World Bank Guide

New Technology and Emerging Trends: The State of Play for Land Administration

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Acronyms

CORS	Continuously Operating Reference Stations
CoFLAS	Costing and Financing of Land Administration Services (for Developing Countries)
CSO	Civil Society Organization
FFP	Fit For Purpose
FOSS	Free and Open Source Software
GLTN	Global Land Tool Network
GNSS	Global Navigation System of Systems (includes GPS)
GCP	Ground Control Points
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICT	Information and Communication Technology
LADM	Land Administration Domain Model
MAST	Mobile Application for Secure Tenure
M&E	Monitoring and Evaluation
NGO	Non-Governmental Organization
OCR	Optical Character Recognition
OSM	OpenStreetMap
RFID	Radio Frequency Identification
RTK	Real-Time Kinematic
SOLA	Solutions for Open Land Administration
SQL	Structured Query Language
STDM	Social Tenure Domain Model
UAS/UAV	Unmanned Aerial Systems/Vehicles
VGI	Volunteered Geographic Information

Preface

In many parts of the world, people do not need to think about the security of their land rights. They are simply taken for granted, either as landlords or tenants. However, for the majority of the world's poor, secure property rights are a rare luxury. Only 30% of the world's population has a legally registered title to their land.

Secure land rights are important for reducing poverty and boosting shared prosperity at the country, community, and family levels. Land rights are fundamental to stimulating investment and growth, particularly in agriculture and infrastructure; for supporting countries and their people in building resilience by preventing land-takings and mitigating forced migration. Addressing land tenure issues is at the center of building sustainable communities. This agenda cannot be achieved without having good land governance in place - including the operational component of land administration systems.

Attempts to introduce conventional (western style) land administration solutions to close the security of tenure gap have lacked success due to weak institutions, inappropriate laws and regulations, high costs, complexity, lack of capacity (especially land surveyors), inadequate maintenance and long implementation time frames; these solutions are not solving the global land issues and in many cases, are only strengthening the hold on land by the elite. New innovative solutions are required to build affordable, pro-poor, scalable and sustainable systems to identify the way all land is occupied and used. The Fit-For-Purpose (FFP) approach (FIG/WB, 2014) (UN-HABITAT / GLTN, 2016) to land administration has emerged as an enabler, accelerator and game changer and offers a promising, practical solution to provide security of tenure for all and to control the use of all land.

The FFP land administration approach provides flexibility in the accuracy specification for recording land rights and opens up the opportunity to use innovative new technologies that are highly participatory and scalable. This Guide is reacting to this significant opportunity and provides decision support to designers of Land Administration programs requiring guidance on what new and emerging technologies could be effectively adopted and integrated within their programs. This guidance aims to ensure that the capture, management and dissemination of land rights information will be achieved using the most cost-effective solutions, meets the accuracy requirements, matches the technical resources within the country, is compatible with social cultures and can be implemented quickly over large areas.

The World Bank expects that this Guide will be instrumental in paving the way forward towards implementing sustainable and affordable land administration systems in developing countries, enabling security of tenure for all and effective management of land use and natural resources. This, in turn, will facilitate economic growth, social equity, and environmental sustainability.

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Who is the target audience for this guide?

The Guide has the following target audience:

World Bank: Staff providing guidance to developing countries designing their land administration programs; staff specifying land administration programs for developing countries.

Donors: Donors providing guidance and aid to developing countries designing their land administration programs.

Policy & Strategy Makers: Senior civil servant decision-makers involved in formulating policies in the land sector; senior level staff in land administration / management agencies.

Implementers: Public and private sector land professionals involved in land administration; NGOs / CSOs.

The Guide, supported by the 'Nordic Trust Fund - A Knowledge and Learning Program for World Bank Staff on Human Rights', has been primarily created by the three authors: Robin McLaren, Kate Fairlie and Giles D'Souza.

The authors would like to acknowledge the guidance of Kathrine Kelm who supervised this project

1 INTRODUCTION

Solutions to the overall global land issues must result in poverty alleviation, social inclusion and stability, investments and economic development, and environmental protection and natural resource management. These land matters are now embedded in the Sustainable Development Goals (SDGs) that form a blueprint for a sustainable future agreed by all the world leaders.

This new agenda presents a historic and unprecedented opportunity to bring the countries and citizens of the world together to decide and embark on new paths to improve the lives of people everywhere, especially within the spirit of the Voluntary Guidelines on Responsible Governance of Tenure (VGGTs), which set out principles and internationally accepted standards for practices for the responsible governance of tenure: public, private, communal, indigenous, customary, and informal. However, this agenda cannot be achieved without having good land governance - including the operational component of land administration systems in place.

> A Land Administration System provides government with an infrastructure for securing land tenure rights, determining valuation and taxation of land, and managing the use of land and land development. It sits within the principles of responsible land governance and the overall framework of National land policies (Enemark et al., 2016).

Even if security of tenure is now placed at the top of the global agenda, there is a “security of tenure gap” between countries that have efficient and effective land administration systems in place, and those who do not; at a global scale the ratio is currently about 30 to 70 per cent, of those who do versus those who do not.

While recognizing that progress will depend on a country's ability to understand, interpret, select, adapt, use, transmit, diffuse, produce, and commercialize technological knowledge in ways appropriate to its culture, aspirations and level of development, it must also be recognized that over many decades attempts have been made to establish land administration systems in developing countries without much success. Constraints relate to a range of legal, institutional and political issues – but also to the fact that implementation of traditional, Western style land administration systems is simply too costly, too time consuming and too demanding of capacity that does not always exist. It is estimated that by current rates, tools and methods, it will take many decades, and probably centuries, to achieve anywhere near full global coverage, because existing methods are simply too difficult to scale-up.

Fit-For-Purpose (FFP) Land Administration Context of Guide

The Fit-For-Purpose (FFP) Land Administration approach (Enemark, et al, 2016) provides an innovative and pragmatic solution to land administration. The solution is focused on developing countries, where current land administration solutions are not delivering, with often up to 90 per cent of the land and population left outside the prevailing formal version. The approach is directly aligned with country specific needs, affordable, flexible to accommodate different types of land tenure, and also upgradable when economic opportunities or social requirements arise. It is highly participatory, can be implemented quickly and aimed at providing security of tenure for all. Most importantly, the FFP approach can start very quickly using a low risk entry point that requires minimal preparatory work. It can be applied to all traditions of land tenure across the globe.

To significantly accelerate the process of recording land rights, the FFP Land Administration approach advocates the use of a range of scales of imagery as the spatial framework on which to identify and record visible tenure boundaries. This fast, affordable and highly participatory approach is appropriate for the majority of land rights boundaries. Using imagery also allows the spatial framework to be used by many other land administration and management activities and generate wider benefits.

Security of tenure does not in itself require precise surveys of the boundaries. The most important aspect of security of tenure for the majority of unregistered land parcels is identification of the land object and its relation to neighboring objects, in relation to the connected legal or social right. The absolute precision of the survey is less important, except perhaps in high value land and properties, and non-visible or contested boundaries when higher precision, but more costly conventional ground survey methods and monumentation, may be necessary.

Rather than mandating a single surveying specification for capturing land rights across an entire country, the FFP approach supports flexibility in adopting a variety of techniques to capture the land rights depending on local circumstances, a flexibility that will ensure lower costs and higher speeds in the capture of land rights (see Appendices B.10 *Spatial Framework* and B.11 *Legal, regulatory and institutional frameworks*). However, this does require that those designing the FFP projects are familiar with and able to select the most suitable options from the myriad of emerging technologies and solutions that show significant promise in accelerating the process even more. This raises questions such as:

- Which imagery (satellite, aerial or drone) and what resolution are appropriate?
- Should we continue with paper orthophotomaps to support mapping and adjudication participation? Or should we adopt mobile technologies?
- How does urban density influence our choice of survey technique?
- Do community mapping and rights adjudication tools have a role to play within formal land administration systems, and can they support mainstream activities?
- Is automatic extraction of linear and settlement features suitable for land administration?
- Are modern SMS or other mass media approaches appropriate to raise public awareness of land registration programs?
- What are the key technological gaps and emerging trends?

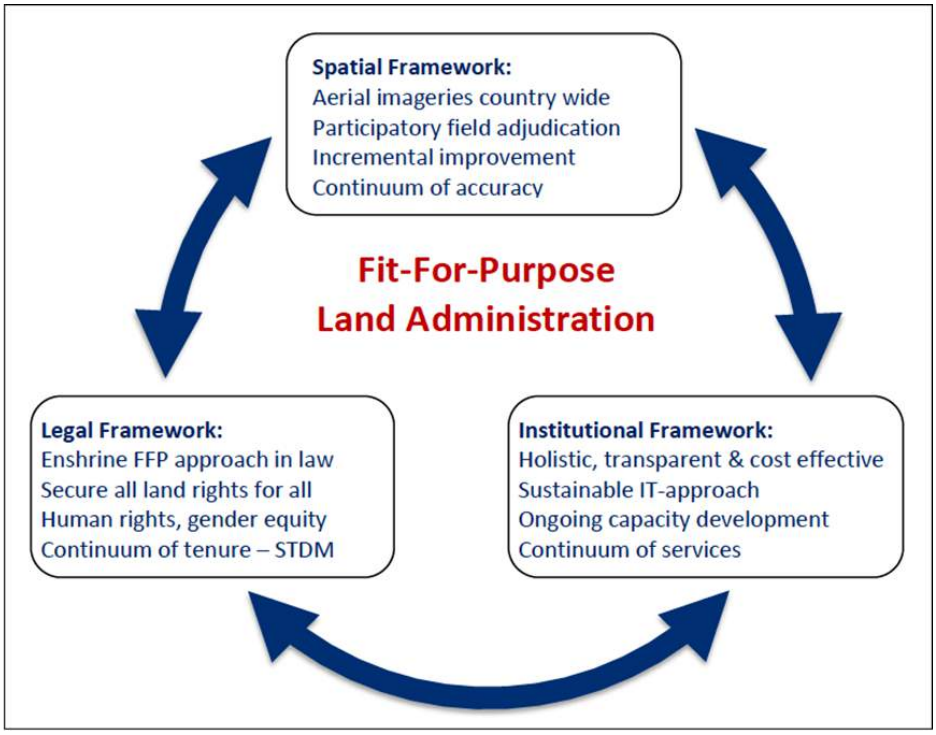
The purpose of this Guide on “New Technology and Emerging Trends: The State of Play for Land Administration” is to provide designers of country-specific FFP Land Administration strategies with guidance on the current status of technology and emerging trends. This should allow the most appropriate technical solutions to be adopted in designing and implementing the Spatial Framework for the FFP Land Administration approach. This guidance will aim to ensure that the capture, management and dissemination of land rights information will be achieved using the most cost-effective solutions, meets the precision and accuracy requirements, matches the technical resources within the country, is compatible with social cultures and can be implemented quickly over large areas.

The building of the spatial framework is not a one-off process. It should be upgraded when opportunities and needs arise through land development and infrastructure activities and improved land and natural resource management. Upgrading strategies will allow incremental improvements towards a spatial framework in line with modern and fully integrated land information systems when they are needed and can be sustained.

This Guide should be used in conjunction with the GLTN sponsored “Fit For Purpose Land Administration: Guiding Principles for Country Implementation.” (Enemark, et al, 2016). The FFP concept includes three core components: the spatial, the legal, and the institutional frameworks – see Figure 1. Each of these components includes the relevant flexibility to meet the actual needs of today, yet can be improved incrementally over time in response to societal needs and available financial resources. The three framework components are inter-related and form a conceptual nexus underpinned by the necessary means of capacity development. Each of the frameworks must be sufficiently flexible to accommodate and serve the current needs of the country within different geographical, judicial, and administrative contexts.

Hence, although this Guide covers technology solutions, it is imperative that the decision making process on technology is made with the full understanding of the impact on the legal and institutional frameworks. Importantly, prior to building the spatial framework and issuing any certificates of land rights, it must be ensured that the regulations and institutions for maintaining and updating the FFP land administration system are in place. Without the institutional capacity and also incentives for the parties to update the system in relation to the transfer of land rights and land transfers, it will quickly be outdated and unreliable and lead to waste of investments for building the system in the first place.

Figure 1: The Fit-For-Purpose Concept and associated Frameworks (Enemark, et al., 2016)

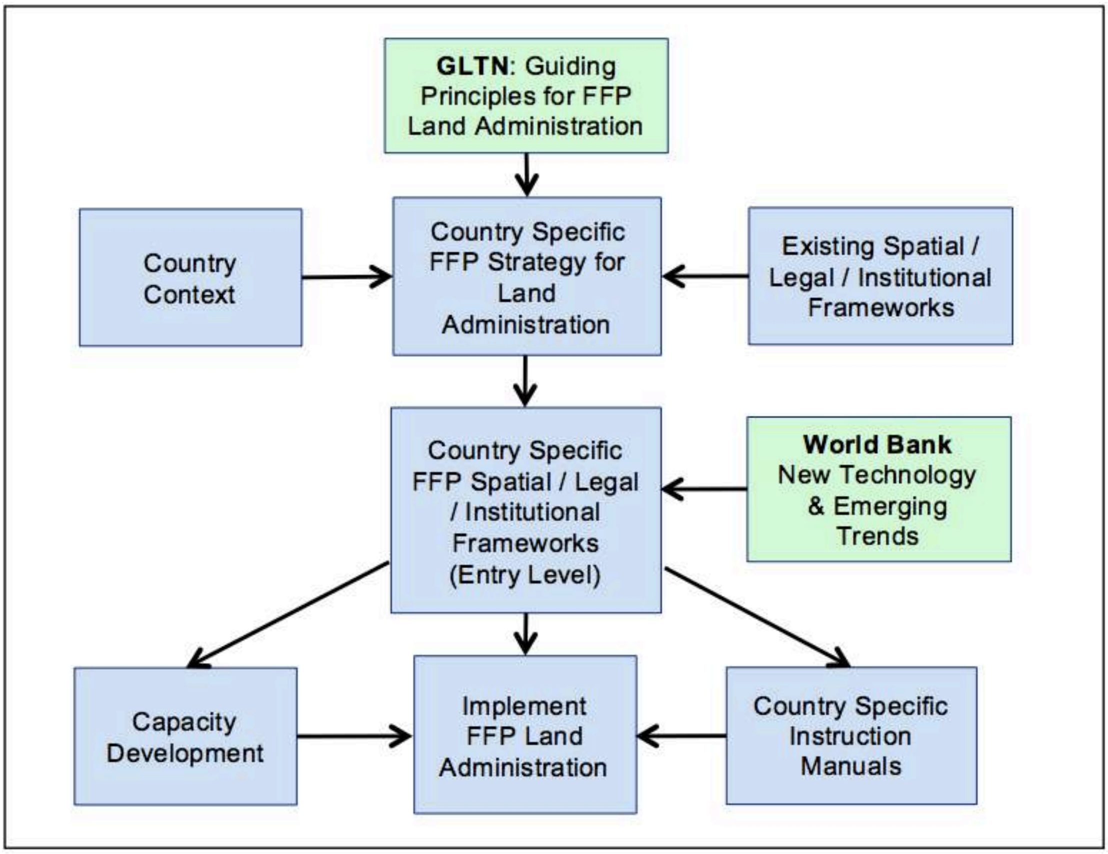


2 OBJECTIVE & SCOPE OF GUIDE

Objective

The process of creating a country-specific FFP strategy for land administration is illustrated in Figure 2. This will be based on a country context analysis and the baselines of the existing spatial, legal and institutional frameworks. The country context analysis will involve identifying the conditions and policies prevalent within country that constrain and shape the way that FFP land administration can be implemented within the country. An analysis of the existing spatial / legal / institutional frameworks will define the current approaches and identify any constraints for change. The GLTN "Fit For Purpose Land Administration: Guiding Principles for Country Implementation." (Enemark, et al, 2016) will then be used as a set of guiding principles to create the country-specific strategy for building the spatial, legal and institutional framework for implementing FFP Land Administration that will also require provision of capacity development measures as well as country specific manuals.

Figure 2: Use of World Bank Guide in Implementing Country Specific FFP Land Administration (adapted from Enemark et al., 2016)



This World Bank "New Technology & Emerging Trends" Guide provides decision-support in formulating the Country Specific Spatial Framework – see Figure 2. This will allow the most appropriate technical solutions to be adopted in designing and implementing the Spatial Framework for the FFP Land Administration approach. This guidance will ensure that the capture, management and dissemination of the associated land rights information will be achieved using the most cost effective solutions, meets the accuracy requirements, matches the technical resources within the country and can be implemented quickly at scale.

Role of Guide in Context of World Bank's Land Administration Agenda

The World Bank promotes foreign direct investment into developing countries to support economic growth, reduce poverty, and improve people's lives. One of the key themes running through the World Bank's activities to achieve these objectives is land. Secure land rights are important for reducing poverty and boosting shared prosperity at the country, community, and family levels. Land rights are fundamental to stimulating investment and growth, particularly in agriculture and infrastructure; for supporting countries and their people in building resilience by preventing land-takings and mitigating forced migration.

In dealing with this land agenda, the global land team, within Social, Urban, Rural and Resilience, needs to find ways to address the demands of the 70% of the World's population that do not have access to land administration services to legally register title and safeguard their land. The adoption of emerging technology, within the context of the Fit-For-Purpose Land Administration approach, has huge potential to create innovative solutions that are efficient, low cost, scalable, highly participatory, upgradable and flexible within the continuum of rights. This Guide is reacting to this significant opportunity and provides decision support to designers of Land Administration programs requiring guidance on what new and emerging technologies could be realistically and effectively adopted and integrated within their programs. The World Bank expects that this Guide will be instrumental in paving the way forward towards implementing sustainable and affordable land administration systems in developing countries, enabling security of tenure for all and effective management of land use and natural resources.

Scope of Land Administration Processes Analyzed for Technology Support

The extent of land administration systems is illustrated in Figure 3 and includes land tenure, land value, land use and land development.

