOBO collect, GEO ODK etc. The use of more than one tool brings up issues of tool or software compatibility. During the development of the open-source tool in land administration, focus should be put on issues of compatibility because data will have to be transferred between the different tools. Data may be transferred between different tools for storage purposes after being collected using a different tool.
5. How will issues of security and privacy of land data be handled in the developed tool? This question is answered after a review of the data policy of a country. Who should access which data on land? Issues of transparency may come up here as a thin balance has to be made between privacy and allowable access.

When these questions have been conceptualized the technical requirements can be scoped out. At this level when the problem has been understood, sprint planning can be done or the tasks at hand can be broken down into more actionable steps.

3.3.3 Designing

When all the requirements are fully in place, the team then should start designing how the software will look and how it will function. The main focus should not be on aesthetics but on the functionality of the tool and flow. This stage involves creating simple wireframes that show how interactions work in the open-source software tool or full-fledged prototypes with tools like Marvel

or In Vision that allow for user testing. At this stage, the stakeholders can validate the ideas captured in the development of the tool and provide valuable feedback to improve tool's development. This step is very important before you move to the step of developing the code of the tool.

3.3.4 Prototyping

When building software, the same screen or features can be built in a lot of different ways. But only a few paths will result in user-friendly functionality. So, how do you know what to build? How do you align stakeholders on design elements? That's where software prototypes come in. Keep reading to learn what they are and how they're used to create successful software products. A prototype in software development is a simulation of how a real product will work and feel. It's used for design feedback and user testing. Purposefully broad in definition, they can come in all levels of sophistication– from an idea sketched on the back of a napkin to a clickable prototype that mimics real software.

A prototype can also serve as a simulation for an entire mobile app or just one digital interaction, depending on your needs. Think of prototypes like scale building models used in architectural design. An architect takes their understanding of a client's wants and drafts blueprints to match, but the blueprints might not be enough. As a result, the architect creates a scale model of the building. A scale-building model is an example of a sophisticated prototype in this case, but it is sometimes required for a more complex project. It allows the client to see the plans for the building (or product) and provide feedback about what they like or don't like.

Of course, it's easier (and cheaper) to make changes based on the early scale model (or prototype) than when the finishing touches are being made to the building two years later. Developing software is a similar process. Prototypes are often used to gather early feedback and make changes as needed, rather than letting a development team fully code the application and try to deal with significant design changes after.

When creating a software product, prototyping is the ideal way to test, evaluate, and validate your idea with users. It lets you confirm that you are building the right product and features before you code anything. In other words, prototyping reduces project risk. You don't want to discover, after months of expensive developer time and budget, that the features don't meet actual user needs. Starting with a prototype, on the other hand, allows you to get user feedback on what key features to build. Prototypes do not have to include all of the features that you may require. Instead, to

ensure a quick and valuable feedback loop, focus only on the core features required to solve your problem.

3.3.5 Software development

When the proposed functionality and design are clear to the stakeholders and developer, the tool's development begins based on the agreed-upon requirements. This stage must be handled with caution because it has the potential to be the most demanding and risky in tool development. However, whether you're working in Agile sprints, building out a Minimum Valuable Product (MVP), or using the more traditional waterfall method (Figure 7), the goal here is to stick to the Scope of Work (SOW), avoid scope creep, and build clean, efficient software. The waterfall method though most preferred due to its systematic process. The Agile process is faster and is recommended for quicker results. The waterfall method would be preferred when sufficient time is available for the software development process. The waterfall approach has been observed not to have room for a change of requirements in the software development process, however, it has been preferred in the procurement processes during software development. This said a hybrid between Agile and waterfall could be encouraged.