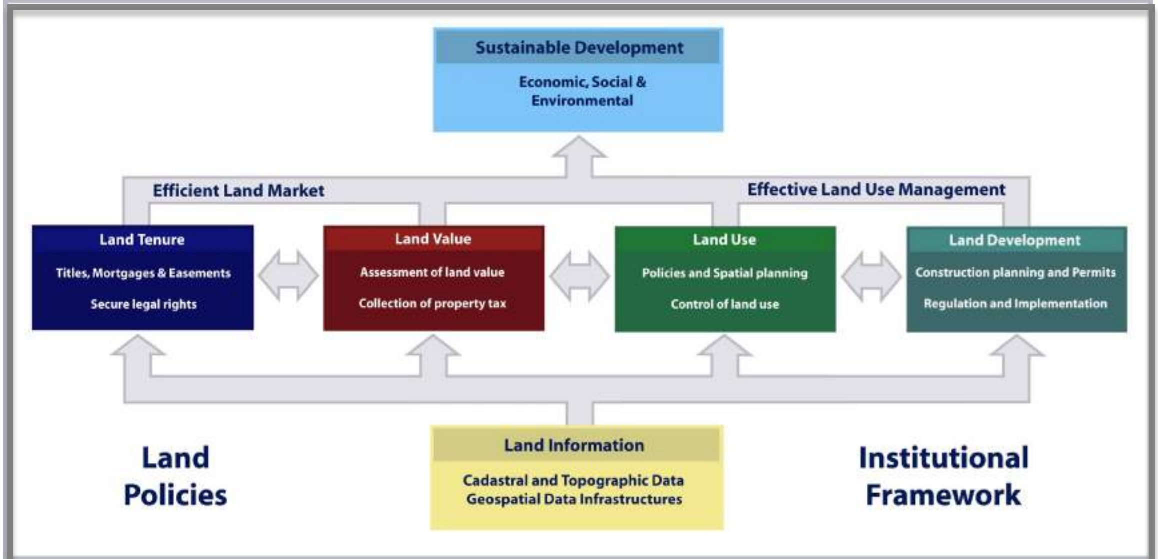
The focus of this Guide will be on the land tenure (land and resource rights) component of land administration and the following aspects will be covered for technology support:

- Identifying perception of insecurity of tenure;
- Raising public awareness of land tenure programs;
- Identifying and digitizing existing records prior to field work;
- Extracting land rights boundaries from imagery prior to field work;
- Capturing and adjudicating land rights in the field;
- Managing and maintaining of land rights;
- Accessing and disseminating of land rights;
- Managing land transactions; and
- Integrating land administration with National Spatial Data Infrastructures.

Some of the technology solutions reviewed operate within formal land administration systems (for example **Appendix A.8 MAST**). However, some of the bottom-up technology solutions reviewed, such as STDM (**Appendix A.12**), Cadasta

(**Appendix A.9**) and Landmapp (now called Meridia) (**Appendix 1.10**), operate successfully in the informal sector, and in many cases, act as a stimulus for governments to react to the insecurity of tenure problems in their countries.

Figure 3: Land Administration Systems (Williamson et al., 2013))



Land Tenure:	Allocation and security of rights in lands; legal surveys of boundaries; transfer of property.
Land Value:	Assessment of the value of land and properties; gathering of revenues through taxation.
Land-Use:	Control of land-use through adoption of planning policies and land-use regulations at various levels.
Land Development:	Building of new infrastructure; implementation of construction works and the change of land-use.

Most land administration solutions are a hybrid of proprietary software and FOSS and the Guide captures this combined approach, however a number of new innovations to approach (rather than technology) have also occurred in the FOSS domain. In combination, open source, open data and open standards are fuelling some of the most innovative solutions in development.

Table 1: How new technology use may overcome previous delays / objections

Possible or previous delay/ objection	Emerging methods that can help overcome objection
Not enough skills and equipment to make precise surveys	Use image-based techniques, with trusted intermediaries to map boundaries and attach rights to them in a participatory and locally accepted process. Adopt paper orthophotomaps and/or digital-assisted methods for boundary delineation. Upgrading is possible when and if necessary.
Waiting for CORS to be established	A network of CORS is not a direct prerequisite for applying a FFP approach to building a national land administration system. In the FFP approach, the spatial framework is mostly built by using aerial / satellite imagery for identifying the individual parcels, and the production of such a spatial framework does not require a network of CORS as a prerequisite. High geodetic accuracy may well be seen as the end target

Possible or previous delay/ objection	Emerging methods that can help overcome objection
	– but not as the point of entry.
Monumentation is prohibitively expensive	Ensure that FFP principles are adopted. Monumentation may not be needed, but where required under legislation or deemed necessary by stakeholders, dwellers should be encouraged to place their own features as boundaries (e.g. trees, bushes, etc.). If this is insufficient, modern demarcation methods like RFIDs can be used. (These are Radio-frequency identification markers that use electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information. Passive tags collect energy from a nearby RFID reader's interrogating radio waves). They can be made quite robust and. can store administrative and positional data, and eliminate costly drawbacks of traditional concrete markers.
Waiting to procure hardware and software to manage the data	Use freely available satellite imagery and OpenStreetMap (OSM) data and systems/services for reconnaissance mapping, upload and management all non-sensitive data. Volunteered Geographic Information (VGI) methods can be harnessed at all stages of land administration activities.
Lack of common data model/standard in which to record rights	Use advances in standards, e.g. LADM and STDM to collect and format data. The Open Geospatial Consortium (OGC) has also established a Land Administration Domain Working Group, seeking to identify enabling standards and best practices to guide countries in a programmatic way towards establishing more cost-effective, efficient and interoperable land administration capabilities.
Too costly or takes too long to procure professional supporting software, e.g. GIS and databases	Top-down, many national and cadastral agencies can get site-wide licenses for surveying and ICT products. Increasingly there is an alternative choice to proprietary solutions. Modern advances in FOSS tools such as: - PostgreSQL and other professional databases - QGIS provide solid, suitable platforms on which to build professional and sustainable solutions
Difficulty in establishing/proving property boundaries	Use and promotion of visible boundaries on imagery as ancillary/surrogate proof of boundary location.
Difficulty in handling previous records	Use modern methods of mass scanning, OCR and digitizing to capture previously recorded rights and dwellers. Photograph in the field if evidence available.
Lack of computing infrastructure	Use modern cloud-based techniques, which are easy to establish and deploy locally or remotely for a time. **CAVEAT: Ensure proper ICT security to prevent hacking** Also, consider blockchain approaches for more secure time-stamped and auditable distributed rights registration, accessible by public and private groups – although not fully proven technology.
Lack of addressing to support title/rights issuance	Universal access to GNSS-based locations on simple digital devices is providing simple and effective

Possible or previous delay/ objection	Emerging methods that can help overcome objection
	locational methods. Initiatives such as what3words are providing further reliable innovation
Previous methods have been biased towards certain groups	Ensure all initiatives are sensitive to marginalized groups, and gender-equity, especially in the recording of rights.
Lack of knowledge about the population, land use patterns and natural resources in an area	Use global imagery databases, collation of previous census data and rapid mapping techniques for quick collation of population profile, land use patterns and natural resources, terrain
Lack of ability for effective public awareness	Use of modern public awareness raising techniques, including local and social media.
Poor monitoring and evaluation baselines	Use of above techniques to create base line information on perception and actual security of land tenure. PRindex is emerging as a possible methodology.
Forgery of records	Use of mobile/smart-phone technology for proper biometric recording of land rights holders. Often can read and link to national ID card systems where these are operational. Use of 2 and 3-D bar codes embedded in certificates for proving reliability of issued records.
Non-Government initiatives clash with Government ones	Non-Government (informal) initiatives need to engage with Governments to ensure that the standards and methods employed are approved by government and the captured land rights will be recognized.
Rights captured by non-Governmental programs or bodies are “less valid” than “officially-recorded” ones	There are several initiatives and recognized processes of including legitimate tenure types in the formal system through the revision of legislation is called national ‘recognition’

Scope of Technology Solutions and Approaches in this Guide

This Guide reviews and assesses new technology solutions that are currently operating successfully in land administration systems, but also emerging disruptive technologies that could significantly accelerate the land administration processes. This will allow the risk of when, and if, to adopt this emerging technology, to be judged. Although there have been advances in supporting technologies such as enterprise content and document management, optical character recognition and biometric recording of individuals, these are not considered here. This emerging technology will include, for example:

- Use of social media to engage with land stakeholders;
- Use of appropriate imagery sources (satellite, aeroplane or drone) to map parcel boundaries, with AI or crowd-sourced solutions to extract features from imagery, and/or extraction of land parcel boundaries from point clouds if LiDAR is collected simultaneously;
- Use of effective emerging methods for capturing rights in the field using smartphones or tablets, and/or auto geo-referencing of interpreted, participatory map-sketching; and
- Use of cloud and/or blockchain technology for immutable recording and management of rights.

These are particularly powerful when combined with less recent technologies, such as:

- Use of freely-available satellite imagery and OpenStreetMap (OSM) data for reconnaissance mapping of the study area to identify possible issues and stakeholders;
- Use of portable digital devices and crowdsourcing techniques to record inhabitants and attitudes (hopes and fears) about land rights; and
- Use of modern data model standards (LADM and STDM) for defining, recording and managing rights, restrictions and responsibilities, especially ensuring no gender or other bias.

The guide will clarify which of the identified techniques are fully operational, what is still in the early piloting phase and what is still pure research.

It is emphasized that the technologies and approaches reviewed here do not represent an exhaustive nor exclusive list, but provides an indication of good practice and emerging trends that should be reviewed alongside additional consultations.

References

Enemark, S., McLaren, R. and Lemmen C., 2016. “Fit For Purpose Land Administration: Guiding Principles for Country Implementation.” UN-HABITAT, GLTN, June 2016.

‘Land Administration and Sustainable Development’, Williamson, I., Enemark, S., Wallace, J. and Abbas Rajabifard. Esri Press, 2013. Retrieved from http://www.esri.com/landing-pages/industries/land-administration/e-book?sthash.I74pPRzE.O531YERd.mjjo&goback=.gde_3731775_member_244210541#sthash.I74pPRzE.QHCUFMtX.dpbs (Last accessed 25 February 2015).

3 STRUCTURE OF THIS GUIDE

The following sections of the Guide lead the reader through the decision-making process in identifying the most appropriate technology options to be adopted in their land administration programs. They are divided into four main parts:

1. Role of Technology – Information Capture.
   - Public Awareness and Preparation
   - Background Information Capture
   - Capturing Land Rights in the Field
2. Role of Technology – Managing, Maintaining and Disseminating the Information.
   - Data Management
   - Data Access
3. Further Key Considerations
   - This section identifies additional considerations largely beyond the scope of technologies and approaches reviewed, including institutional and legal frameworks, capacity development and sustainability.
4. Appendices
   - Appendix A: Detailed descriptions of the new and emerging technology solutions.
   - Appendix B: Detailed discussion on key considerations to support choice and implementation of the technology solutions.

Sections 1 and 2 provide the following decision support structure:

- A short description on the land administration component processes covered by this section.
- A decision support diagram guiding the user through the key decisions.
- The main body of text then directly addresses key considerations and decisions to be made, referring to the corresponding existing and emerging technology/approach descriptions in Appendix A and additional 'key considerations' sections in Appendix B.
- Short case study examples provide experiences with applying the technologies.

An overview of the Guide structure is illustrated in

Table 2: Structure of Guide and Appendices

Table 2: Structure of Guide and Appendices

Chapter	Section	Technologies/Approaches Refer to (Appendix A)	Key Consideration Sheets (Appendix B)	Illustrative Case Studies
4. Role of Technology - Information Capture	4.1. Public Awareness and Preparation	A.1: PRIndex (Perceptions of tenure security) A.2: Social media for land administration	B.1 CoFLAS B.2 Trusted Intermediaries B.3 Formal and Informal Land Rights B.5 Public Awareness	
	4.2. Background Information Capture	A.3: Use of unmanned Aerial Systems (Drones) A.4: Automated Feature Extraction	B.6 Imagery Sources and Comparisons	1. Kosovo UAS
	4.3. Field Information Capture	A.5 Paper Orthophotomaps A.6 Field Papers A.7 Smart Sketchmaps A.8 MAST A.9 Cadasta A.10 Landmapp A.11 Open Tenure A.12 STDM A.13 Mapping for Rights		2. Rwanda LTR 3. Tanzania MAST 4. Colombia MARD
5. Role of Technology Managing, Maintaining & Disseminating the Information	5.1. Data Management	A.14 Block-chain A.15 Advara	B.7 Data Standards	5. Georgia Block-chain in Land Transactions
	5.2. Data Access	A16. What3Words	B.8 NSDI	6. Geoscape 7. Ukraine Crowdsourcing for improved data quality 8. Czech Republic Open Access Land Administration 9. Moldova M-Cloud, MOLDLIS and NSDI
Cross-cutting			B.9 Capacity Development B.10 Legal, regulatory and institutional frameworks B.11 Spatial Framework	

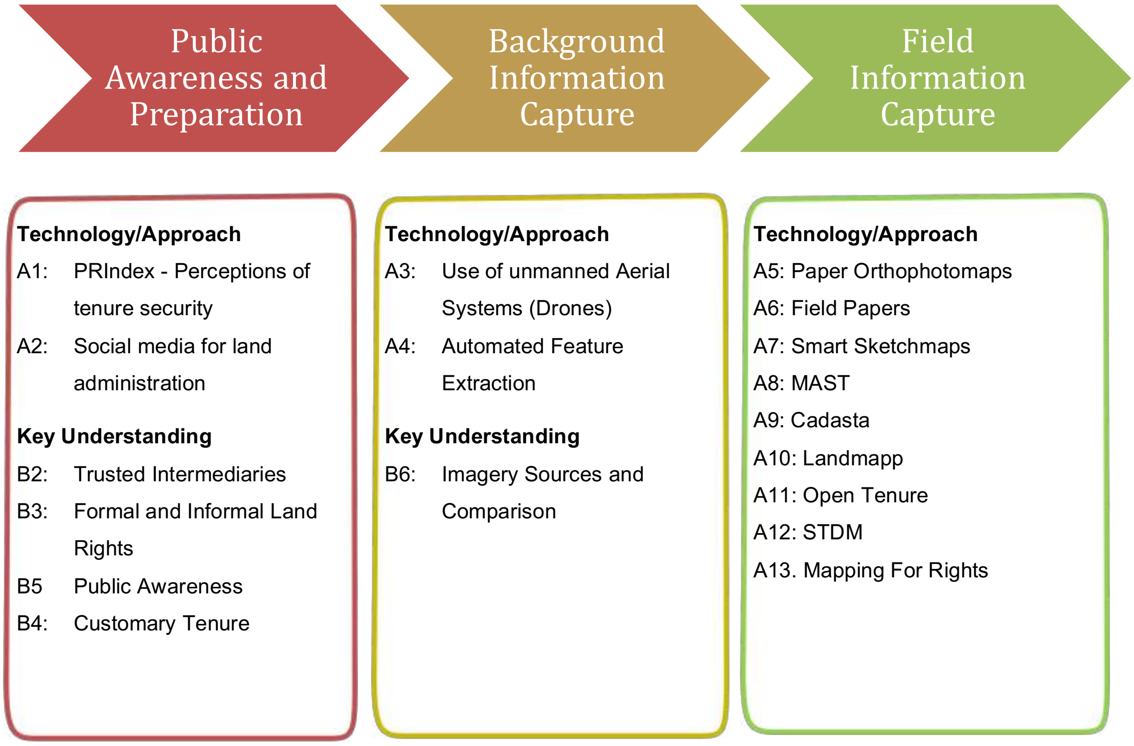
4 ROLE OF TECHNOLOGY – INFORMATION CAPTURE

Information capture is a critical activity for addressing the 70% of lands that remain informal and undocumented. This section considers capture of land information in a modular way across three key categories: public awareness and preparation, background (office-based) capture of supporting information and capturing land rights in the field (see Figure 4).

It provides an overview to guide readers to identify the appropriate activities and technologies to be used for their project context, of which more detail is provided in the Appendices.

Note that, although many of the more recent technological advances have focused on the 'Field Information Capture' category, this does not imply any relative importance; indeed successful field information capture is highly dependent on good execution of the preceding two activities.

Figure 4: Technologies and approaches included in this section. (Numbers refer to Appendix sections)



4.1 Public Awareness and Preparation

Technologies and approaches relevant to this section:	
PRIndex (A.1)	… Global Property Rights Index, a statistical indicator of citizens' perception of the security of their tenure rights
Social media (A.2)	… online websites and applications that enable users to network between themselves and share and create information and content.

Public awareness and preparation are essential components to any project or project design, and are often overlooked in terms of technology. Core decisions are typically around what is, and what is not, in scope (and what factors determine the scope), who is involved (and at what stage), and what communication methods are most appropriate not only for awareness creation and project sustainability, but also for monitoring and evaluation (M&E) of project success.

Preparing and Defining Scope

The first steps to any project design or implementation should always include data gathering, preparation, planning and stakeholder awareness, to ensure a fully participatory, all-inclusive process with effective conflict minimization and resolution. Thus, any initial public awareness raising campaigns must ensure the representation of all groups. This may require specific attention to vulnerable groups, communication in different languages and approaches to ensure absentee rights holders are also included in both campaigns and the impact evaluation / M&E measures.

Project (and project design) preparation can be guided, and even contribute to, the recommended National (digital) Atlas (see **Appendix B.10 Spatial Framework**). A National Atlas can provide an overview (or stratification) of the spatial distribution of legally recognized and legitimate tenure types across a country, including areas of customary tenure, areas of informal tenure, areas of private ownership, state land, etc. These, together with any available census information, will assist in identifying key stakeholders, likely methods and issues to create the most appropriate FFP Spatial Framework for a country.

A tool developed by the Global Land Tool Network – Costing and Financing of Land Administration Systems in Developing Countries (**CoFLAS, Appendix B.1**) – also provides a solid foundation for preparing and designing land administration projects. The tool steps through four stages that provide guidance in key decisions that impact the costs of land administration projects, ultimately providing a clear overview of core steps and considerations for land administration reform. Stage 1 particularly guides users through steps to identify scope and the readiness of a country or region to commence a land administration project.

Perhaps missing from the CoFLAS tool are discussions around the use of '**trusted intermediaries' (Appendix B.2)** and **when to capture informal rather than formal land rights (Appendix B.3).** A FFP approach encourages the use of trusted intermediaries to reduce costs, promote local stakeholder engagement and transparency and ensure sufficient scale-up. In the case of informal land rights capture, there is a strong argument to commence pro-poor land recordation even where there is a lack of political will or commitment for national-scale programs, in order to protect the rights of vulnerable peoples. This is even more relevant to the case of **customary tenure (Appendix B.4).**

Prior to commencing a project, clear baseline measurements are required, against which progress can be measured. Ongoing M&E can then be undertaken throughout the life of a project (and beyond) to measure project success and efficiency. The Global Property Rights Index, or **PRindex (see Appendix A.1)** is one supporting emerging tool that could be used in the development of this baseline. PRIndex is being developed as a method that can be used to provide an indicator of citizens' perception of the security of their property rights. Still under research/development, it aims to provide the basis for tenure-related measures in support of the Sustainable Development Goals (Agenda 2030), the Voluntary Guidelines for the Governance of Tenure of land, fisheries and forests (VGGTs) and other land-related initiatives. The PRIndex methodology may provide insight to project designers and implementers in determining appropriate baseline measures and priorities.

Public Awareness

Once background, scope and initial planning have been undertaken, essential public awareness campaigns can be planned and established. Good public awareness is a critical success factor in many international projects to register rights. Campaigns to promote public awareness impact both the length of time needed to systematically identify, adjudicate and register rights and the extent of uptake to register subsequent land right transactions. Many methods are available and choice can be informed by data collected in earlier stages (see **Public Awareness, Appendix B.5**). For example, with largely rural projects, village meetings and promotion by village heads is essential. In more urban projects, project implementers may find that strategically placed advertisements – and even TV advertising – more appropriate. As with many decisions, a combination of methods will usually be beneficial.

A number of technologies can be used to support both initial scoping and public awareness, many of which fall under the category of **Social Media (see Appendix A.2),** but which have largely been untested in land administration. Social media has been extensively used in cases of land grabbing and land activism, and there is growing research in adoption of social media for urban planning, for example. Significant attention outside of land administration has been placed on volunteered geographic information, and there is some opportunity, albeit untested, for this to support identification of project areas, or specific communities and their interests in project areas. Similarly, related technologies – such as *minecraft,* and virtual reality[1] – could potentially be brought in to support community consultation in the future; although these are most likely to be applicable in terms of high-density urban areas, particularly where stakeholders are seeking to apply participatory land readjustment and/or strong youth engagement is needed.

Online access to information services is growing exponentially with the expansion in broadband infrastructure and the use of mobile phones to deliver Internet and SMS-

[1] See for example UN-Habitat 2015 *Using Minecraft for Youth Participation in Urban Design and Governance.* UN-Habitat. Accessed at https://unhabitat.org/books/using-minecraft-for-youth-participation-in-urban-design-and-governance/

based services. A whole new generation of information services are being provided to users in developing countries through mobile phones: providing agricultural information services for prices, weather and farming tips; gathering health information in the field to help manage drug stocks and verifying the authenticity of drugs. Some of the most innovative bottom-up solutions came from East Africa, notably:

- Ushahidi (www.ushahidi.com) which was initially developed to map reports of violence in Kenya after the post-election violence in 2008, and now developed into a social (”activist-oriented”) enterprise that provides software and services to numerous sectors and civil society to help improve the bottom-up flow of information.
- Sisi ni Amani, Kenya (SNA-K) uses its SMS platform to mobilize communities to attend open-air forums and other events relevant to land management and violence prevention. It also uses SMS to educate community members on relevant issues, including how they can voice grievances over land-based issues peacefully, and sends violence prevention text messages to target demographic groups when tensions arise at the grassroots level.

Social-media approaches have the advantage of being “free to use”, and emerging top-down approaches can be seen to include use of Facebook sites and groups and embracing of WhatsApp and Snapchat mediums. Specific land-related initiatives and mobile apps such as MapAction and MapSwipe engage the general public and encourage contribution of their time and interpretative skills to improve local understanding and knowledge.

4.2 Background Information Capture

Technologies and approaches relevant to this section:	
Choice of Imagery, Including Drones (A.3)	…small unmanned aerial vehicles can host sensors that lower the costs for on-demand imagery, but cover much smaller areas.
Automated Feature Extraction (A.4)	…algorithms and machine learning developed to extract vector information from images. Automated change detection can be used for ongoing governance and management.

Capture of background information should take place at project design or inception and include the following activities:

- Collate and catalogue existing information, including census data, imagery and other spatial data, deed or title files, etc.
- Digitize existing information if/as deemed necessary, especially existing deed and title (land rights) files.
- Identify areas where imagery is needed, decide appropriate method of obtaining imagery (**Appendix B.6**), and initiate procurement. Manually digitize or adopt/implement automated feature extraction (**Appendix A.4**) to develop a spatial layer containing visible boundaries.

Design and implementation of these steps will be dependent on the existing context – some digitization may have already been undertaken or may be deemed unnecessary in light of the age of files, and/or there may be insufficient capacity to undertake manual feature extraction. National, regional and local governments should consider that satellite imagery may have already been purchased for areas of interest and/or national price-beneficial deals may be possible with commercial satellite imagery providers.

Decisions to be made at this stage of the data capture process (prior to field mobilization) include:

- Time and budget allocated to collating and **digitizing existing information** (and whether this can reduce fieldwork, or whether subsequent fieldwork will make such steps redundant).
- **Choice of imagery collection type** and minimum resolution necessary to meet legislative FFP requirements.
- Time and budget allocated to manual or **automated feature extraction** and/or change detection for initial fieldwork and/or ongoing land management.

The following sections focus on aiding decisions on these topics.

Digitizing Existing Rights and Records

It is imperative to ensure that any existing rights are maintained, safeguarded and/or renewed even where documentation may exist In various forms (e.g. in the form of land books, deeds or even maps). These should be scanned and indexed into some form of document management system. Mobile devices can be used to not only scan (image) documents, but also later on refer to these in the field and add biometric forms of identity (e.g. face or fingerprints). Advances in optical character recognition (OCR) have proven effective in capturing much information in printed or typed documents, and even in encoding the key information items in structured way (e.g. types of rights, restrictions or responsibilities between holders and their basic administration units). Although these technologies are improving, they are relatively well established and considered outside the scope of this document.

Displaying, querying and inter-combining any existing maps, census, land records and other geo-spatial information can increase the identification of marginalized or gender-relevant data at regional, national, local level in a very short period of time and with a low cost, showing the areas with a persistent gap and providing the possibility to define and measure the results of actions taken.

Choice of Imagery Type and Resolution Necessary

Figure 6 (shown in section 4.3) illustrates decision-making steps to assist in deciding whether, and where conventional ground survey or image-based capture is better, addressing legislative requirements and context. Whilst relevant to capturing land rights in the field, it assists in identifying whether parcel boundaries in some areas can be captured via manual or automated feature extraction (and hence for which areas imagery may be required for and at what resolution).

If it is determined that imagery is the most appropriate approach then the topography and population density will inform the choice of image resolution and sensor platform (satellite, plane, or drone, see

Table 3). Typically, higher population densities and higher land values will require a higher imager resolution, which may require aerial or drone capture rather than satellite. However, satellite imagery is typically cheaper, particularly over larger areas, and more easily obtained and processed than aerial or drone captured imagery. Consideration of laws surrounding drone usage and import may also heavily influence decisions (see Table 4).

Ultimately, a multi-sensor approach may be best suited, especially at national contexts. This may, for example, include early acquisition of satellite images for lower resolution background mapping, to support the public awareness /sensitization and initial data collection (for impact evaluation, for example), whilst aerial imagery is commissioned for greater detail in selected areas and / or drone image capture for small urban / peri-urban areas where the highest spatial resolution is required, and it is preferred to keep and develop local equipment and skills to repeat acquisitions.

Where satellite imagery is selected, several organizations and commercial providers can conduct image searches or feasibility studies for new imagery at no cost and no obligation for future purchase[2] that will show image dates, resolutions and 'quick-looks' to ascertain which will be suitable. Whichever imagery is collected, it will need geometric (orthographic projection to match a known ground reference system) correction and processing either to support production of paper orthophotomaps or as backdrop to mobile digital devices such as smart-phones or tablets (discussed in section 4.3).

[2] Such as https://imagehunter.apollomapping.com/

Table 3: Categories of urban and rural land, preferred mapping scale and imagery resolution (Adapted from Byamugisha et al., 2012)

Area type	Description	Preferred Mapping Scale	Image GSD[3] Resolution (m)	Platform	Is LiDAR Possible?
Urban central High density, high value	Dense development and very high land values require large scale mapping to be performed by conventional terrestrial surveys or large scale image maps	1/500 – 1/2,000	0.10 - 0.50m	Aeroplane Drone Satellite	Yes
Residential Urban Medium density, high value	In residential areas the dwellings and parcels are normally easily identified in image maps	1/1,000 – 1/2,000	0.25 - 0.50m	Aeroplane Drone Satellite	Yes
Peri-urban Mixed density, good value	Peri-urban areas include a mix of land uses depending on the density and complexity of developments.	1/2,000 – 1/5,000	0.50 - 1.25m	Aeroplane Drone Satellite	Possibly
Informal/slum Very high density	Slum areas can be mapped for many purposes. Ideally, the individual housing structures can be identified as a basis for various kinds of administration and service delivery.	1/500 – 1/2,000	0.10 - 0.50m	Aeroplane Drone Satellite	Possibly
Small towns, villages High density, low value	Rural villages may be mapped separately or they may be mapped as part of a major rural area	1/2,000	0.50m	Satellite Aeroplane Drone	No
Rural agricultural Medium density, good agricultural value	In rural agricultural areas the individual parcels will normally be visible on satellite image maps	1/2,000 – 1/5,000	0.50 - 1.00m	Aeroplane Satellite Drone	No
Rural remote, forest Low density, low value	Mapping more remote rural areas may serve various purposes, such as land rights, natural resource management, water catchment, etc.	1/5,000 – 1/10,000	1.00 - 2.50m	Satellite	No
Rural mountainous	Mountainous areas can be covered by maps to a scale of 1/5,000 – 1/50,000 depending on the topography and settlement activity.	1/5,000 – 1/50,000	1.00 - 10.00m	Satellite	No

[3] Ground Sampling Distance, also known as "pixel"

Table 4: Summary of advantages and disadvantages of different sensor types

Topic	Satellite	Aerial	Drones
Spatial Resolution	0.5 – 1m	0.05 – 0.5m	0.02 – 0.10 Very high spatial resolution
Supply	Commercial supply	Need commercial operator	Very easy to learn and deploy
Flexibility	Little (programming request)	Little (commercial operation)	Very flexible
Cloud cover	Can be effected by cloud cover	Highly dependent on weather	Almost weather independent
Can support LiDAR	No	Can support LiDAR	Can support LiDAR
Availability	Availability improving with more and more providers and pointing capability	Several reliable international companies competing	Becoming more available and economical
Coverage	Excellent for large area coverage	Good for large areas	Difficult to fly over large areas, better for small areas at a time (< 3sq.km)
Composite creation	Reliable compositing	Good product expected	Can be image composite errors
Flying Restrictions	Independent of flying restrictions	Could be flying restrictions	May be subject to flying restrictions
Equipment Import	None needed	Could be restrictions	Could be restrictions on import or flying of equipment
Processing Requirements	Easy to use and process on today's computers	Should be supplied as digital finished products	Software is quite expensive and needs considerable resources
Skilled Manpower requirements	None required	Black-box	Can be trained quite easily
Speed	Takes time to search and order and deliver	Could take time to arrange plane etc.	Can be done very quickly
Maturity	Extremely mature	Very Mature	Quite new
Cost	Low cost	Highest cost	Lowest cost (total cost of ownership). Can deploy at will after purchase and training

Automated Feature Extraction

Once imagery is obtained and processed, it is useful to extract visible, land feature boundaries, so that these can be overlaid on orthophotomaps to be included as part of the participatory approach to collecting land rights evidence from citizens and communities. As an *a priori* approach, feature extraction may also identify areas where no boundaries are visible on imagery as candidate areas for field survey and possibly monumentation (e.g. areas used by nomadic pastoralists).

Such delineation is conventionally carried out by manual digitization, but as computer processing / learning and artificial intelligence improves, automated or semi-automated methods may be possible. This is particularly promising where multi-sensor / multi-view data provides voluminous, informative "point clouds" from which land boundary feature types (such as building edges, walls, hedges, trees, etc.) may be inferred from their heights and shapes provided in the point clouds (see

Appendix A.4). LiDAR data from aerial- or drone-based imagery can further support effective automated boundary feature extraction.

Automated feature extraction, in the form of image change detection, may also serve to support flow-on land administration services, such as property taxation, urban planning and urban development, by identifying changes (developments) of buildings, infrastructure, etc.

Finally, beyond the scope of this document, but of potential interest in the future is research that uses crowdsourced photogrammetric methods to extract information to build 3D city models. Examples include VarCity - https://varcity.ethz.ch/ - an initiative by the Swiss Federal Institute of Technology (ETH) Zurich, and Mapillary – http://mapillary.com. Applications already suggested for these technologies include urban design, navigation, and video gaming; and the technology developers highlight the potential to use tourism photos uploaded to platforms such as Facebook. These technologies are yet to be applied to the land administration domain, but could have potential, particularly in urban areas. Key limitations would include data security and privacy and the level of community participation throughout the process.

Case Study 1: Kosovo Drone Capture and Processing

Building on previous work carried out in Kosovo, World Bank is implementing a US $12 million Real Estate and Cadastre Project to assist the government in producing a national cadastre system and geospatial data infrastructure. The current phase includes three components: (a) Introducing new technology for field data collection; (b) Working with the Kosovo Cadastral Agency (KCA) to ensure that the field work met the requirements to formally register the rights in the KCLIS; and (c) providing legal information and support for women to formalize their property rights

In April 2016, using two UAVs operating in parallel, a total of 53 flights and 44 500 images were produced with a 12 MP canon camera at a pixel size of 5 cm from approximately 145m flying height. Flight planning in 3D (including DTM) was found to be very efficient in the eMotion-2 software and was performed and dynamically adjusted more or less “on the fly”. With enough batteries, a good system for recharging in the field, enough camera data storage and sufficient spare parts, well organized teams were able to execute flights and check that all data were captured before leaving the field. Cold, snowy and icy temperatures were avoided as these can reduce the battery performance, but other weather conditions, even light winds and poor lighting from cloudy or overcast conditions were deemed appropriate for UAV operation.

The inclusion of RTK measurements onboard one of the UAVs, was shown to significantly reduce the number of GCPs needed, and produced an overall positional accuracy of 5 – 15cm. Although some of the sales material intimated that no ground control was necessary, it was found that pre-marking and measuring some GCPs was essential, not only in helping to achieve the required accuracy, but also to contribute valuable information to overcome processing difficulties.

The biggest challenge was in the processing of the enormous amount of data obtained from the field. The processing took a long time to run and some of the produced orthophotos had more seamlines and building edges than would normally be expected from fewer images obtained at a higher flying height.

The project was carried out with two drones operating concurrently:

- One non-RTK one which cost about US$ 25k with 5 software licenses
- Another RTK one which costs about US$ 50k with 5 software licenses

Overall, it was found that the UAVs provided FFP mapping, in an affordable, improved and accelerated spatial data acquisition for targeted areas. It was possible to:

- Acquire current high-resolution imagery for multiple purposes, extremely quickly with locally-trained manpower
- Create virtual models for realistic visualization
- Promote participation of landholders and other stakeholders

The new methodology offered:

- Significant cost- and time savings (days vs. months or years)
- (Potentially) Affordable tool for local survey professional, governments and communities
- Transferable technology - facilitates development and decentralization of mapping capacity and stimulates/broadens local innovation

The processing, especially in-field attempts, provided the biggest challenge.

4.3 Capturing Land Rights in the Field

Technologies and approaches relevant to this section:	
Paper orthophotomaps (A.5)	…well established process of participatory boundary demarcation on hardcopy imagery.
Field Papers (A.6)	…image application and process that supports the quick digitization of manually drawn boundaries on printed orthophotomaps
Smart Sketchmaps (A.7) (under development)	…converts hand drawn sketch maps into spatially corrected orthophotomaps.
Mobile Application for Secure Tenure – MAST (A.8)	..mobile and cloud platform that supports smartphone participatory capture of formal land rights in customary areas.
Cadasta Platform (A.9)	…secure, hosted suite of mobile and web tools and organization that support community land rights collection.
Kadaster International Colombian pilot – MARD (Case Study 4)	… piloted process that links off-the-shelf technology (Trimble R1 and ESRI Collector App) with participatory mapping methods.
Landmapp (A.10)	… social enterprise that has turned rural pro-poor land certification into a business model with supported services.
Mapping for Rights (A.13)	…robust participatory mapping methodology using mobile devices for forest communities' land rights.
Open Tenure (A.11)	…mobile application supported by web based community server for community and citizen-based recording of land rights.
Social Tenure Domain Model (tool) (A.12)	…FOSS to maintain a wide range of people to land relationships; desktop-based solution looking to software-as-a-service implementation.

In the process of capturing land rights in the field, the following activities are typically undertaken:

- Delineation of land parcel boundaries
- Adjudication of land rights

- Dispute resolution to verify and correct land rights as necessary
- Recording of rights in a land registry
- Issuance of a certificate of title

Capturing land rights in the field has traditionally been the domain of professional surveyors, who undertake precise boundary demarcation of properties via ground survey, installing physical monuments on property corners. Such conventional methods are hindered by the limited number of surveyors worldwide, the cost of ground survey – not to mention the provision of materials for conventional physical monumentation – and the time necessary for this limited trained resource (the qualified surveyor) to attend and demarcate each parcel boundary. Rapid and efficient progress clearly requires change, as advocated under FFP via image-based, participatory methods. Hence the bulk of the technologies and approaches identified in this section address the challenges of cost-effective, timely, efficient and scalable methods to delineate parcel boundaries, and to record related rights transparently in a land registry. This does not negate the time and cost savings that can be brought about by supporting efficient dispute resolution mechanisms, and reviewing the logistics of printing, managing and issuing certificates[4].