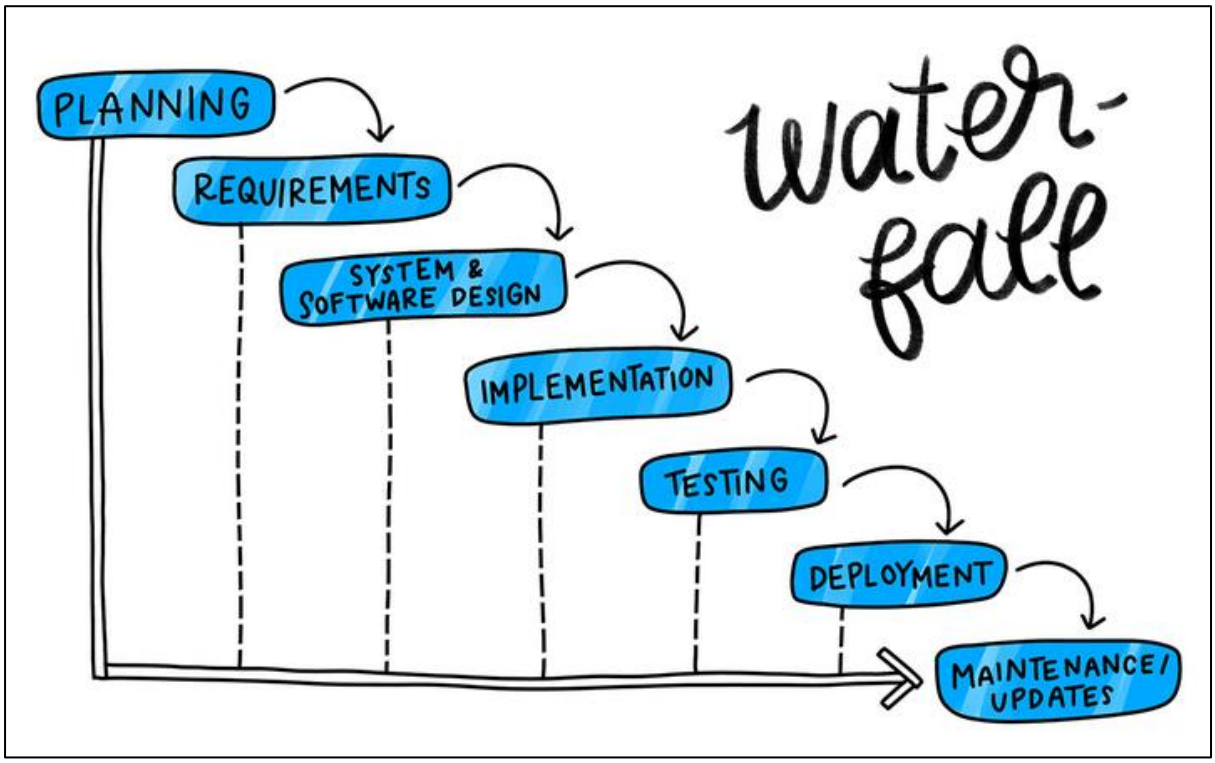

Figure 7: The waterfall development process of open-source tools

For software projects, if the requirements are clearly defined upfront with minimal probability of any changes between the time the software is requisitioned and when it is delivered, then the

Waterfall method makes sense. For software development projects that involve ongoing engagement between the development team and the project stakeholders, choose Agile over Waterfall. Choose Agile, not Waterfall, when developers and stakeholders can easily exchange feedback and be transparent about the development process. The advantages of choosing agile are summarized below.

1. Agile encourages testing and validation earlier in the software development lifecycle.
2. Continuous delivery in Agile is consistent with the DevOps' continuous deployment model.
3. The Agile feedback loop more directly involves stakeholders in the development process.
4. Agile makes it easier to adapt to changed requirements midway through development.
5. Agile projects are easier to start because development doesn't depend on complete requirements and analysis cycles.

Table 8: Agile vs Waterfall comparison chart

No	Comparison	Waterfall	Agile
1	Inception	1950	2001
2	Roots	Infrastructure and engineering	Software development
3	**Client interaction**	**Minimal**	**Encouraged**
4	Founding artefact	Managing the Development of Large Software Systems by Winston Royce	The Agile Manifesto
5	Implementation frameworks	Agile fall, Sashimi, Incremental Waterfall, Wagile	Scrum, Kanban, Lean, XP, Crystal, FDD, DSDM
6	Preferred by	Banks, governments, insurance companies, large teams	Start-ups, small teams, SaaS products, small companies
7	Highest priority	Deliver an end product that matches the initial requirements	Continuously deliver working software to the client
8	Benefits	Enables organizations to do extensive, upfront estimation and planning	Enables teams to rapidly respond to changing requirements
9	Drawbacks	Lack of customer involvement and an overwhelming amount of upfront documentation	Software delivery timelines can be difficult to estimate if requirements frequently change

3.3.6 Testing

As the team is developing the tool, simultaneous testing, tracking and fixing of bugs should be taking place. However, when the tool is deemed to have been completed, then it has to undergo another round of in-depth testing. This could imply releasing the tool to a small group of land administrators who could act as beta testers. Alternatively, UX tools can be used to track how users interact with the developed tool. Attention should be given at this stage to ensure that buggy software is not going to be shipped to the real planned users of the software. It should be noted that bugs in the software can cause a loss of revenue and at worst take up hours of development time that would have been used in building new features of the tool.

3.3.7 Deployment

This is the time to launch the tool and it is advisable to launch it as pilots before the actual rollout to the whole country. Because the tool cannot be fully tested during the testing stage, deployment during the pilot stage is critical. The following aspects should be tested: tool compatibility, software agility, data format interoperability, meeting user requirements, and so on. The tool will be tasked with real situations and if it passes the test then it can be rolled out. However, if the test fails the designing and prototyping are repeated. This is because the different data requirements that arise due to legal reform will require further development of the tool during piloting.

3.3.8 Operation and Maintenance

The deployment of the tool is not the end of the development process because customer requirements are constantly changing. Customers' changing needs in the land sector will necessitate land reforms, which will necessitate a continuous update of the tool. Furthermore, as departments within the Ministry of Land begin to use the tool, they will undoubtedly discover bugs, request new features that improve their work efficiency, and request additional or different tool functionality. Furthermore, the software only requires basic upkeep and maintenance to ensure that it works as well as it did at the time of deployment.

3.3.9 Integration of developed tool.

An assessment should be done to check for the compatibility of the developed tool with other existing tools which may be proprietary. This is critical because the open-source tools in land administration are not used in isolation. Issues of software or tool compatibility, and data exchange formats to mention a few will arise and these have to be given thought during the development stage. The developed tool needs to connect to the financial systems of a country or be able to receive data from other agencies that collect data on the natural resources of a country.

3.4 Gender considerations in the development

A gender expert should be part of the development process of the open-source tools. The gender expert will critically analyse the gender data needs and parameterize these such that they are programmed into the tool. The tool will be able to collect data well disaggregated to represent gender aspects if proper planning was done in the beginning. Gender experts should be involved in the planning phase, particularly during exchange visits, to learn from other countries' experiences about how well gender data can be disaggregated and why it is important to have data broken down to this level. During the development stage, consider whether the data can be broken down to answer the following questions: how many females and males own land? How are the women and men distributed geographically? What are the age ranges for the men and women? what is the disability status of females and males owning land? how is the production disaggregated into females and males? This information is relevant when planning interventions that will target different categories of people and ages. The open-source tools should also be developed in such a way that they can accurately capture female and male data in varying cultural and religious contexts of different IGAD member states. It has been observed that in most cases, cultural and religious differences are associated with polygamy, and the recording of land rights should be carefully considered.

4.0 APPLICATION OF OPEN-SOURCE TOOLS

4.1 Introduction

The process described in this section refers to the application of open-source tools in the collection of land rights data for importation into a land information system. The application of open-source tools in land administration includes six major steps; raising public awareness of the tool and land rights, capacity building on the tool, adjudication, demarcation, approval, production and issuance of the certificates using the developed tool. The last section discusses the consideration of gender in the application of the developed tool.

4.2 Public awareness

4.2.1 Identification of pilot implementation areas

A pilot area for the tool should be carefully selected, taking into account the following factors; is there political and traditional support to have their land demarcated? Is there a basic infrastructure to support the application of the tool? Do we have the human capacity? How skilled is human capacity? What are the land administration issues we want to deal with in the area? What is the economic viability when a particular area is selected for implementation?

4.2.2 Mobilization and sensitization of stakeholders

The memorandums of Understanding (MOUs) should be developed between the implementors (consulting firms) with the Ministry responsible for land issues, District local governments/ decentralised structures of Government and Civil society organisations (including organising with gender and inclusion focus). In addition to the contracts that the consulting firms or implementing partners will have with the donors or international agencies facilitating the project. These will specify the roles and responsibilities of the different actors on the project to enable smooth implementation of the project. Each party will be aware beforehand of their tasks and terms of engagement. The ministry responsible for lands, district leaders, local level leaders and technocrats should visit the project site and the project objectives explained. During the visits, an evaluation should be done of the technical, infrastructure and human resource capabilities, and challenges and explore gender concerns which would affect the project implementation.

The mobilization and sensitization of stakeholders should be done at all levels that is international, regional and national. This is critical if the application of the tool is to be sustained over a long period.

4.3 Capacity building

4.3.1 Identification of trainers of trainers (ToTs)

Trainers of trainers should be identified before the training commences. These include the technical officers at the local levels and technical personnel from academia who are specialized in land management and administration. The majority of the trainers of trainees should be locally based. The trainers being locally based supports sustainability because training has to be continuous. The selection of local trainers also promotes a better impact of the knowledge as these have a better way of delivering the knowledge and skills. It has also been observed that the more local trainers you have, the cheaper the capacity building will be. For Capacity building, it's important to have a fair gender-balanced team.

4.3.2 Training of stakeholders

The stakeholders should be trained on the open-source tool to be used in adjudication and mapping. The team should further be trained in procedural and legal matters in adjudication and mapping. In addition, they should be trained on gender-responsive dispute resolution mechanisms which arise during the adjudication and mapping process, basic knowledge of computers, and the legal provisions in securing and recording land rights, gender and land rights.

4.3.3 Formulation of adjudication and demarcation teams

The adjudication teams should comprise a representative from the local land administrative unit, technical personnel (surveyor/GIS Expert/IT personnel/land registrar), a village local chairperson, a para surveyor or field assistant, an elder or chief and paralegal (optional) one of these should at least be a woman. The land registrars and paralegals should be available only when disputes arise during adjudication and should not be part of the field teams daily. The representative from the local land administrative unit represents the government and he/she ensures that the adjudication and demarcation are legally binding. The technical personnel are knowledgeable in using the technology and should provide mentorship to the para surveyor or field assistant. A coached para surveyor or field assistant ensures skill transfer as they are normally born and grow in the village where the projects are piloted. The village local chairperson guides the teams, based on this knowledge of the community members. A woman representative ensures that the rights of women are preserved during the adjudication and demarcation process. The elder or chief supports the teams by providing historic information on challenges in land rights during the adjudication and demarcation process. These are also instrumental when disputes arise on land. They are highly respected in the communities and are normally listened to when mediating

disputes on land during adjudication and demarcation. A field supervisor knowledgeable in mapping should be appointed to coordinate the different field teams.