There are a number of decisions to be made to identify the appropriate approach for capturing land rights in the field, and these revolve around:

- The use of ground survey and/or the FFP-preferred imagery approach;
- The use of manual or digitized processes ;
- The use of professional surveyors or trusted intermediaries;
- The choice of software and hosting.

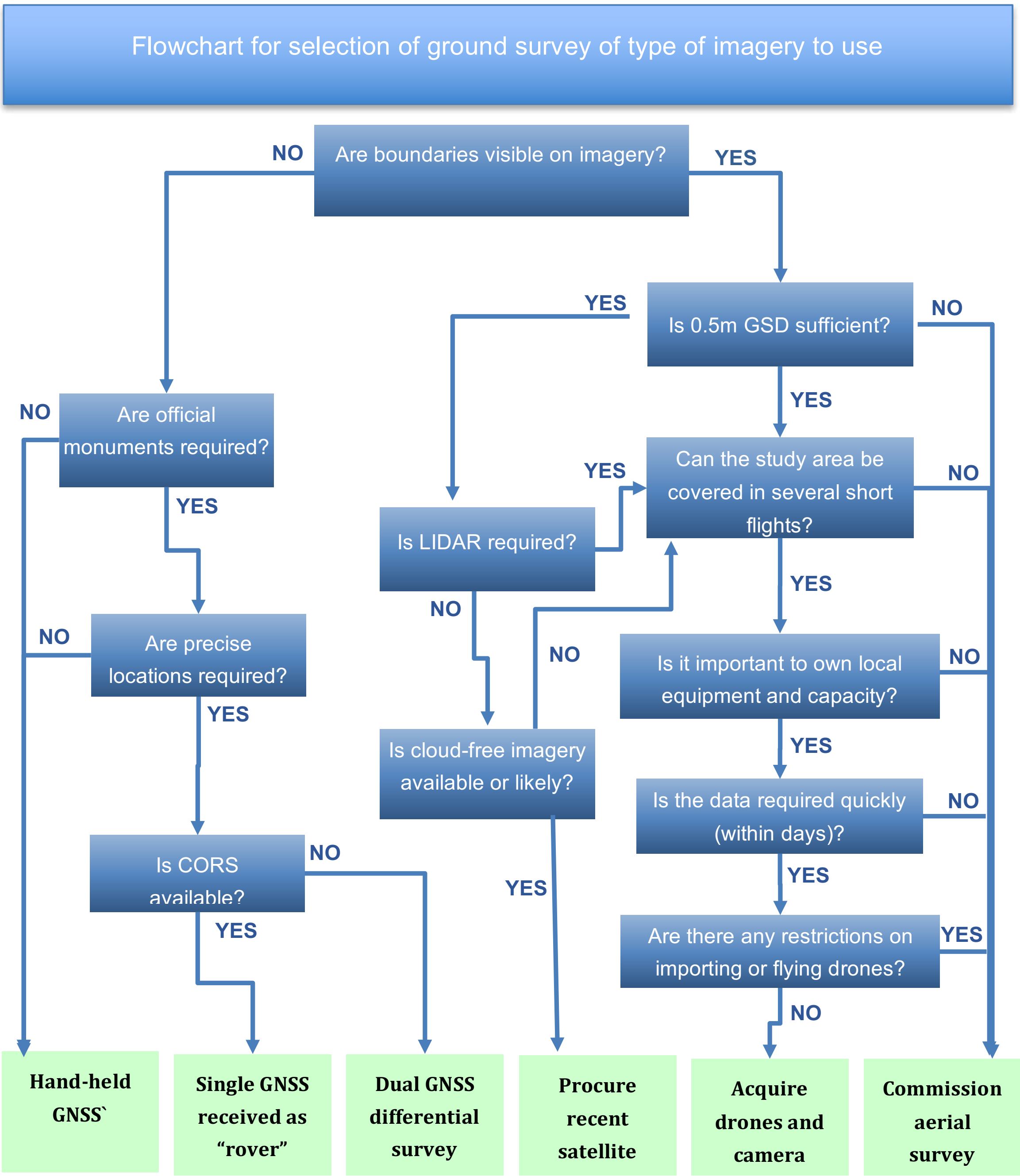
Ultimately, decision-makers will likely find that a combination of approaches appropriate to different regions and contexts will be necessary, as identified in **Appendix B.10 Spatial Framework**. This decision-making process is discussed below.

Ground survey and imagery

[4] In the case of Tanzania, the actual crested-paper Certificates of Rights of Occupancy (and Certificates of Customary Rights of Occupancy) cost US$2 or more to issue due to legislative requirements – a significant proportion of the total cost of systematic registration per parcel.

Figure 5 provides an overview of key decisions relating to selecting appropriate ground survey or image-based options. Consideration should be given to legislative requirements around precision required and the role of professionals, to existing capacity and resources (including CORS establishment, adoption of an appropriate coordinate system, existing imagery or access to imagery, existing equipment or access to equipment) and to appropriate timelines. Even where legislation prescribes high-precision boundary mapping, ground survey costs can be reduced by using handheld GNSS and integrated technologies as illustrated in **Case Study 4: Colombia MARD**.

Figure 5: Key decisions relating to the selection of ground survey or imagery

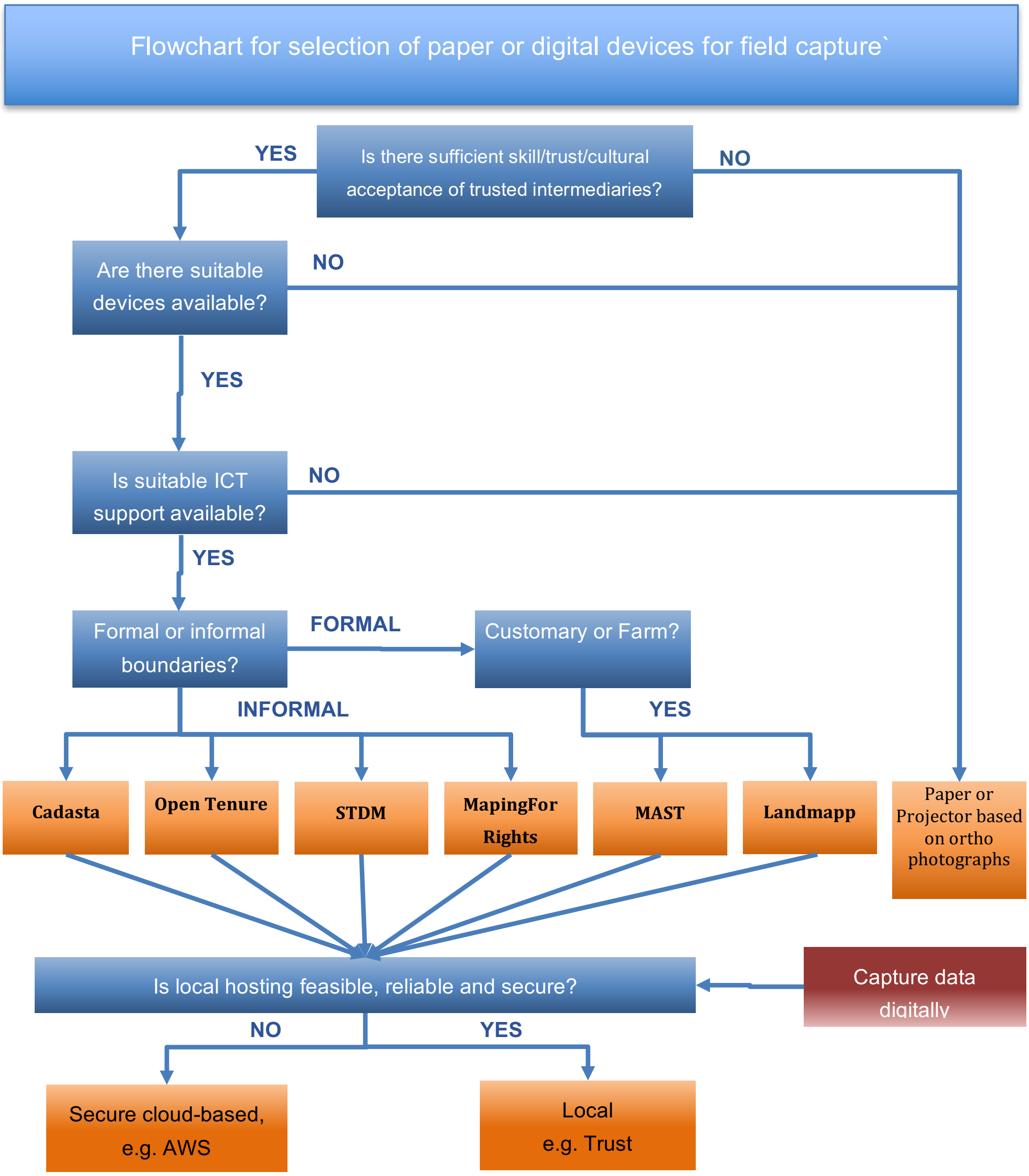


Much easier to carry out and scale-up to national levels, are methods based on **paper orthophotomaps (Appendix A.5),** which are very easy for large and participatory mapping and have been clearly demonstrated and applied nationally (see **Case Study 2. Rwanda LTR)**. They may result in lower resolution than ground survey and will require the provision and maintenance of some infrastructure and equipment, especially large-format printers (which may struggle to operate optimally in dusty / humid/hot environments). Paper orthophotos also require subsequent digitization, and several tools have emerged to assist digitization (at least the geo-rectification part), including **Field Papers (Appendix A.6)** and the still-being-developed **Smart Sketchmaps (Appendix A.7)**).

Manual or Digitized Processes

Figure 6 provides a flowchart of key considerations for adoption of paper or digitized processes. A number of approaches discussed here utilize handheld mobile devices to capture boundary information digitally in the field, hence reducing the need for large-scale paper orthophotomap printing and post digitization of agreed property boundaries (**Cadasta Appendix A.9, Landmapp Appendix A.10, MAST Appendix A.8, Open Tenure Appendix A.11).** Others suggest projecting imagery for community meetings, which provides better community participation and transparency and also obviates the need for large-scale printing (**Mapping for Rights, Appendix A.13)**. Digital mobile devices will require ICT capacity and support but, as youth are generally more au fait with the devices, can provide opportunities for them to be more involved in processes (many have included consideration for capacity development; Landmapp, operating as a business, largely undertakes tasks internally). Many applications have been developed with bottom-up or community-led approaches in mind (Cadasta, Open Tenure, Mapping for Rights, **STDM Appendix A.12**), but most have also been at least piloted with national or regional government. **Appendix B.3** provides a discussion of capturing informal versus formal land rights. Regarding resolution, options for mobile phone GNSS-augmentation are also available (Trimble R1, see **Case Study 4: Colombia MARD)**.

Figure 6: Key decisions around adoption of paper or digital-device approaches



Overall guidance only. Solution may be a combination of different approaches in different areas, or may evolve and change over time. Some paper maps will be required for sensitization, publication of results and other activities, even if mobile devices are selected for primary capture of boundaries. Mobile digital devices may be useful to capture some stakeholder information, even if boundary capture takes place primarily on paper/projector.

Decision makers should consider mobile penetration within an area of interest and be aware that whilst some applications may be both Android and iOS supported (**Open Tenure, Appendix A.11**) many may only be Android-supported.

Cadasta (Appendix A.9) report that mobile tablets are generally preferred as more user-friendly and versatile than handheld GPS, whilst tablets were preferred to mobile phones because of the larger screen size. Other projects do report problems with reading screens in strong sunlight, and of course, neither paper nor digital devices can be used well in wet conditions. Key reasoning for selecting mobile devices includes:

- Data entry processes were streamlined.
- Associated files (like photographs) were more easily linked to the spatial data at the time of capture.
- They are multi-use and can provide additional functions to communities.
- They are easier to repair and accessorize locally.
- Paired with Bluetooth GPS receivers (such as the Garmin GLO) accuracy was comparable, and at times better, than the Garmin eTrex 20x during field testing

A key advantage of digital device methods is that several appropriate functionalities may be combined into one single device, e.g. linking image-based data acquisition to handheld GNSS, biometric data (fingerprint identification and facial / iris recognition) and voice / video recording in support of owner / rights-holder identification.

Table 5 provides an overview of the pros and cons of the different approaches to capturing and adjudicating land rights.

Table 5: Relative requirements for different rights recording types

Topic	Paper Orthophotos	Projector/Screen, e.g. Mapping For Rights	Digital Device, e.g. smart-phone or tablets, e.g. MAST, Open Tenure,
Ease of participation	Very easy for anyone to participate in the rights delimitation and adjudication	Quite easy participatory collaboration	Very difficult for mass participation. Have to place more reliance on the trusted intermediary.
Skills to use	Very easy to use, some general orientation and relation to scale and image depiction or real features	Very easy to use, some general orientation and relation to scale and image depiction or real features	Digital devised need some training for trusted intermediary
Openness/ participatory	Very open and participatory for anyone attending	Very open and participatory for anyone attending	Small devices are difficult to see by many people, so mass adjudication is less open/participatory
Ancillary Records	Need to have paper forms and accompanying paraphernalia to record rights against each polygon identified	Need to have paper forms and accompanying paraphernalia to record rights against each polygon identified	Ancillary records, e.g. photographs, biometrics and recordings of rights holder can be carried out at the same time as the boundary delineation, effecting better integrity of the spatial and non-spatial data
Capture of Ancillary Records	Need to have data entry people to enter records	Need to have data entry people to enter records	Ancillary data captured digitally in the field

Topic	Paper Orthophotos	Projector/Screen, e.g. Mapping For Rights	Digital Device, e.g. smart-phone or tablets, e.g. MAST, Open Tenure,
Post-processing	Needs subsequent digitization and possible re-publication in order to prove to participants' accurate transposition of boundaries determined participatorily. Field Papers and Smart Sketchmaps offer some assistance in geo-correction of scanned participatory maps	Needs subsequent digitization and possible re-publication in order to prove to participants' accurate transposition of boundaries determined participatorily	Some post-processing required (e.g. removal of overlaps, fixing topology, etc.)
Large-printer	Required	Not required although may assist by printing maps for validation.	Not Required, although may assist by printing maps for validation.
Paper maps	Required	Not required although may assist with validation.	Not Required, although may assist with validation.
Software	Software required for reliable plotting to scale. Large-scale scanners may be required to reproduce the in-field maps reliably	Software required for reliable plotting to scale. Large-scale scanners may be required to reproduce the in-field maps reliably	Generally open-source and configurable, e.g. Open Tenure, MAST,

Choice of software and hosting

Without a secure, organized, data management system, mapping data is vulnerable to loss, abuse, or theft. Good data management must be planned in advance, in order to ensure that as the mapping program starts to generate hundreds of records, they are adequately and safely managed. Key supporting technologies for many of the mobile applications are based on the maturing and widespread use of FOSS database products, especially PostgreSQL, which has its own advanced spatial extension (PostGIS). Quantum GIS (also known as Q-GIS) has become the most common, multi-lingual and effective desktop FOSS GIS.

One of the key recent developments in land administration has been the development and widespread adoption/use of the Land Administration Data Model (LADM) adopted by ISO as ISO 19152:2012 (see **Appendix B.8 Data Standards**). This provides a robust extendable reference model covering basic information-related components of land administration, which allows reliable and flexible depiction of parties, properties and the various types of rights, restrictions and responsibilities pertaining to them. The STDM (Social Tenure Domain Model) is a 'specialization' of the LADM, with some differences in the terminology and in the application area. **STDM (Appendix A. 12)** also exists as a system that provides the software and process to implement the model.

However, even when software is FOSS, care should be taken to ensure that the infrastructure, including human capital and skills for designing, creating, and maintaining a data management system for geospatial data are established and built upon. Some of the technologies and approaches identified may have only been piloted in a small number of contexts. For example, MAST and Landmapp have only been implemented in rural and customary areas.

Section 5 in this Guide will address hosting and security in further detail, but decision-makers should have regard to: the types of data that will result from land rights capture; who has the responsibility for and ability to manage and maintain this data; who has access rights to this information; what hardware and software is necessary to manage data; and how sustainable and tested these solutions are. Too often, projects consider only the mapping (first registration part), but it is essential to plan and model for property transactions, so that the initial data are not quickly obsolete.

Professional surveyors and trusted intermediaries

Professional surveyors will certainly be required at some stage in projects, but the costs and time associated with their role can be used most effectively by adopting participatory methods. This allows time for the profession to be developed to support future land transactions. Of the technologies and approaches identified in this section, **Landmapp (Appendix A.10)** presents the only approach with a clear, demonstrated and successful business model, but it is not clear if, and how, this can be scaled – the transition of this concept to the Indonesian market will be of interest to follow. **Appendix B.2** provides a discussion of the role of **trusted intermediaries**. Consideration of the **legal and institutional framework** (see **Appendix B.11**) is again necessary to determine to what extent trusted intermediaries can be included in the process without legal or regulatory amendment, and if an appropriate level of capacity development (see **Appendix B.9**) and support can be provided. Both professional surveyors and trusted intermediaries will play integral roles in ensuring the sustainability of land rights registers.

Case Study 2: Land Tenure Regularization in Rwanda

Rwanda's ongoing land reforms were initiated in 1999 and rapidly accelerated from 2008. The Land Tenure Regularization (LTR) Program ultimately registered all the land in Rwanda (10.3 million parcels) for the first time. The unit cost of land tenure regularization was estimated at US$6/parcel (Nkurunziza, 2015)[5]. Key success factors of the project have been identified as strong political commitment, a detailed plan developed early on and flexibility, including the use of paper orthophotomaps. Some concerns remain, however, as to the long-term sustainability of the program, primarily threatened by the fact that continued transactions and changes in land rights are not being recorded.