4.3.4 Training of adjudication and demarcation teams

The members of the adjudication and demarcation team mentioned in section 4.3.3 should be trained together with the district technocrats, lower-level leaders and technocrats. These should be trained on land laws, adjudication and mapping, adjudication and mapping tool, gender land rights (gender sensitive registration), Alternative Dispute Resolution (ADR), Physical and land use planning, the process of land registration and management and storage of land data.

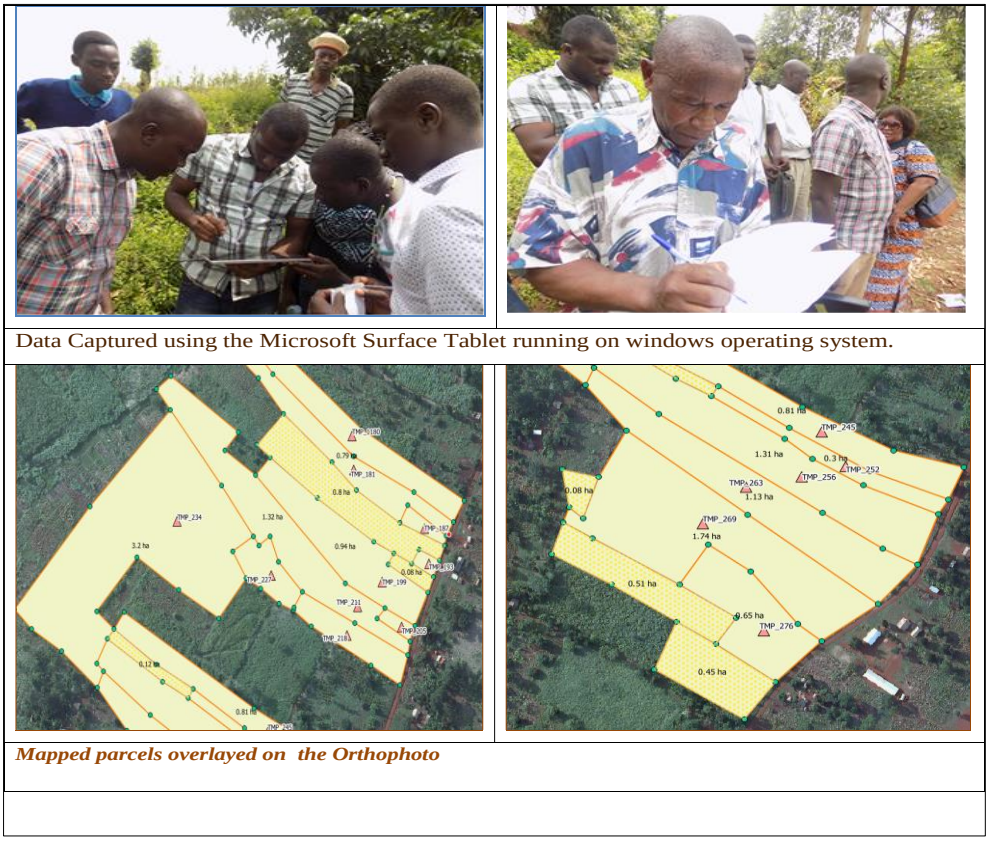

Figure 8: Training on data capture (spatial and textual).

4.4 Adjudication

4.4.1 Application or public notice

The local leaders and technocrats trained in the registration process should in turn assist the communities to fill in the application forms as specified by the law and regulations of a country. The applicants should be encouraged to pay the mandatory application and issuance fees but this should not be a stumbling block to the registration process. The fees even if can be paid by the donors, it is encouraged they be paid by the communities except for the most vulnerable. The

most vulnerable groups will include widows, single women, youth-headed households, People with Disabilities (PWDs), and the elderly among others. When beneficiaries pay a certain small portion, they shall attach more value to the document that they will receive. The communities should ensure that the applications are complete and filled and scanned to append to the software tool. Poorly filled application forms may be contested in the future and rights recorded may be overturned.

4.4.2 Adjudication process

This should be done following the regulations of a country ensuring complete adjudication. The gender-balanced adjudication and demarcation teams mentioned in section 4.3.3 should move over the whole parcel recording all the information about the parcel when in the field in the presence of witnesses and the local leadership. The adjudication process should be led by at least one technical personnel from the local level legally mandated to carry out the adjudication of parcels.

4.4.3 Dispute resolution mechanisms

Resolution of the disputes should be done from the application stage, through the adjudication stage and also at the mapping stage. It is discouraged to map parcels that are disputed and it is advised to forward such to the ADR committee and later court if not resolved. Beneficiaries whose disputes are solved within the duration of the project should be mapped. The project should encourage reconciliation and negotiation during mediation other than arbitration.

4.5 Demarcation

4.5.1 Mobilization of support data

Support data should be mobilized before the adjudication and mapping process is done. The support data includes administrative boundaries, location of protected or sensitive ecosystems for example wetlands, roads and forests, available high-resolution satellite data or orthophotos and the existing cadastral maps.

4.5.2 Monumentation of parcels

Monumentation of parcels is done during the adjudication process. When a boundary is confirmed, boundary markers should be fixed at all the corners in the presence of all the neighbours and witnesses. It should be discouraged to plant the monuments during mapping instead it should be done during the adjudication. Planting markers at mapping slows down the mapping teams' process.

4.5.3 Mapping

Mapping should be done with at least a member of the local technocrat, a field assistant, a village chairperson, representatives of vulnerable groups, and a para surveyor or student survey intern. The local technocrat guides on the legal processing in mapping, the para surveyor or student survey intern the mapping technology and the field assistant support the local technocrat, para surveyor or student survey intern. The mapping should be done using high-resolution satellite imagery or Ortho rectified Aerial Photos supported with GPS.

4.5.4 Data entry, cleaning and conversion

The data should be entered into the tool and uploaded onto the databases. After the upload, the data should be cleaned for possible overlaps or japs that may appear in the collected data. This should be a continuous process that is done daily to allow for efficient cleaning of the data. The respective data conversions could be done where necessary to support a cleaned database. It should be noted that this is done at the computer level before the data is later uploaded onto the national land information system. Issues of data interoperability at that level should be considered. A gender-balanced team should be trained in data entry, analysis and retrieval.

Figure 9: Data entry, cleaning and indexing operation

4.5.5 Public display

The cadastral maps of the mapped communities should be displayed every after two weeks in the villages for the communities to verify the mapped and recorded rights holders. When errors are identified, these should be rectified by the teams before preparations are made for the submission of the applications for approval. The communities should have access to check the collected information. An office should be established at the local level with personnel ready to support the community members seeking information. Preferably a map of the village neighbourhood is

plotted and stationed in a public place to allow the community to validate. They should only then visit the validation office if there are complaints. To address concerns of the illiterate groups and those with sight disabilities, there should be a social development expert assigned at every public display centre to support the vulnerable groups.

4.6 Approval, production and issuance of certificates (leases)

4.6.1 Approval of recorded rights

The applications should be checked and made ready for approval. The approval process should however be modified in a project situation. In a normal situation, the applications are few and can be handled with a few sittings over a long period. In a project setting, where applications are in orders of thousands, rapid approval is necessary which may not be provided for in the law. Support is critical with proper procedure to encourage rapid approval to ensure that the project does not stall as the project waits for the statutory sittings.

4.6.2 Export into the National (State) Land Information System

Issues of a standard data exchange format should be considered when exporting data to the land information system. This should have been considered at the development stage to avoid the back and forth at this stage. The government should have the collected data in its custody even if it has been collected at the local level and the law support storage of the data at such levels.

4.6.3 Production and issuance of certificates (Leases)

Clear structures should be set up to facilitate payments and document collection by communities. Awareness of the readiness of documents should be made as it has been observed for projects to produce a massive number of documents which have not been collected from the land offices because the communities are either not aware of the readiness of the documents or they feel the documents are safe at the land offices. The communities should also be sensitized on how to make utilization of the documents they receive. How to transfer, mortgage or place a caveat, post registration transactions should be fronted.

The provision of cabinets for the storage of paperwork from the adjudication and mapping process is critical. In addition to the manual paperwork is digital data which needs to be placed in a digital database requiring a computer. These have been observed to be absent at the local level in most of the IGAD member countries. Another challenge is that even when these are availed, the technical capacity to operate them is absent. The teams which are employed during the project implementation stop working at the issuance and then these offices are left with no one to support the prevailing structures. It should be noted that these projects introduce additional steps in land

administration which are not provided for by the government. Making these processes dependent on projects fail after the project ends.

4.7 Gender considerations in the application of the tool

The legal framework of a particular IGAD member state should be linked to the implementation of the tool at this level. A clear gender architecture should exist on how gender will be considered in the application process of the tool. The value women add to the implementation process should be emphasized to ensure that their participation and engagement are useful to ensure that all the key gender concerns in respective member states are taken into account and aimed at generating the required gender and sex-disaggregated data in line with national, regional, continental and global frameworks. Affirmative action has been implemented in different IGAD member states where 30 - 35% of the set of land institutions should be women. In addition, the implementation team should also have a basic understanding of gender in order to properly include gender into all procedures. The potential difficulties that each gender might experience when using the instrument should be evaluated. Before the application process, strategies to address these difficulties, which may differ greatly in each IGAD member states, should be established.,.

5.0 SUSTAINABILITY

5.1 Introduction

Sustainability means meeting our own needs without compromising the ability of future generations to meet their own needs. In addition to natural resources, we also need social and economic resources. Sustainability is very important when tools have been developed. The tools in most cases have been deployed in specific regions and it is planned to roll these out to the whole country. This however faces many challenges especially when support and funding from either international donors or the government are non-existent. The sustainability of the developed tools depends on the existing policy, capacity and resources in the IGAD country, otherwise the tools have been observed to be shelved after a few pilots.