The Rwandan project was undertaken in two phases, with the first phase (2005-2009) documenting a feasible approach via a Strategic Road Map; and the second phase (2010-2013) registering the 10.3 million parcels through a one-off, low-cost and community-based process involving the design and implementation of a new Land Administration System, including significant Legal Reform. Some 110,000 people were employed, 99% of who came from the communities in which the work was being carried out. Employment of women was particularly high, with women filling 70% of staff field manager positions and 40% of trusted intermediary positions (Nkurunziza, 2015).

The approach adopted by Rwanda was one of general/visible boundaries, using high-resolution orthophotos and satellite imagery. Teams of locally recruited and specially trained staff outlined parcel boundaries on imagery printouts that were then scanned, geo-referenced and digitized. Printouts of the parcel plans became part of the legal parcel ownership document. The non-spatial data relating to owners' rights and particulars were captured in claim registers by legally constituted adjudication committees.

The information from the registers was entered into the LTR Support System and from this, titles could be printed and issued. The Land Administration Information System was used for processing transactions and for updating the register. A land surveying program to train surveyors ("geomatic engineers") is underway to address existing shortages.

Implementation was a shared responsibility between a wide range of stakeholders, with Rwanda Natural Resources Authority taking the lead. Development partners led by the United Kingdom´s Department for International Development were involved and other partners included Swedish International Development Cooperation Agency, European Union, Royal Netherlands Embassy and IFAD.

The importance of the land tenure regularization has been widely recognized and subsequent, similar initiatives are underway in Ethiopia and Tanzania. In Rwanda, Geonet, a network of 8 CORS, has been established and INES has launched, in the last five years, educational programs in surveying and land administration and management.

(Sources: E. Nkurunziza and D. Sagashya, Rwanda Natural Resources Authority)

[5] Note the US$6/parcel cost is subject to very local and specific conditions and it should not be expected that this can be matches elsewhere. Achieving a target of US$10 or US$15/parcel is probably more realistic.

Case Study 3: Tanzania MAST

Mobile Application to Secure Tenure (MAST) is a technology and project funded by USAID under their Land Tenure Assistance (LTA) activity from 2014 – 2016 – now extended - with the aim to document land rights information at village level in Tanzania using mobile technology. The intention is to use low cost solutions (Samsung tablets with an open source Android application) for parcel adjudication by trusted intermediaries.

MAST was designed to capture land rights information in a manner that is consistent with the decentralized (district-level) administrations requirements of the Tanzanian Village Land Act of 1999, but which can be implemented in a more efficient and cost-effective manner than previous projects which used Government professional surveyors, depended on dual differential GPS survey and monumentation. Key elements of the MAST workflow include:

- Adoption of high-resolution satellite imagery (50cm resolution or better) for boundary identification with non-visual boundaries added using handheld GPS or field survey.
- The use of villagers as 'trusted intermediaries' hired on a low daily payment rate, in contrast to the payment of (higher) DSA for central government staff/experts.
- Reduction in office work and potential error in data entry, by ensuring direct data input/download.
- Security and transparency of systematic adjudication based on participatory methods

Total funding provided to the MAST program was approximately US$1 million, with the LTA project for 26 villages in 2 districts costing about US$6 million.

A study visit undertaken to the pilot in Iringa in 2017 identified the current cost of producing CCROs under the program as just over US$15/parcel (am amount higher to previous pilots) with plans to reduce this to US$10/parcel. A review of costs identify:

- The impact of large team sizes on cost (e.g. Village Councils and committees, adjudication teams) as well as the impact of allowances (which may be higher for higher ranking village officials).
- The impact of stationery costs in creating physical certificates (approximately US $2/parcel).

Identified problems that need to be addressed include:

- Use of small hand held devices is impacted by glare, and limits participatory processes as only one operator can see the screen at a time. This could be addressed by printing and displaying material for public consultation, but budget was not allocated for this.
- Stability of internet connections and power supply in rural Tanzania hinders the use of the cloud-based platform and impacts data management in the field.
- Low quality input data has necessitated significant data cleaning and ultimately offset time savings

Hence, LTA is making the following changes to MAST:

- Enhancing the accuracy of the mapping software and improving the training of field operators;
- Upgrading the parcel numbering system and display to support mapping and work in the field;
- Refining attribute editing capabilities to prevent erroneous entries in the field and back office;

- Revising the attribute process to make individual claimants unique, thereby allowing for better management and analysis of patterns in land holdings (such as gender ratios, the number of multiple parcel holders, family links, etc.);
- Tightening claimant attribute data entry criteria to enable claims to be checked more effectively prior to titling;
- Modifying claimant attributes so that attestation of claims, disputed claims, boundary issues, unclaimed land, and planning breaches can be properly recorded and addressed;
- Adding editing and sorting functions to enable more effective data quality checks and claimant searches; and
- Enabling more effective batch processing and printing—for public display, consultation, adjudication, monitoring and evaluation, and publication of basic statistics and reporting. Eventually, LTA will require production of maps, titles, and field issuance procedures on an industrial scale.

Source: http://dai-global-developments.com/articles/using-mobile-technology-for-first-registration-of-land-lessons-learned-in-tanzania/

Case Study 4: Ministry of Agriculture and Rural Development in Colombia

In Colombia, it is estimated that there are over 4 million rural parcels lacking formal registration. An urgent need to accelerate data acquisition and management for formalization is hindered by overly strict accuracy specifications requiring time-consuming, costly and cumbersome processes.

In 2015, in the municipality of Tenjo, a proof-of-concept was conducted to demonstrate that a fast, affordable and reliable field data collection method was possible. This was carried out by IGAC, MADR, SNR, Dutch Kadaster & universities, in close collaboration with software and hardware providers. The method follows a FFP approach in which boundaries are identified in the field in a participatory manner and drawn on orthophotos by locally trained technicians. Claimants are then provided with a small piece of paper on which the boundaries are drawn, and must give this to the person responsible for recording administrative attributes.

▲ Figure 1. Fit-for-purpose land administration. Identified boundaries are drawn in the field on top of an orthophoto (left), while administrative data is recorded simultaneously (right).

Formal surveys are then only needed for data completion if boundaries are not visible on orthophotos. Fieldwork is largely paper-based and data can be digitized in the office.

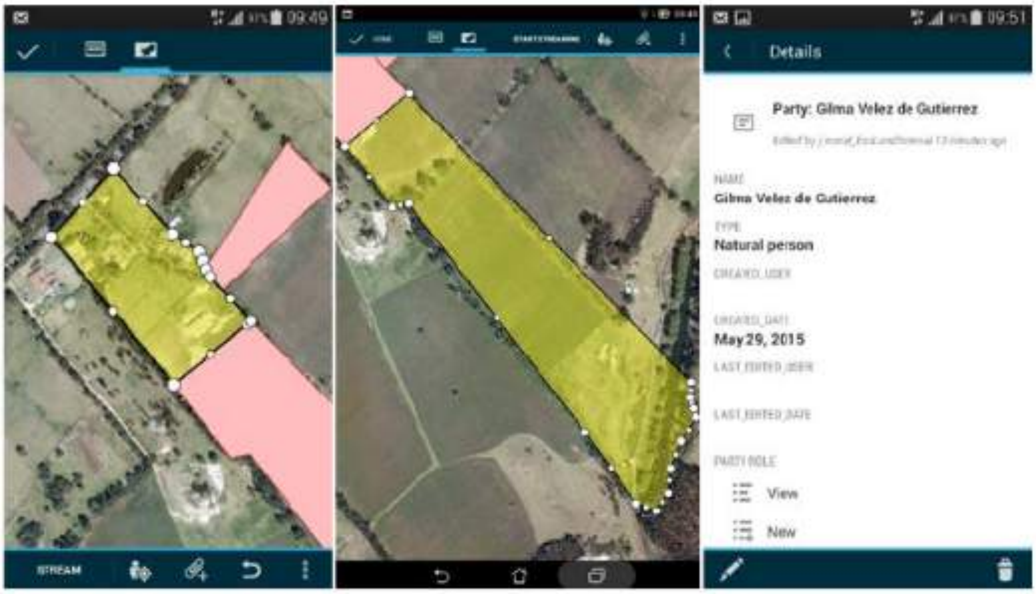
However, whilst the Ministry of Agriculture and Rural Development in Colombia has experience with this paper-based fieldwork approach, they are interested in further computerization in order to improve efficiencies and reduce margins for error. Hence a FFP smartphone app has been developed that enables farmers and grassroot surveyors (the 'trusted intermediaries') to walk the perimeters of properties themselves. Those grassroot surveyors are young adults from the villages, trusted by the communities and educated and guided by professionals.

▲ Figure 2. The Trimble R1 has a Bluetooth connection with a mobile on which also Esri's Collector App is installed.

The freely downloadable app comes with an orthophoto of the specific area, and the spatial and administrative information can easily be collected in the field based on a standard data model. The data is collected only once; the spatial and administrative details of one property are integrated right from the start of the formalization process and are interoperable. All data can be collected offline and later transparently uploaded in the cloud. At a village meeting in the town hall, the community members gather to view all the collected data on a map and discuss and reconcile the results.

During the adjudication process in the field, disputes may lead to the creation of overlaps between polygons. In that case, those overlaps are mapped and the related conflicts have to be solved. Bigger ‘gaps’ represent areas to be surveyed. This may concern government-owned lands, which have to be identified and included in the system.

The design environment in this case is based on Esri’s Collector App, which allows for very efficient data collection. The app was used in combination with the Trimble R1, for sub-metre accuracy, via a Bluetooth connection. The interface between the R1 and the Collector App could be managed from a smartphone.



▲ *Figure 3, Perimeters of spatial units (parcels), this is polygon-based cadastral data acquisition. Results of collected geometry with the Trimble R1 are superimposed on orthoimagery on the smartphone’s screen (left and middle). At the same time administrative data is collected and linked (right).*

This configuration is fit for purpose, given the often rather low value of rural land, the intrinsic accuracy of boundaries and even the existing norms for area calculation. The data structure of the cloud-based database with collected attributes is based on the LADM and the STDM (the model), which provides the concept for the app. The data collection method is ‘polygon-based’ rather than ‘boundary-based’. The collected polygons with associated attributes are considered to be ‘evidence from the field’. Data collected from the field can be processed and handled in a (cloud-based) geographic information system (GIS), where the collected polygons can be superimposed onto the imagery. Between the polygons, the boundaries will be visible as objects in most cases: fences, hedges, trees, ditches, roads, etc. If those visible objects are not spatial units in themselves, the boundaries can easily be vectorised today, and in the future, it may be possible to conduct automatic feature extraction. Topology can be introduced if needed. Imagery is loaded in advance. Most boundaries are clearly visible on aerial photos or on satellite imagery. Data collection should be fast, reliable and cheap (i.e. “trusted intermediary” can do the job). It is expected that this app for field data collection will speed up and improve the formalization process. The app should support acquisition of spatial data and administrative data in an integrated approach. If only handheld devices are being used (i.e. no survey equipment is needed), the work can be done in very efficiently.

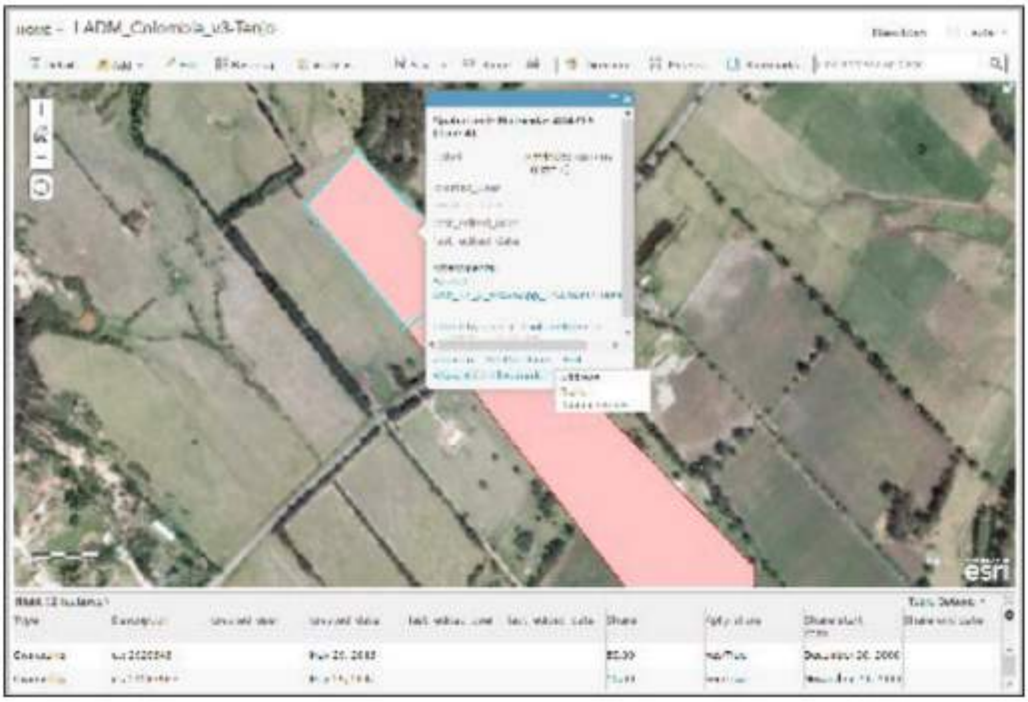


Figure 4, The results are available in the cloud immediately.

The proof of concept has been much debated and well received in several forums, both inside and outside Colombia, and the results are promising. The following should be noted in this context: currently, it costs around USD1,000 to measure and register an average two-hectare parcel in Colombia.

With millions of parcels still to formalize, FFP methods and techniques are being explored, tested and implemented

Light Mobile Collection Tools for Land Administration - Proof of Concept from Colombia (PDF Download Available). Available from: https://www.researchgate.net/publication/284176876_Light_Mobile_Collection_Tools_for_Land_Administration_-_Proof_of_Concept_from_Colombia [accessed May 17, 2017].

5 ROLE OF TECHNOLOGY – MANAGING, MAINTAINING & DISSEMINATING THE INFORMATION

Data management is a key aspect of the modernization of land administration systems and it is particularly crucial for economies in transition, where the technical infrastructure is still being developed.

Effective management of accurate data is critical to:

- Ensure accurate first-time field visit with no data errors or losses;
- Ensure transparent and standardized data management processes, which will increase transparency;
- Data managed within a secure environment with associated privacy and access rights; and
- Ensure efficient processes that encourage public uptake of first-registration, transactions and ultimately lead to self-sustaining, revenue-generating systems.

This section considers the management, maintenance and dissemination of land administration information into the two broad categories of data management and data access. These outline decisions to be made around choice and establishment of software and hardware platforms, considerations for sustainable data management practices and options to enable both public and private sector access to data, including potential for revenue.

Technology / Approach

A.9: Cadasta

A.12: STDM

A.14 Blockchain

A.15 Advara

Key Understanding

B.7 Data standards

Technology / Approach

A.16: What3Words

Key Understanding

B.8: NSDI

5.1 Data Management

Technologies and approaches relevant to this section:	
Blockchain (A.14)	…a distributed database holding a public ledger of all transactions, such as bitcoin, but increasingly being applied to land registries to lower cost and reduce fraud.
Advara (A.15)	…proprietary, cloud-based 'land registry as a service' platform being implemented by Western Australian land registry.

It is difficult, if not impossible, to understate the importance of data management to land administration reform projects. Strong data management processes will not only ensure the integrity of data throughout the lifecycle of a land administration, but will also facilitate good business processes, foster good customer service, build trust with stakeholders, support additional revenue streams and fundamentally underpin the land registry.

Key data management components include:

- Data policy development, including ownership, process documentation and software / hardware support;
- Data maintenance, including metadata, quality, back-up and control; and
- Data security, including privacy.

Data management is essentially about trust. Governments / implementers can have confidence that the data represents reality on the ground, and land rights holders and other stakeholders can have the confidence that the information they provided will be correctly interpreted, secured against fraud and support their rights. Strong and agreed data policies are needed to ensure clear and efficient processes are identified and implemented, with sufficient redundancy to guard against loss or security breaches. Given the likely lifespan of land data, clear plans for sustainability – including upgrading of software and hardware – are also essential.

Decisions around data management for land administration will typically center on the software, hardware and capacity. These are extensively captured in other documents – including CoFLAS (see **Appendix B.1 CoFLAS**) – as well as in the detail of several technologies identified here (including STDM, **Appendix A.12**, and Cadasta, **Appendix A.9**) and are hence largely considered beyond the scope of this document. Some of the central 'land information system' choices (with limited depth) are provided in overview below.

Data Management Systems

Key considerations in selecting system-level data management solutions include the inter-related considerations of :

- Security;
- Functionality;
- Usability;
- Integration;
- Cost and suitability;
- Scalability;

- Support and development;
- Hosting (Internal or external);
- Update frequency and automation;
- Flexibility to upgrade; and
- Accessibility of data for publication.

Whilst considerations of price and no vendor lock-in often favor FOSS, historically proprietary technologies have claimed a larger presence in the market, likely as a result of implied reliability and support. More recently, the larger vendors are seen to be claiming bigger developer communities than FOSS, re-emphasizing the demands of flexibility from consumers. Ultimately, the decision of FOSS vs. proprietary software may not need to be an either / or, as individual system-element solutions can be sourced to be best suited to context. It may be appropriate to migrate at certain points; hence the conformance to open standards (such as LADM) and interoperability of data must be ensured whichever system is initially adopted.

In the realm of FFP, it is likely that FOSS will best meet the needs of developing countries in the short-term, however capacity and sustainability (including ongoing support) are serious considerations. The software **Advara (Appendix A.15)** highlights one potential future model of land information system, being the 'Land Registry as a Service' model, which encourages business process re-engineering to streamline services prior to adoption, demonstrates a form of public-private partnership via software implementation and service provision.

Advara is one example of a general trend in land information systems, from sizeable (and costly) infrastructure to cloud-based solutions. Large systems implemented to date have been based on proprietary systems, largely developed to address concerns around stability, security, etc. These have typically needed to be centralized with replicated systems for failover. The growth of cloud-based solutions, however, especially Amazon Web Services, is significantly reducing the costs of required data management infrastructure and many developed countries are moving towards distributed cloud-based technology. Limitations may include the location of data hosting, which may be skewed in favor of developing countries (see Cadasta, **Appendix A.9**, for some discussion of this).
Smaller projects, including those in developing countries and / or those applying to informal rights, are more likely to be based on FOSS (including projects using Open Tenure (**Appendix A.11**) or STDM **(Appendix A.12**)). These tend to be much more agile and tend initially to rely on cloud services, which are faster to procure and establish, and implementers may be less worried about hosting locations.