5.2 Sustainability assessment

An assessment should be done to determine the tool sustainability challenges and these may be specific in each IGAD member states. The challenges may vary from political, cultural, religious, legal or economical. Each IGAD country may have these variations. When these are effectively determined, then ways to deal with these could be analysed and deployed.

5.3 Policy, capacity and Resources

5.3.1 Policy

The development and application of open-source tools in land administration will be sustainable and replicable provided a policy is in existence to support their development and implementation. The policy should give guidance on digital data creation, storage, sharing and authentication. A government may support the procurement of open-source tools more than proprietary ones. A policy for a country could be deliberate in promoting the use of open-source tools in land administration. It should be observed that one of the reasons the open-source tools have not been sustained after project implementation is that these are not necessarily fully provided for in the policies and laws at the time of development and application. This, therefore, necessitates the development of the policy and laws which fronts the development and application of these tools by all land officers and donors who support any interventions on land.

5.3.2 Capacity

Capacity should be built at all levels both in the development and application of these tools. Establishments should be made to support the development and application of open-source tools. The establishments should provide the technical personnel suited for the purpose and the

infrastructure. International and national networks are critical in addition to the availability of good internet, electricity, and computer infrastructures. The curriculum in academic institutions should be reviewed to incorporate the development and application of open-source tools in land administration. The staff at the land offices both at national and local levels could undergo training on the open-source tools at either initiation or refresher levels. A continued pool of skilled people in the development and application of open-source source tools should be promoted and not only stop at isolated project interventions by different development partners.

5.3.3 Resource

Resources are very important in the successful sustainability and replicability of the development and application of an open-source tool for land administration. It is not necessarily that because the tools are open source a budget is not necessary. A budget is necessary to hold policy review meetings, train stakeholders and provide the infrastructure that supports the development and application of open-source tools in land administration. Many times, consultants should be procured to participate in the development and these need to be paid. Self-financing models can be developed to support these tools at local levels through charges on the prevailing land transactions.

5.4 Open-Source Software Security

The security could be broken down into software, legal, infrastructure and data security. The developed open-source tool should be able to guarantee all the above security concerns. This will be done by ensuring good open-source software security.

Open-Source Security, commonly referred to as Software Composition Analysis (SCA), is a methodology to provide users with better visibility into the open-source inventory of their applications. This is done by examining components via binary fingerprints, utilizing professionally curated and proprietary research, matching accurate scans against that proprietary intelligence, as well as proving to developers this intelligence is directly inside their favourite tools.

Open-source software security is the measure of assurance or guarantee of the freedom from danger and risk inherent to an open-source software system. Proprietary software forces the user to accept the level of security that the software vendor is willing to deliver and to accept the rate at that patches and updates are released. It is assumed that any compiler that is used creates code that can be trusted, but it has been demonstrated by Ken Thompson that a compiler can be subverted using a compiler backdoor to create faulty executables that are unwittingly produced by a well-intentioned developer. With access to the source code for the compiler, the developer

has at least the ability to discover if there is any mal-intention. Simply making source code available does not guarantee a review. An example of this occurring is when Marcus Ranum, an expert on security system design and implementation, released his first public firewall toolkit. At one time, over 2,000 sites were using his toolkit, but only 10 people gave him any feedback or patches. Having a large number of eyes reviewing code can "lull a user into a false sense of security". Having many users look at source code does not guarantee that security flaws will be found and fixed.

5.5 Method of security system measurement

5.5.1 Number of days between vulnerabilities

It is argued that a system is most vulnerable after a potential vulnerability is discovered, but before a patch is created. By measuring the number of days between the vulnerability and when the vulnerability is fixed, a basis can be determined for the security of the system. There are a few caveats to such an approach: not every vulnerability is equally bad, and fixing a lot of bugs quickly might not be better than only finding a few and taking a little bit longer to fix them, taking into account the operating system, or the effectiveness of the fix.

5.5.2 Poisson process

The Poisson process can be used to measure the rates at which different people find security flaws between open and proprietary source software. The process can be broken down by the number of volunteers and paid reviewers. The rate at which volunteers find a flaw is measured and the rate at that paid reviewers find a flaw is measured. The expected time that a volunteer group is expected to find a flaw and the expected time that a paid group is expected to find a flaw.

5.5.3 Morningstar model

By comparing a large variety of open-source and proprietary source projects a star system could be used to analyse the security of the project similar to how Morningstar, Inc. rates mutual funds. With a large enough data set, statistics could be used to measure the overall effectiveness of one group over the other. An example of such as system is as follows:

1. 1 Star: Many security vulnerabilities.
2. 2 Stars: Reliability issues.
3. 3 Stars: Follows best security practices.
4. 4 Stars: Documented secure development process.
5. 5 Stars: Passed independent security review.

5.5.4 Coverity run

Coverity in collaboration with Stanford University has established a new baseline for open-source quality and security. The development is being completed through a contract with the Department of Homeland Security. They are utilizing innovations in automated defect detection to identify critical types of bugs found in software. The level of quality and security is measured in rungs. Rungs do not have a definitive meaning and can change as Coverity releases new tools. Rungs are based on the progress of fixing issues found by the Coverity Analysis results and the degree of collaboration with Coverity. They start with Rung 0 and currently go up to Rung 2.

1. **Rung 0**. The project has been analysed by Coverity's Scan infrastructure, but no representatives from the open-source software have come forward for the results.
2. **Rung 1**. At rung 1, there is a collaboration between Coverity and the development team. The software is analysed with a subset of the scanning features to prevent the development team from being overwhelmed.
3. **Rung 2**. 11 projects have been analysed and upgraded to the status of Rung 2 by reaching zero defects in the first year of the scan. These projects include AMANDA, NTP, OpenPAM, OpenVPN, Overdose, Perl, PHP, Postfix, Python, Samba, and TCL.

5.6 Comparison between proprietary and open-source software security

The battle between open-source and proprietary software has been throwing a fit for a long. Multiple issues and concerns are being examined and scrutinized by both sides of the story. In the most recent phase of this fanatical dispute, both camps have inspected the issue of security with serious tenacity.

Proprietary software is more secure than open-source software. This myth comes from many prejudices. But a commercial license doesn’t assure security. Unlike proprietary software, open-source software is transparent about potential vulnerabilities.

Closed-source software or proprietary software might be more secure since the code is not available. But unfortunately, it is not the case! The contribution and development teams of proprietary software are smaller, which makes it evident that there is a probability of missing out on mistakes and bugs in the code. You might not know what issues the proprietary system has had in the past or is having currently because the provider of the proprietary software isn’t going to voluntarily reveal this information. This sets a major drawback for proprietary software users in terms of security as well.

There are myths about proprietary and open-source software and tools that need to be debunked. These include;

1. Anyone can view the code. Because it is open source, anyone can view the code. People often want to argue that being able to view the code allows nefarious hackers to look at it and exploit vulnerabilities. However, this openness enables collaboration. Unlike, say, one proprietary software, which is developed and maintained by a single company, Drupal is developed and maintained by more than one hundred thousand programmers around the world. These programmers might work for companies that compete with each other, or they might volunteer to create something new that's then given away. For free. In fact, in 2015 Google open-sourced its artificial intelligence engine, TensorFlow. Something which is a core part of its business. It hoped more developers would make the software better as they adapted it to their own needs. And it did, by making it open source, Google boasts of more than 1,300 developers, outside Google, who have worked on TensorFlow making it one of the standard frameworks for developing AI applications, which could bolster its cloud-hosted AI services.
2. Proprietary software is secure and not prone to attacks. There have been multiple instances in the past that depict that proprietary software has been attacked several times. Such as:
    i. **Melissa Virus and ILoveYou Worm.** It spreads through Microsoft Word email attachments. The email contained an attachment. If the victim's system had the Microsoft outlook application installed, then the virus would send the email to 50 to all contacts in the Outlook program's address book. It would also overwrite & consequently destroy various types of files on the victim's device including MP3 files, JPEG files, and more. It led Microsoft to shut down its inbound email system.
    ii. **Wannacry**. A worldwide cyberattack took place in 2017. It was a ransomware crypto worm attack that aimed at computers using Windows operating systems, encrypting all the files on hard drives on these machines. It didn't let users access the files until they paid a ransom in the cryptocurrency Bitcoin. With that said, it's evident that proprietary software is also easily vulnerable to attacks.

5.7 How to protect yourself when using open-source software and tools

Enterprises need to secure not just the code they write, but also the code they consume from open-source components. That's why many organizations are using Sonatype to automate open-

source governance at scale across the entire SDLC, shifting security left within the development and build stages.

To discover the best-in-class, integrated solution for custom code and open-source code security with Fortify and Sonatype. With integration to Fortify on Demand, precise open-source intelligence provides a 360-degree view of application security issues across the custom code and open-source components in a single scan. You can perform searches for Open Source and Custom Code Vulnerabilities in a Single Scan and Dashboard.

There are standard practices that could be adopted to ensure security when using open-source tools and these include;

1. Adoption of newer free open-source software upgrades whenever they are available. Each release made in the open-source community is with improved protection from vulnerabilities and bugs.
2. To be critical of the type of open-source components adopted. It has been observed that some opponent source components may have dependencies, which dependencies be points of weakness through which a system may be attached.
3. Continuous monitoring should be done to detect when a potential risk is possible. This is a standard procedure done not only for open-source software and tools but also for proprietary equivalents
4. Internal capacity should be built on how to maintain system security when open-source software and tools are used. This should be tagged on the contract during the development of the tools by the external consultants.

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GLOSSARY OF WORDS

The terms below are commonly used both internationally and nationally in land governance. It is necessary to provide their definitions in the context of the legal and administrative perspectives.