Table 6 gives a high-level overview of data system considerations, with relation to cost and capacity.

Table 6: High level overview of data system options

Data system component	"Low-End" – *low cost, low capacity needed*	*Middle option*	"High-End" - *high cost, higher capacity needed*
Servers	Local	Cloud-based	Secure, centralized, data centers
Software	FOSS	Hybrid	Proprietary
Database	PostgresSQL+ postGS Firebird MySQL		Oracle, SQL Server
Operating Systems	Linux/Ubuntu		Windows
Field Data Capture Software	Open Source (STDM, Open Tenure, etc.)		ESRI Collector App
GIS	Open Source: Q-GIS, OpenJump	ESRI ArcGIS Online	ESRI, MapInfo, etc.

Data Policy and Security

Information created, managed, and disseminated by land administration processes will be guided and constrained by a country's public-sector information policy. The use of land administration information will therefore be subject to degrees of restrictions based on laws that protect the use of personal data, freedom of information laws, and copyright and licensing arrangements. In many countries, an e-Government Strategy provides an overarching framework that can be used to guide technology decision-making within the government sector. The primary goal of these strategies is to ensure all government organizations and their direct affiliates use a consistent approach for delivering e-Services to citizens using compatible technologies and/or technology standards. Many effective land administration data management systems follow closely the national revenue authority systems – data and information needs to be secure and closely monitored, systems need to be reliable and protected, often with central disaster recovery and need to provide services nationally in all urban and rural areas.

With regards to security, **Blockchain** (Appendix A.14) is one technology that is being piloted for land administration services. It is being implemented to reduce the reliance on trusted third parties, lower costs through the automation of land registry functions and reduced opportunities for fraud and errors. A short case study 5 below presents one of the first implementation example.

Case Study 5: Republic of Georgia to Use Bitcoin Blockchain in Land Transactions

In a vote of confidence for a fledgling technology, the Republic of Georgia committed to use the bitcoin network to validate property-related government transactions.

[*Papuna Ugrekhelidze, the Chairman of the National Agency of Public Registry of Georgia, and BitFury CEO Valery Vavilov at the signing ceremony (Salvatore Kosta)*]

In April 2016, the government and bitcoin hardware and software firm BitFury Group, a bitcoin mining company based in San Francisco, launched a pilot project to register land titles via a private blockchain, which is a tamper-proof ledger, and then to make those transactions verifiable using bitcoin's blockchain, which is public.

It is the first time a national government has used the bitcoin blockchain to secure and validate official actions, signifying a vote of confidence for a technology still somewhat tainted by an early association with illicit activity.

Having so far built the software and tested it with a couple dozen land title registrations, BitFury Group and the Georgian National Agency of Public Registry have now signed a new memorandum of understanding to expand the service to purchases and sales of land titles, registration of new land titles, demolition of property, mortgages and rentals, as well as notary services. Three reasons have been cited for adopting it: it will add security to the data so the data cannot be corrupted; the public auditor will also make a real-time audit; and it will reduce the friction in registration and the cost of property rights registration, because people could do this in the future using their smart phones - blockchain will be used as a notary service.

The BitFury Group and Republic of Georgia initiative is just one of several collaborations aimed at creating blockchain based land-titling services. (Such software is also being created in Sweden (with Chromaway), Honduras (with Factom) and Cook County in Chicago (Velox).

Tea Tsulukiani, Georgia's Minister of Justice, said in a statement, "We will be able to work with Blockchain technology from this [2017] summer [to] place real estate extracts in a totally safe and innovative system."

Source: https://www.forbes.com/sites/laurashin/2016/04/21/republic-of-georgia-to-pilot-land-titling-on-blockchain-with-economist-hernando-de-soto-bitfury/#1730f79f44da

5.2 Data Access

Technologies and approaches relevant to this section:	
What3Words	… an approach to addressing that divides the globe into 3m x 3m squares and assigns each square a unique 3 word address.

Land registry systems should be publicly accessible in accordance with national law, with well-published details concerning processes for accessing the registry and associated costs for doing so. Where possible, land information should be accessible or searchable at the sub-national level, ensuring that citizens can access or request data without travelling to the central office.

Lack of available and / or accessible public data about existing land tenure and holdings is a significant barrier to the basic functions of the government, effective land administration and achievement of developmental objectives. Furthermore, it inhibits private individuals and communities from understanding and protecting their own tenure security, and provides a significant disincentive for potential investors in the land, agriculture and natural resource sectors. In many cases of unavailable or inaccessible public data, governments themselves lack a comprehensive integrated registry and cadaster, and land agencies that manage this data may be chronically under resourced, leading to inefficient record management and potential for rent-seeking behaviors.

In the context of this Guide, this section addresses three key technology-related elements of data accessibility in an informative, rather than interpretative manner:

- Developing effective policies to support ICT-based information services;
- Establishing e-government services, including mobile device accessibility, crowdsourcing and revenue opportunities; and
- Establishing and maintaining National Spatial Data Infrastructures (NSDI).

Developing effective Public-sector Information Policies to support ICT-based Information Services

Compliance with public-sector information policy and regulations will most likely restrict the type of information services that can be provided; influence the associated charging regimes, and will ultimately affect sources of revenue. For example, many countries do not release information on prices paid for properties in the land market into the public domain on the grounds that it is personal information.

Since open, transparent access to land administration information is a prerequisite for developing effective land markets, reducing corruption, and building a trusting relationship with civil society, it is essential that land administration agencies work closely with the public information policy makers to ensure the maximum exposure and re-use of land administration information in the public domain. Recent progress in making copyright, licensing, and pricing arrangements as simple and consistent as possible includes:

- Many countries release land administration information, at a charge, to the private sector to allow innovative information services to be created. Such services require robust copyright, licensing, and pricing arrangements, but if these arrangements are too complex and too variable across customers, they will deter uptake, innovation, and potential revenues. The case study on Geoscape provides some insight into opportunities for innovation opportunities.

- A number of governments have introduced 'Open Data' transparency agendas, e.g. Finland, USA and UK, which emphasize the need for governments to be accountable to taxpayers and have driven programs to publish key government datasets through the establishment of a single access point for government data. In parallel with this development, governments have also developed Open Government Licenses, which provide a single set of terms and conditions for anyone wishing to use or license freely available government information. This form of licensing allows developers and entrepreneurs wishing to use government data to create new applications without any formal application for permission.

Key decisions or questions that guide the design and implementation of ICT services for land administration then revolve around:

- What laws exist for open data, copyright freedom of information and data privacy, and how do these influence ICT services for land administration?
- What are the core needs and goals of the land administration reform project, and what elements of open data and data service provision (whether public or private) will best support these?
- Is there an existing base of entrepreneurs and/or businesses that will take up the opportunities presented by open data in land administration – and/or how can this base be created to foster land services and outputs from land administration reform?

Establishing e-Government Services

Online access to information services related to land administration is expanding with support from broadband infrastructure growth and increased mobile phone penetration delivering both Internet and SMS-based services. There is significant potential for land agencies to capitalize on this, by becoming more inclusive and building public trust through the provision of simple, transparent, and accessible services.

Although the outreach of e-services and the use of mobile phones to communicate with customers are significantly increasing, the digital divide still excludes many customers from these communication channels. Therefore, to provide security of tenure for all, more conventional channels, such as distributed offices and mobile offices, should also be provided. This ease of access to services must remain in place nationwide to support the on-going maintenance of land rights and not just be transient through the first registration phase. Where mobile penetration is low, and in more rural areas, many land administration service providers have implemented the use of one-stop-shops, including the use of a data terminal (e.g. computer or similar) to allow individuals to access information. Ultimately, the needs of urban/rural, individuals/entrepreneurs, government/private sector need to be balanced, and the ethos of FFP is to adopt pro-poor measures to 'achieve as little as possible and as much as necessary' to fit current needs and context.

Case Study 6: Geoscape, Public Sector Mapping Authority, Australia

Developed by the Australian Public Sector Mapping Authority (PSMA), Geoscape is a suite of national digital geospatial datasets, which represent buildings, surface cover and trees across the Australian continent. The purpose of the national dataset is to represent spatially buildings and related features and deliver in a manner that can be productively used by industry, academia and government. The dataset links to existing PSMA products including G-NAF (addressing spatial layers), Cadlite (cadastre and property spatial layers) and Administrative Boundaries (suburb/locality spatial layers).

Geoscape represents one application of automated feature extraction and machine learning, leveraging DigitalGlobe’s WorldView-3 satellite-based sensors, a multi-payload, superspectral, high-resolution commercial satellite sensor platform, providing 31cm panchromatic resolution, 1.24m multispectral resolution and 3.7m short wave infrared (SWIR) resolution. With an average revisit time of less than one day, it is capable of collecting up to 680,000 square kilometres per day. The full capture and production of Australia’s foundational dataset providing location, distribution and physical characteristics for over 20 million structures across 7.6 million square kilometres was expected to be completed in just 18 months. The attribution, scale, scope and innovative approach is unprecedented and enabled through the combined use of various disruptive and emerging technologies, including:

• High and low resolution multi-spectral satellite imagery

• Satellite derived digital surface and terrain models

• SWIR spectral analysis

• High quality national foundation data

• Sophisticated geo-integration

• Collaborative crowdsourcing

• High performance cloud computing

• Machine learning and automated feature extraction

• High quality ground control

The continental scale dataset provides an increased level of knowledge about the attributes of a location, especially in terms of buildings and feature linkages (including polygon, roof area, pitch/complexity and roofing material, ground level coordinates for roof vertices, number of roof vertices, ground level building centroid, maximum roof height, solar panel indicator, residential land use indicator, feature level quality information), vegetation (including tree coverage and height, grass coverage and unspecified vegetation), impervious surfaces (including built up areas, roads and paths, bare earth), land and water cover, and related property information (such as geocoded address, cadastre boundary, property boundary, and zoning)

Collaborative crowdsourcing has further been applied to support machine learning, with Tomnod – DigitalGlobe’s crowdsourcing geospatial intelligence technology platform - used to assist in the identification of features such as swimming pools and solar panels. In this manner, thousands of reliably labeled properties were collected in a matter of days.

By linking data about buildings and land with the existing national geospatial database, Geoscape provides a stronger understanding of what exists at every address to support geospatial analytics for Australian government and business.

Geoscape was presented at the World Bank Annual Land and Poverty Conference in 2017, and the paper authors noted the following potential applications:

- Supporting the rural landholding registration process by offering a foundational dataset to support the move to digital record-keeping that is actively enhanced by participatory adjudication
- Determining population hubs via buildings or structures to address spatial

misallocation in cities, in terms of where land may be devoted to slums compared to the desired location of slum residents

- Supporting administrative and institutional reforms for land, housing and urban development by providing foundational and maintenance data to support development of a GIS web portal and publicly accessible data
- Monitor and identify deforestation

Maintenance of the dataset is a serious concern, and the ongoing cost of maintaining large datasets such as Geoscape is a significant disincentive for undertaking such initiatives. A minimal annual maintenance process is thus applied, focusing on significantly changing regions in Australia, such as growth suburbs, and updating surface cover for urban areas on a 12-month capture cycle.

Case studies on how private industry is using the geoscape dataset are available at: https://www.geoscape.com.au/showcase/

PSMA was formed by the governments of Australia in 1993 to collate, transform and deliver their geospatial data as national datasets. The organizations first major initiative was to support the 1996 national census through the provision of Australia's first digital map at a national street-level. PSMA makes data available to industry through value-added reseller and integrator network, which includes geospatial analysts, software developers, marketing service providers and consultancies.

Source:

Geoscape Product Description, Accessed 23 May 2017 https://www.psma.com.au/sites/default/files/geoscape_product_description.pdf

Paull, D. 2017 *Cost-effective Building Capture at Continental Scale Using Satellite Imagery and Automatic Feature Extraction* 2017 Annual World Bank Conference on Land and Poverty, Washington D.C. https://www.conftool.com/landandpoverty2017/index.php/12-01-Paull-807_paper.pdf?page=downloadPaper&filename=12-01-Paull-807_paper.pdf&form_id=807&form_version=final

What3Words (Appendix A.16) is one example of how governments can support entrepreneurship in reverse. What3Words provides a unique and easy-to-implement addressing system, with the globe divided into 3m by 3m squares and each square given a unique combination of three words. The technology has been adopted in Mongolia to provide a national addressing system, and there is potential for linkages with the establishment of point cadastres, or the facilitation of location-based services with limited preliminary work or investment required. What3Words has been integrated into the land tenure software solution provided by company Camidus (see https://what3words.com/partner/camidus/) to address transcription and communication issues presented by GNSS coordinates when undertaking land measurement.

Key considerations relating to web- and mobile-enabled access then include:

- Where is the population located, and how are individuals and businesses enabled to access data on land?
- What is the penetration of mobile phones (and is data or SMS more typical for usage)?

- How can e-government services be adopted in a manner that increases transparency and reduces opportunities for corruption (and not the other way around)? See case studies on Ukraine and the Czech Republic

Case Study 7: Ukraine - Crowdsourcing for Improved Data Quality and Completeness

During the World Bank-funded land administration program in Ukraine, 16.8 million ownership documents (35 million pages) were scanned, indexed, data entered, verified and uploaded to a secure database environment in just five months. The agency was well aware that the quality of the data was limited and decided to expose these records to their customers openly via web services to crowdsource improvements to their records. An on-line service for reporting errors was created. During the first month of operation, 11,000 errors were reported and 8,000 records were corrected. The feedback from customers provided the Agency with an insight into the types of errors prevalent within their records. For example, out of 88 errors reported, 56 were found to be similar. This led to the automatic correction of over 2,000 errors. Automatic tools for error identification, classification and correction were subsequently created [Source: Tonchovska, R. and Kelm, K., 2014].

Case Study 8: Czech Republic – Open Access Land Administration to promote data credibility

In the Czech Republic, the cadastre of real estate is public and everyone is entitled to consult it, make copies, extracts and sketches for their need or obtain data from the collection of documents managed by the Czech Office for Surveying, Mapping and Cadastre. The agency has introduced an open portal to provide access to map products and services – see Figure 7.

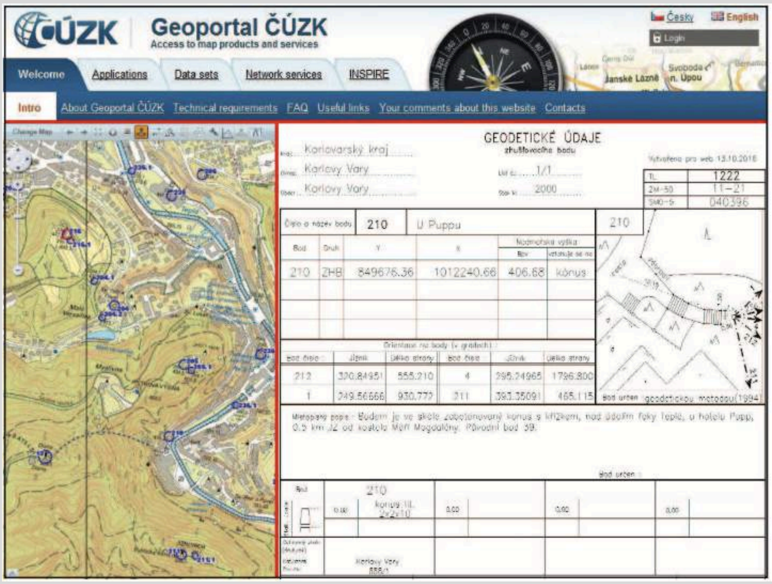


Figure 7:Portal to Access Mapping Products and Services

[Source: Tomandl, L., and Zufanova, V., 2016]

The Agency has opened up a consultation with their customers where they can report errors in the data and provide proposed corrections. As part of this engagement, the agency has color-coded the boundary points defining the parcels based on their accuracy. See Figure 8 where green boundaries are high quality and red boundaries are poor quality. This quality classification has been achieved by combining the digital parcel boundaries with digital orthophotomaps to identify the level of discrepancies. Customers can then decide if they want to involve surveyors to upgrade the quality of their boundary definitions.

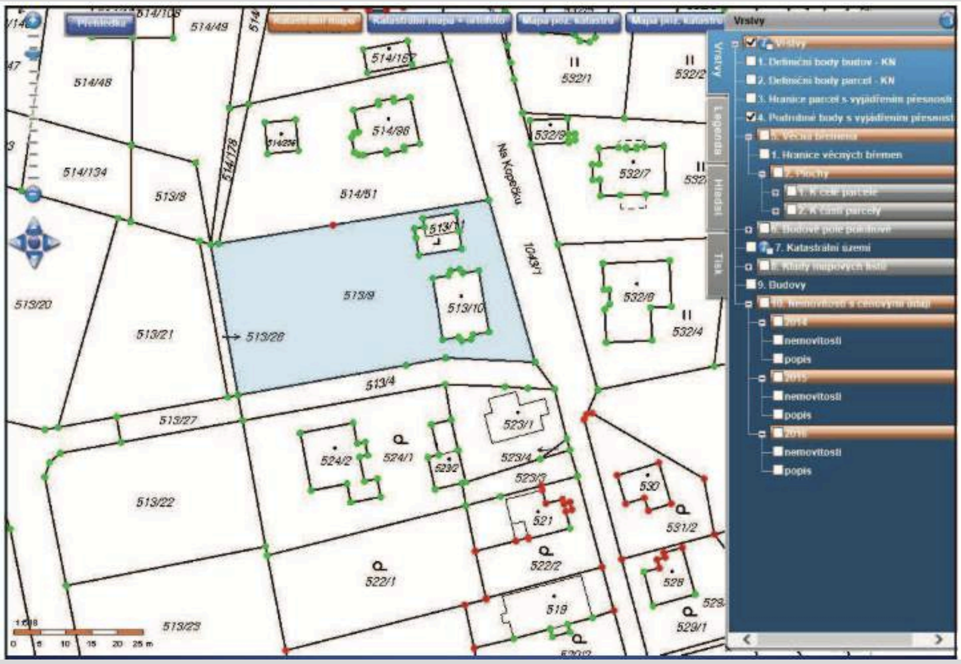


Figure 8: Differentiation of Quality of Parcel Boundaries

[Source: Tomandl, L., and Zufanova, V., 2016]

NSDI and Land Administration

Government geospatial information is being increasingly considered as an integral part of the structure necessary for the operation of good governance, underpinning the services and facilities necessary for effective functioning of national and regional economies. The term **National Spatial Data Infrastructure (NSDI) (Appendix B.8)** has thus been adopted to cover the set of technologies, measures, standards, implementation rules, human resources, services, datasets and other factors that enable the efficient management, maintenance and integration of spatial datasets.