Terms	Definitions
Adjudication	Adjudication is the process whereby all existing rights in a particular parcel of land are finally and authoritatively ascertained. It is the ascertainment and conclusive determination of rights in land.
Adjudication Team	The technical and community group of individuals who carry out adjudication and demarcation of parcels as well as record the rights holders of the parcels.
Cadastre	A parcel-based and up-to-date land information system containing a record of interests in land (i.e., rights, restrictions and responsibilities)
Cadastral Survey	The branch of surveying is concerned with the survey and demarcation of land to define parcels of land for registration in a Land Registry.
Communal Land Rights	Those that arise when land is used by a group of persons which is clearly defined as collective and, the group has the right to exclude third parties from the enjoyment of those rights.
Community Land	That land under the use, care and management of a specific or identifiable community subject to the rules and customs of that community
Customary Tenure	The holding of land under the customs of a given community. It is provided for in the Constitution of Uganda and regulated by the Land Act (1998) Cap 227.
Dispute Resolution	The process of resolving disputes (land); in Uganda, we have a parallel dispute resolution mechanism including the formal or judicial through the courts, the quasi-formal or administrative courts or mediators also known as state-administered or

	sanctioned alternative dispute resolution (ADR) mechanisms. The informal dispute resolution systems involve community or cultural leaders, elders, and village assemblies whose decisions can have formal recognition by the state once registered at the magistrate's court.
Freehold land tenure	The holding of registered land in perpetuity is subject to statutory and common law qualifications.
Group	A collection of households or kinfolk residing in a locality and operating under some common organization or set of rules and norms which is recognized by the State. Some of these groups include forest dwellers and nomadic and pastoral communities. In the urban context, these groups include organized informal settlements, collectively organized migrants who cluster in a particular locality and clusters of traditional communities.
Informal Settlement	The occupation of an area by a group of individuals (households) that is not legally registered in the name of the occupiers. It is unplanned and without access to social goods such as roads, water and power.
Indigenous	Refer to "Indigenous Peoples" in a generic sense to refer to a distinct social and cultural group possessing the following characteristics in varying degrees: Self-identification as members of a distinct indigenous cultural group, recognition of this identity by others, language, customary social and political institutions, and primary subsistence-oriented production.
Land	Generally, this applies to the universe and its natural resources including, water, minerals, rocks, forests and trees. "Land: any portion of the earth over which rights of ownership, stewardship or use may be exercised, including the earth's surface, water-covered lands, water and mineral resources, as well as features and resources attached to the earth whether they be natural or artificial. For anything to become a part of the land by attachment it must be so attached to the land and it becomes a part of the land.

Land Administration	The processes of determining, recording and disseminating information about different tenures, values and use of land when implementing land management policies.
Land dispute	A contestation over land and rights in land. A land dispute occurs where a specific individual or collective interests relating to land are in conflict
Land management	The all-encompassing process of managing the use and development of land and land-based resources in both the rural and urban settings
Landowner	Any person who owns a piece of land. However, people who live and use the registered land of another person are tenants
Land Parcel	A clearly defined piece of land belonging to a person or group of persons
Land Rights	Entitlements (inherent and otherwise) that a person enjoys in a piece of land, are acquired through many ways including purchase, inheritance, marriage, gift, rent or tenancy, or adverse possession.
Land Tenure	How people hold land. It is the relationship among individuals concerning land. This relationship can be legal or customary. Land tenure is also an institution, and the rules governing land tenure were invented by societies to regulate the behaviour and use of resources. Tenure rules define how property rights to land are allocated within societies.
Land tenure systems	Which explains who can use what resources and for how long; they assign rights in land to an individual or entity that is said to "hold" the land.
Land title	The legal document issued by the Government recognises a registered person as the owner of that particular piece of land.
Legal Framework	The Judicial, statutory and administrative systems include laws, regulations, bylaws, directions and instructions that regulate society and set enforcement processes.

Mailo Tenure	The land is titled land whose incidents arose out of the 1900 Buganda Agreement between the colonial administration and the Buganda Kingdom.
Mapping	The use of technically advanced geographic information technologies, such as aerial photography, remote sensing technology and Geographic Information Systems (GIS) for land and natural resource rights, use and management.
Otho photo Map	A raster image, of a landscape, such as an aerial image has been rectified (e.g., for relief distortions) to possess the geometrical properties of maps such as coordinate systems and scale.
Open-source tools	These are software tools that are released under a permissive license that allows the study, modification and redistribution of source code of the software by the user for any purpose.
Registered Land	Refers to land that has been surveyed and the rights of the holders of that land are recorded in the land administration system. It should be noted that surveyed land whose particulars are recorded may not necessarily have a final certificate or title issued.
Tool development	Refers to a set of computer science activities dedicated to the process of creating, designing, deploying and supporting software. The software itself is the set of instructions or programs that tell a computer what to do.
Tool Application	This for this manual will mean the implementation of the developed tool. This will be the use of the tool to collect data on land rights.