Components of an NSDI might extend to:

- Spatial data sources;
- Metadata system;
- Network services and technologies;
- Implementation rules, agreements on spatial data sharing, exchange, access and use;
- Terms of use;

- Coordination and monitoring mechanisms;
- Processes and procedures;
- NSDI Geoportal; and
- Human resources.

An NSDI is ultimately a, typically government, service that enables individuals to make better-informed decisions. It is fundamentally tied to open data and e-government services. The decision is thus not whether to develop and NSDI, but over what timeframe should an NSDI be developed, and what elements should be prioritized. The World Bank Group land / geospatial team, together with FAO, has created a Spatial Data Infrastructure Diagnostic Tool package to facilitate a standard measure and approach to assessing a country's SDI readiness and geo-maturity, which may support NSDI development and planning.

Case Study 9: Moldova- M-Cloud, MOLDLIS and NSDI

In Moldova, substantial support from the World Bank and other international donor institutions, particularly the Norwegian Ministry of Foreign Affairs (NMFA) through the Norwegian Mapping and Cadastre Authority Kartverket has been directed to:

i) Establishing and operating a unified property registration system;
ii) Registering over 75% of properties;
iii) Developing and implementing a land administration and property valuation system for taxation purposes.

In 2013, also with World Bank support, the Government of Moldova launched its **M-Cloud** platform. This platform is now operating across all Government Ministries and agencies to deliver e-Government services to the public. That includes:

- Implementing a shared platform across Government to consolidate the existing data centers;
- Transforming Government processes to increase public administration efficiency through the use of Information and Communication Technology;
- Developing electronic services for citizens and businesses; and
- Adopting an e-Governance regulatory framework according to international best practices, including opening governmental data to citizens and businesses.

E-Government provides digital interactions between a government and citizens (G2C), government and businesses (G2B), government and employees (G2E), and also between government and governments/ agencies (G2G).

The new Moldova Land Information System (MOLDLIS), like any Moldovan national or local government system, is mandated to link through the M-Cloud using web-services for the direct access to common official registries, using e-Government products such as:
- MPass (government authentication and access control service),
- MSign (government digital signature service), and
- MPay (government electronic payment gateway) see http://egov.md/en

Common access is provided and made available to the MOLDLIS to the Civil Register, Company Register and even the Fiscal Authority, which can send list of tax payers and receive list of land value of the tax payers

As part of the e-Government initiative, in April 2012, the Government of Moldova joined the Open Government Partnership initiative where it committed to increase public access to information, promote transparency of governance and ensure citizens participation to

governance, by using advanced information technologies. One of the tools that ensure Government openness is the open data portal http://www.date.gov.md, where all government institutions are able to post data sets. The e-Government Center is responsible for developing and implementing the e-Government agenda by applying widely the Information and Communication Technology, the institution aims is supporting the reforming the public sector, enhancing the performance of authorities and the transparency of state institutions, increasing the access to information and promoting e-Services, with a view to better meet citizens needs and contribute to the creation of a more accessible Government and increase the country's international competitiveness. The NSDI Law in Moldova prescribes 22 public institutions across 6 Ministries and 5 other Agencies/ Authorities and local authorities (most are involved in a demonstration pilot area for EU Twinning project). There are 37 datasets and 17 spatial data services described by metadata on http://www.geoportalinds.gov.md/geonetwork/srv/eng/catalog.search?node=srv#/metadata/6dec85e8-eb6a-4a49-9688-c83f527bf7a5 Most of the data available on the Open Data portal are protected by a Law nr. 305 regarding Reusing of Information in Public Sector. The open data portal http://www.date.gov.md The Open Data portal http://www.date.gov.md applies to currently around 944 data sources and around 30 applications

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6 FURTHER KEY CONSIDERATIONS

This guide has identified a number of technologies and approaches to support the design and implementation of land administration projects from planning and preparation, desk- and field-based information capture through to data management and data access. It is not designed as an exhaustive list of technologies, more an indication of current good and emerging *technological* practices that best meet the requirements of FFP land administration. Adoption of technologies and approaches identified must be informed by context, and the key contribution of this guide is the decision-support presented alongside the technology and key considerations information presented in the Appendices.

Appendix B: Key Considerations contains further information on key land administration topics that will help users of the Guide to understand the consequences and shape the decisions on the type of technology to use in land administration. This appendix provides more in-depth information about a supporting framework for decision support. It includes:

B.1 Costing and Financing Land Administration Systems - is essentially a decision-support tool for the costing and project design of land administration. It prompts discussion on a country's readiness for land reform, providing a series of templates to assist public agencies to identify the core needs and necessary minimum investment for land reform processes.

B.2 Role of Trusted Intermediaries - A key feature of these citizen centric approaches is the use of a network of locally trained land officers acting as trusted intermediaries and working with communities to support the identification and adjudication process. This approach builds trust with the communities and allows the process to be highly scalable. A strategy for recruiting and training trusted intermediaries is crucial for success

B.3 When to Capture Informal rather than Formal Land Rights – In countries where there is lack of political commitment or other constraints to recognize all legitimate rights then support may well build incrementally through the influence of local pro-poor recordation initiatives, which recognize and record legitimate rights in communities.

B.4 Customary (Social) Tenure - While many tenure rights are defined in formal law, there are often other rights that are not similarly defined, but yet people use them every day because they are recognized by the local community and others. These rights have a social legitimacy even if they lack legal recognition.

B.5 Public Awareness - Good public awareness is a critical success factor in many international projects to register rights. Campaigns to promote public awareness impact greatly reduce the length of time needed to systematically identify, adjudicate and register rights and the participation rate of landholders in these activities.

B.6 Imagery Sources and Comparisons - The selection of technology for cadastral survey depends upon a wide range of factors. There are about a dozen commercial satellite operators that provide imagery of 1m or better. This section provides comparison of different imagery and when to use them.

B.7 Emerging Standards in Land Administration - It is essential that land administration programs adopt international standards wherever possible, e.g. LADM. This section provides an overview of existing and emerging standards in land Administration.

B.8 NSDI and Land Administration - Increasingly, geospatial information within a country is becoming an integral part of the national data infrastructure that promotes data sharing and consumption. Similarly to other infrastructures, it is a structure needed for the operation of a society as well as underpinning the services and facilities necessary for an economy to function effectively. This section argues that land administration information needs to be an integral part of a NSDI.

B.9 Capacity Development - Implementing a FFP land administration system at a countrywide scale is demanding in terms of both financial and human resources, and will take years. The need for human resources and skills must be assessed up front with regard to developing the various aspects of the land administration system and also with regard to the capacity for running and maintaining the system. Therefore, a strategy for capacity development is critical

B.10 Factors Influencing the Design of the FFP Spatial Framework - The FFP spatial framework for a country is not a homogeneous framework with the same approach to capturing and recording land rights being adopted across all regions of a country. Instead the spatial framework will be a patchwork of different approaches depending on local circumstances. Legal, social and geographical factors influencing the design of the spatial framework are discussed to help guide the decision support.

B.11 Legal & Regulatory Framework Considerations - To allow a country specific strategy for FFP land administration to be implemented, changes will have to be made to the Legal & Regulatory Framework to accommodate full recognition of all tenure types in a country and to allow new approaches and technologies in the capture and recording of land rights to be adopted.

Sustainability is a fundamental component of FFP. Each technology presented in the Appendices is provided with a brief assessment of the sustainability of the solution, which may identify existing or theorized challenges relating to the longevity of hardware or software, the ability of local actors to sustain bottom-up solutions once project support is removed and the need for political will. Sustainability considerations listed are not exhaustive, but are intended as a guide for project designers and implementers, who may identify further sustainability considerations relating to their specific context.

Sustainability, of course, cannot be achieved without:

- Capacity development, which must take place at the societal, institutional and individual levels, and the design of capacity development activities must guide implementation approaches and have consideration for FFP approaches in the land sector (**see Appendix B.9**);

- The overall legal & regulatory and institutional frameworks (see **Appendix B11**); and
- The spatial framework (see **Appendix B.10**)

APPENDICES

Appendix A ‘Technology Descriptions’ and Appendix B ‘Key Considerations’ are contained within a separate document.

World Bank Guide

New Technology and Emerging Trends: The State of Play for Land Administration

Appendix A: Technology Descriptions
Appendix B: Key Considerations

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Acronyms

CORS	Continuously Operating Reference Stations
CoFLAS	Costing and Financing of Land Administration Services (for Developing Countries)
CSO	Civil Society Organization
FFP	Fit For Purpose
FOSS	Free and Open Source Software
GLTN	Global Land Tool Network
GNSS	Global Navigation System of Systems (includes GPS)
GCP	Ground Control Points
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICT	Information and Communication Technology
LADM	Land Administration Domain Model
MAST	Mobile Application for Secure Tenure
M&E	Monitoring and Evaluation
NGO	Non-Governmental Organization
OCR	Optical Character Recognition
OSM	OpenStreetMap
RFID	Radio Frequency Identification
RTK	Real-Time Kinematic
SOLA	Solutions for Open Land Administration
SQL	Structured Query Language
STDM	Social Tenure Domain Model
UAS/UAV	Unmanned Aerial Systems/Vehicles
VGI	Volunteered Geographic Information

1 APPENDIX A: TECHNOLOGY DESCRIPTIONS

This appendix contains detailed descriptions of the new and emerging technologies for land administration that are referenced in the main body of the Guide. Wherever possible, the producers of the technology have been asked to check the accuracy of the technical content. However, the authors have still retained their objectivity in appraising the technology. References are also provided for users of the Guide to obtain further information on the technology.

Costs

The technology description includes a section on capital and operational costs items associated with the technology. Rather than embed the costs in each of the technology descriptions the following tables of generic costs have been produced that can be cross-referenced. These are typical capital and revenue / operations costs, but will vary within country contexts.

Table 1: Generic Capital Cost Items

Capital Item	Unit Price US$
Large-scale A0 printers	US$ 5,000
A ruggedized Android or IOS tablet	US$ 1,000
A non-ruggedized Android tablet or phone	US$ 400
PC for editing and managing data	US$ 1,200
Differential GNSS device	US$ 5,000
Handheld GPS Device	US$ 250
Wi-Fi Hotspot – essential (for wireless model)	US$ 1,000
Satellite imagery where recent high-res imagery is not publicly available	US$ 15 per sq. km.
Fully equipped mobile mapping laboratory for Mapping my Rights	Approx. US$ 1,500 Free to project partners?

Table 2: Generic Revenue / Operational Cost Items

Revenue Item	Annual Price US$
Internet access service	US$ 6,000
Cloud service	US$ 2,500
PC/laptop maintenance	US$ 100
Tablet maintenance	US$ 15
Access to Cadasta Foundation cloud platform	US$ 500 Free to project partners?
Paper for printers (per printer)	US$ 500

Revenue Item	Annual Price US$
Paper and cartridges for ink-jet printers (per printer)	US$ 1,500
Skilled manpower	US$ 20 per day??
Unskilled manpower	US$ 15 per day??

Spatial Accuracy

A range of technologies and approaches are used to record the parcel boundaries. These produce a range of spatial accuracies. Rather than explicitly stating the corresponding accuracy (ies) associated with each of the technologies and approaches, a generic table of positioning technologies and corresponding accuracies is contained in Table 3.

Although GNSS satellites calculate a position with a high degree of accuracy, a lot of error is introduced between the time the signal leaves the satellite and hits the receiver on the ground. The atmosphere, reflective surfaces, and electromagnetic interference among other things can throw things off. These sources of error generally leave raw, autonomous GNSS positions with an accuracy rating of only +/- 5m m or so. Besides varying quality and design among GNSS receivers' hardware, more accurate location is possible through **differential correction.** This is a process that estimates the amount of interference by observation at a fixed known point, and uses this estimation to reduce the error in other receivers. Differential correction can occur through various sources including other satellites or base stations on the ground.

Most GPS receivers these days support differential correction through satellite-based augmentation systems (SBAS) such as the United States' Wide Area Augmentation System (WAAS). A lower-end professional GPS device that is WAAS enabled may provide 2-5 m accuracy in real-time and on a professional mapping or survey-grade device, such as the Trimble R1 used in the Colombia case study, may achieve sub-metre accuracy in good conditions. However, anything better than sub-meter real-time accuracy requires a more robust differential correction source, even with the most expensive receivers on the market.

Data may be collected in the field at an accuracy of +/- 1m with a professional device and **postprocess** the data later in the office with software such as GPS Pathfinder Office. This allows the application of differential corrections to field data using base data from hundreds of permanently installed base stations throughout the world, which can yield sub-metre accuracy, but only in the office after you have collected your data in the field.

To get real-time accuracy in the field down too as good as 1 cm you must have a connection to a real-time differential correction source. There are a few components to this type of a solution: (a) a compatible GNSS receiver (like the Geo 7X), (b) compatible software (such as TerraSync, Positions, or TerraFlex), (c) real-time instantaneous communications between the field receiver and the real-time source (Internet via Wi-Fi or cellular, UHF radio) and (d) the real-time source itself. The rover hardware and software are pretty straightforward, communications add some logistics to be dealt with, and the source itself may be hard to come by. Surveyors often have their own portable base station they take to a job, but this can be complicated and very costly. Trimble's new RTX system is a satellite-based real-time differential correction service that is broadcast over the Internet or directly through satellites to produce as good as 4 cm **real-time accuracy** with compatible receivers. Elecdata has a permanently installed base station at its home office in Jerome, Idaho that broadcasts corrections over the Internet and can be accessed through an IP address, username, and password. However, perhaps the most useful solutions are real-time networks (RTNs), which are often referred to as continuous operating reference systems (CORS). These systems provide a network of base stations that provide real-time kinematic (RTK) corrections over the Internet anywhere in the coverage area, resulting in up to 1-2 cm accuracy on compatible devices.

There is currently considerable ongoing research to reach better accuracy with common **smartphone** devices. The Android N operating system now allows access to raw GNSS measurements from smartphones or tablets through various APIs. Making this data available opens up the possibility of precise positioning information from smartphones. Preliminary results indicate that the noisy pseudo-range observations can, at the moment, only provide meter-level accuracies. However, the current quality of carrier-phase measurements can potentially allow for a precise centimetre-level displacement of a smartphone to be computed. The biggest obstacles preventing smartphones from competing with low-cost RTK units, includes the quality of the antenna and the duty cycling of the GNSS receiver to permit efficient correction. The high level of computation also provides a considerable challenge to mobile device batteries. Some of these obstacles may be overcome with improvements in battery life, and the use of external Bluetooth connected antennae, which can help improve the carrier-phase measurements.

Table 3: Positioning Technologies and Corresponding Spatial Accuracies

Grade	Mobile Phone	Hand-held simple	Hand-held advanced	Advanced chipset	Survey Grade
Example	Android, iPhone, iPad	Garmin Glo, Bad Elf GPS Pro, Cedar Tree CT4, CT7	Bad Elf Surveyor, Eos Arrow Lite, DT Research 307	Trimble R1, R2 SX Blue ii, EOS Arrow 100, CHC X20i, Geo 7X	Trimble R8, R10 SX Blue iii, EOS Arrow 200, CHC X20i w/RTK Spatial
Approximate Cost	US$ 200 - 400	US$ 100 - 250	US$ 600	US$ 2,000 – 3,000	US$ 5,000+
Horizontal Absolute Position Accuracy	± 5 Metres	± 2-3 Metres	± 1 Metre	± Sub-metre	± Centimetre
Reliability	67%	55%	40%	80%	90%
With DGNSS*				0.5 – 0.9 m	0.05m
With Kinematic post-processing or RTK	Under research				0.02m
Vertical Positional Accuracy					0.20m

[*] DGNSS = differential GNSS, differential either to a base-station at a known point, or using correction services, such as SBAS

A.1 Global Property Rights Index (PRIndex)

- The Global Property Rights Index, PRIndex, is a fast, low-cost and globally comparable indicator of citizens' perception of the security of their property rights.
- PRIndex is still in research/development phase to identify the core methodology to measure perceptions of tenure security.
- Ultimately, PRIndex will provide the basis for tenure-related measures under the Sustainable Development Goals, Voluntary Guidelines on the Responsible Governance of Tenure of Land, Forests and Fisheries, and other land-related initiatives.

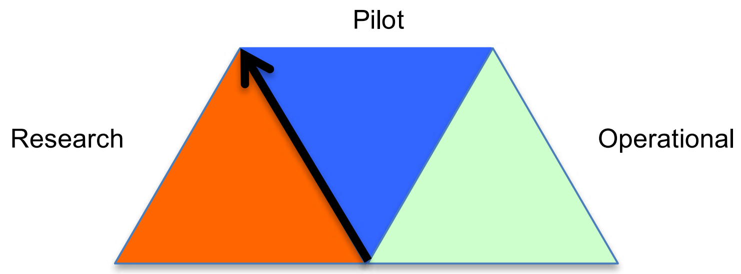
A. Description

PRIndex stands for the Global Property Rights Index, an indicator of citizens' perception of the security of property rights.

PRIndex is an initiative of Omidyar Network and UK DFID, being implemented by Land Alliance in association with Gallup, Inc. An initial phase of development of the index and testing its application is being carried out in ten countries during 2016 and 2017. After the development phase, the index will be globalized through the Gallup World Poll and other data collections in 2018.

A key motivator for the development of PRIndex has been the need to monitor the Sustainable Development Goals and the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Forests and Fisheries. A further potential application for PRIndex will be the monitoring and evaluation of the impacts of land administration interventions.

B. Maturity of Solution



C. Technology Details

PRIndex was launched in December 2016 and as at early 2017 is still in its first development phase. To date, there has been no well-established methodology to provide reasonable comparisons of property rights as perceived by average citizens over time, and across countries. PRIndex will demonstrate both progress and gaps in the provision of secure tenure through citizens' perception-based responses, helping to fill the evidence gap on the "demand side" of the property rights issue.

This first development phase of PRIndex conducts an initial set of surveys of citizens' perceptions of their tenure security globally, in the form of traditional household door-to-door surveys, in order to refine the approach and establish baseline data. These surveys include:

- **India State Survey** (completed) with data collected from 14,000 individuals in 14 states in India. Data obtained is representative at the state level.
- **10 country surveys** (nearing completion), with data collection being completed for nationally representative surveys in Brazil, Colombia, Egypt, Ethiopia, Greece, India, Indonesia, Nigeria, Tanzania and Peru.
- **A mobile phone and Internet based survey** in India (on-going) to collect data from 30,000 individuals, with data to be representative at the national and state levels.

Two reports have been released documenting preliminary results:

- Gallup 2017 *Global Property Rights Index 2016 Testing of a New Survey Module on Perceptions of Land Tenure Security in Nine Countries* March 2017 http://s3.amazonaws.com/prindex/publications/2/PRIndex_2016_Analytic_Report.pdf?1489608294
- Land Alliance 2016 *Building a Secure Future: Perceptions of Property Rights in India* http://s3.amazonaws.com/prindex/publications/1/Land_Alliance_-_India_Perceptions.pdf?1480937798

A Technical Advisory Group (TAG) of research experts in property rights is providing guidance on the design and methodology of surveys and analysis of data, including representatives from the World Bank.

Essentially the surveys all aim to answer the question: How worried are people, especially in poorer communities, about the risk that they could lose their homes or their land? The exact questions to determine this with a strong degree of accuracy and legitimacy are still being refined.

The work so far has categorized owner and renter responses into three tenure security categories:

- **Secure**: Those who indicated that they do not believe it is possible they could lose the right to live in their home against their will in the next five years.
- **Somewhat insecure:** Those who said it is possible that they could lose the right to live in their homes against their will in the next five years, but that it is not probable (i.e., they did not think that this was likely to happen in the next 5 years).
- **Very insecure:** Those who said it is both possible and probable that they will lose the right to live in their homes in the next five years.

Preliminary findings are shown in the PRIndex database – see Figure 1 and Figure 2 below. This is intended to be an open dataset, which will function as a global public good to monitor and encourage property rights reforms. It is expected that methodologies will also continue to be made public, and thus can be adopted in other projects. Global stakeholder consultations will continue throughout 2017 with a second round of country surveys also planned.

Figure 1: Country-level results from a preliminary measure of perceived tenure security. (Chart 4, P. 12, Gallup 2017).

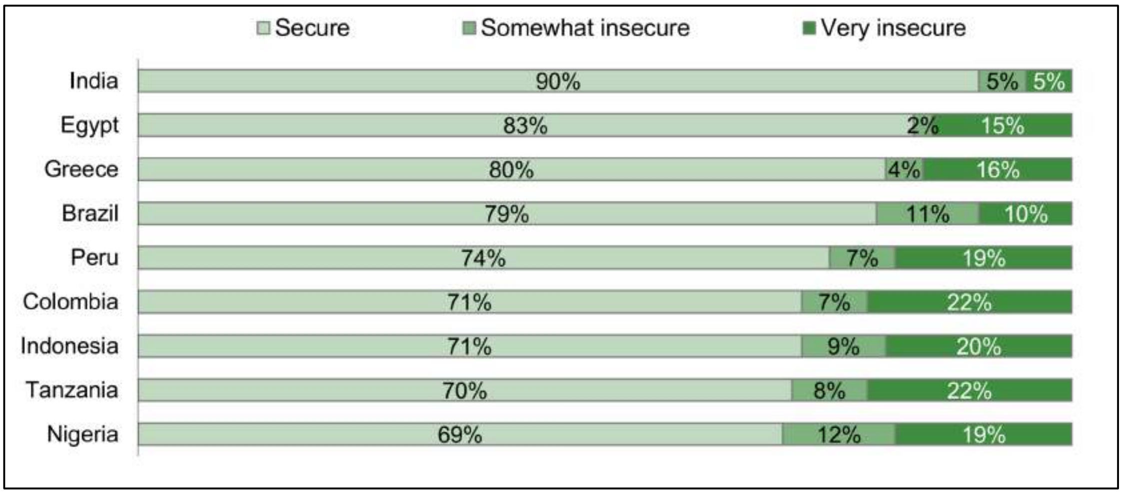
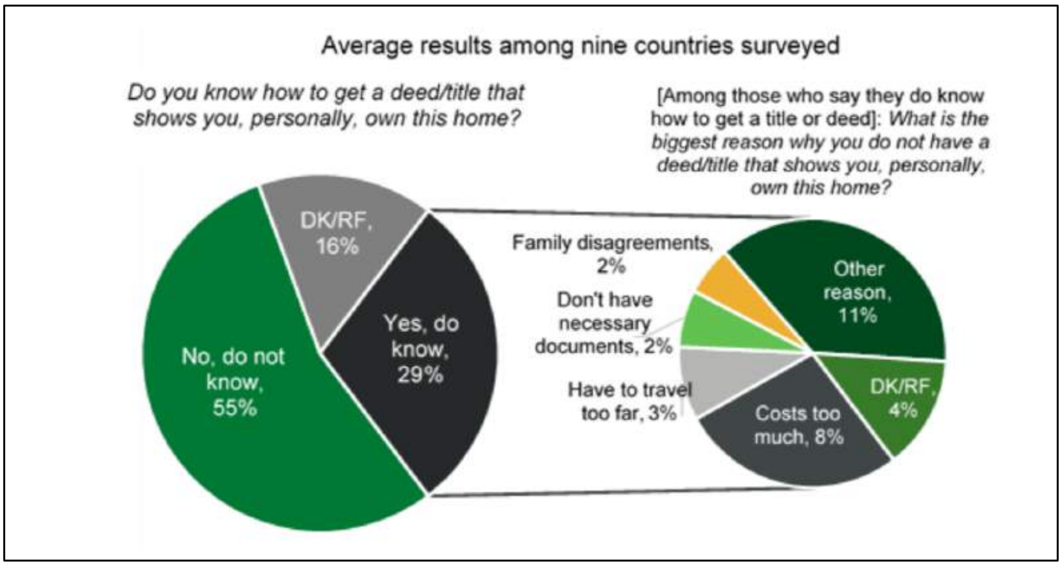


Figure 2: Reasons why homeowners who lack formal property documents do not have them (Chart 15, p. 24, Gallup 2017)



In 2017 PRIndex is moving to a new test phase, incorporating larger sample sizes and a wider question module that tests a greater variety of perception and self-reported questions on documentation. PRIndex is also investigating a multi-vendor solution - based on affordability, timing, and analytic needs – to address some of the mobile phone survey limitations. PRIndex is also seeking to work more closely with national statistics offices in order to support the reclassification of the SDG Indicator 1.4.2.

D. Limitations of Solution

- PRIndex provides a measure for perception of tenure security only; it does not measure actual tenure security and is dependent on respondents' own awareness and access to information.

- Level of coverage and comprehensiveness of PRIndex is so far limited. Much more extensive work is required to achieve usable results.
- Initial trials of mobile phone surveys have received limited responses. Work so far is thus resource intensive and further research is required to achieve scalable methods.
- Complete methodologies have not yet been published; hence wider users cannot yet replicate/undertake these surveys at project-level.
- Some concerns have been raised regarding research methodologies with respect to ensuring accurate responses regardless of gender, social/wealth status, etc. These appear to be recognised and will be addressed.

E. Supporting Documents and Reviews

PRIndex website: www.prindex.net

F. Contact

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A.2 Social Media (for Land Administration)

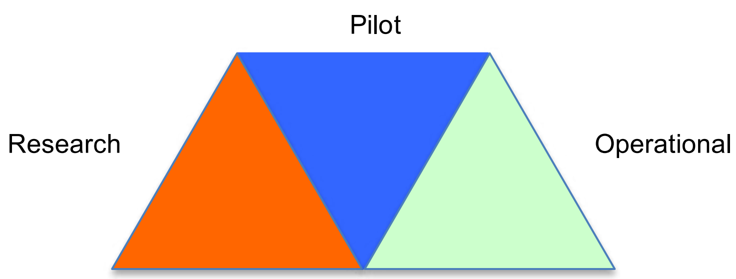
- Social media includes web-enabled applications that allow users to network and share content.
- Social media has been underutilised in land administration, but there is significant potential. This technology sheet addresses ……
- Obvious benefits of social media for land administration include increased public awareness, increased capacity for sharing information and improved trust and transparency.
- Users should have concern for smartphone and other technology penetration; social media uptake will likely be more appropriate to urban rather than rural contexts.

A. Description

Social media includes a multitude of applications that link to the web and allow users to actively and passively participate in a network and share and create content. Arguably it encompasses any content that has been created by multiple end users. Facebook, Twitter and LinkedIn are some common and widely used examples, but for the purposes of this technology sheet we'll extend the net more widely to include applications linked with SMS, online mapping platforms and online forms and forums available for user input.

This technology sheet is a departure from others in that it covers several technologies/approaches, most of which have not as yet been directly applied to the land administration sector. A core theme of the technologies selected is the 'user-generated' nature of the content, that is geographical in nature, and that in some way addresses some of the challenges of land administration – including participation, inclusiveness, public awareness, cost, time, capacity, etc. There is clear potential for social media technologies to support land administration particularly by facilitating interaction between citizens and government, however there are a number of challenges and the limited number of pilots utilising social media is perhaps indicative of such risks.

B. Maturity of Solution



It is difficult to truly assess the maturity of social media for land administration – specific, contextual applications may be mature whilst other platforms are yet to be considered for land administration. The technologies and approaches below provide a variety of maturities.

C. Technology Details

Social-media approaches typically have the advantage of being “free to use”, and can often support both passive and active information gathering. Emerging top-down approaches can be seen to include the use of Facebook sites and groups embracing of WhatsApp and Snapchat mediums to push out information or seek input. Specific land-related initiatives and mobile apps such as MapSwipe engage the general public and encourage contribution of their time and interpretative skills to improve local understanding and knowledge. Growing attention to Big Data suggests there are opportunities to draw from passive data to support tenure security.

There are many ways to categories social media uses for land administration and one example is the following three categories:

- E-governance – including the provision of land information via the web, and formal public access to land information, including some use of feedback forms.
- Online dialogue - Hosting of online dialogues and discussions via social platforms
- Volunteered Geographic Information and mapping – utilising mapping and geographic information tools to gather input and provide decision support in a networked environment.

These areas are clearly not the sole domain of social media, but provide a clear categorization. They also have common advantages and challenges are common across platforms – ultimately more people can be targeted and included but caution is necessary to ensure the same power structures are not simply reinforced with technology, and that sample sizes are indeed representative.

Some examples of social media for land administration – and opportunities for social media for land administration – are discussed under these categories below.

E-governance

The increasingly pervasive mobile phone in developing countries provides opportunities for governments to both reach further in terms of sharing information more frequently and more widely, and to obtain data from more remote citizens/communities. This data could pertain to perceptions of tenure security (as with PRIndex), collection of land administration data, provision of land administration services, and so on. Social media has also been extensively used in the land rights activism space, to share information internationally on land rights violations

Some examples of opportunities include:

- ***Big Data.*** This includes the use of datasets such as property valuations, micro-financing, mortgages, addresses, business registers, school registers, census, marketing campaigns, social security payments, property tax, agricultural grants, mobile phone users, etc., combine also with passive data from twitter, Facebook, and even mobile phone GNSS (with permission). These data could be used to model, analyse and derive perceptions of insecurity of tenure, to provide further evidence of tenure and/or need for land administration services.
  One example of Big Data tools is Neighbourlytics (www.neighbourlytics.com), a social analytics platform for neighbourhood development. It uses big data to map and measure social connectedness in neighbourhoods in real time, with the aim to provide information to property developers and city councils on

what built environment/urban planning tools work to support community values and social identity. The platform is being piloted in Australia with Frasers Property across five development sites. The platform demonstrates the opportunity of using passive social media data

- ***SMS-based systems for information sharing and reporting.*** For example, the UNICEF uReport outreach to youth in Uganda. This is a free SMS-based system that allows young Ugandans to speak out on what's happening in communities across the country, and work together with other community leaders for positive change

- ***Outreach through Social Media.*** The increasing use of social-media (Facebook, Twitter, LinkedIn, WhatsApp, etc.) across the globe (Facebook now has over 1.6 billion users) provides excellent opportunities to tap into these communication channels and forums to derive information on perception of insecurity of tenure.

Online Dialogue

- Local radio communication campaigns can be designed with facilities for citizens to leave voice messages or SMS responses. The deciphering and geo-referencing of the voice messages could be crowdsourced.
- Sisi ni Amani, Kenya (SNA-K) uses its SMS platform to mobilize communities to attend open-air forums and other events relevant to land management and violence prevention. It also uses SMS to educate community members on relevant issues, including how they can voice grievances over land-based issues peacefully, and sends violence prevention text messages to target demographic groups when tensions arise at the grassroots level.
- Market research with SMS surveys. SMS based surveys can be arranged through mobile service providers, globally. For example, Geopoll (http://research.geopoll.com/) is the world's largest mobile survey platform, with a database of 200 million users in Africa and Asia. The approximate cost is around $5 / completed survey.

VGI and mapping

A significant number of community mapping initiatives are being activated across the globe, and there are opportunities to build on these through social media. For example:

- The Extreme Citizen Science (ExCiteS) research group at UCL are recording community resources with forest villages (it is described at http://www.scidev.net/global/indigenous/multimedia/mapping-the-congo.html). This could be extended to ask the anthropologists who are working in the field to assess perceptions of ownership and land use.
- MapSwipe: (www.mapswipe.org) is a mobile app that asks users to search for key features on satellite imagery to help humanitarian agencies target efforts. Users install the app, join a project and then swipe through satellite imagery, marking tiles that include the features being sought. These tiles then become the base layer of detailed maps drawn by other volunteers. MapSwipe demonstrates the potential for VGI in land administration, whereby automated

feature extraction could be supported (or better targeted) by drawing from similar apps/functions.

- Mapping of tweets. PetaJakarta.org, an Indonesian-based open-source platform, used crowd-sourced information from Twitter to make a real-time map during the Indonesian floods of December 2014. Ushahidi, Humanitarian OpenStreetMap, MicroMappers and other organisations/applications use crowdsourcing to assess and map tweets in real time to support disaster and humanitarian response. (see e.g. http://micromappers.com/)
- Urban Voice Cambodia (urbanvoicecambodia.net) is an online web tool and app that seeks input via SMS, web and app on traffic conditions, road conditions, waste disposal and other urban issues affecting residents of Phnom Penh, Cambodia.

A.3 Use of Unmanned Aerial Vehicles (UAVs)

- Small Unmanned Aerial Systems or Vehicles (UASs or UAVs), more commonly known as drones, have become very affordable
- They are capable of providing high-resolution imagery, down to centimetres
- They can be transported and deployed very conveniently
- Software is well advanced in supporting flights over desired areas and processing imagery to match accurate geo-corrected imagery
- Limitations include small area limits because of flying time, possible security restrictions

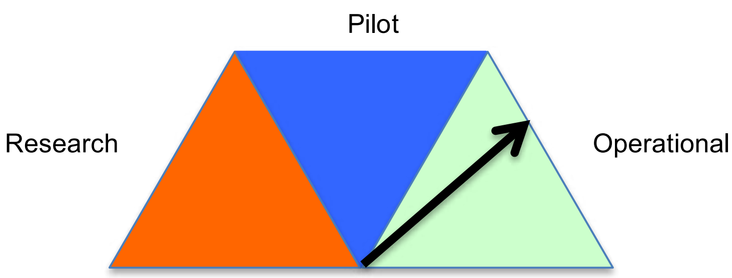
A. Description

As discussed elsewhere in this report, the FFP Land Administration approach advocates the use of a range of scales of imagery as the spatial framework to identify and record visible boundaries. However:

- Satellite image acquisition is often hampered by cloud cover, image availability and insufficient resolution for clear mapping in dense areas (some of the best satellite sensors are capable of obtaining imagery at 0.5m GSD, whereas many cities and dense areas may require 0.2m.
- Aerial ortho-photography can also prove expensive and time-consuming. Often international tenders have to be run and foreign companies may have to mobilise aircraft, pilots and equipment for the aerial photography campaign. The cost of providing small survey craft, along with trained staff, could be in the order of a few hundred thousand US dollars, so it is not normally viable for small areas.

UAVs, mounted with appropriate imaging and inertial measurement units (IMU), and supported by sophisticated and powerful planning and post-processing software, have become more lightweight, available and affordable for local surveying purposes. They can be locally owned and operated, providing a sustainable local solution for survey over small areas. The area of coverage is limited by battery lifetime in the drone, and also because most of the countries that permit them to be flown, stipulate that they must remain in sight of the operator.

B. Maturity of Solution



Several pilots have been carried out for small areas with excellent results of image resolution and geometric fidelity to facilitate image ortho-photomap consultation and adjudication.

C. Technology Details

UAVs, defined as “powered aircraft system that are remotely piloted, either manually or semi-autonomously by remote control or autonomously through the use of an on-board computer navigation system or a ground control station that sends commands wirelessly to the aircraft”, have rapidly become more lightweight, available and affordable for local surveying purposes.

Drones can be mounted with sophisticated equipment, including cameras and LiDARs and can be flown at a height that can provide very high-resolution detail. They can fly at low altitudes; hence avoiding the cloud issue. The camera and inertial measurement systems (including some with RTK) are supported by advanced software, which permits accurate geo-correction to provide ortho-corrected imagery.

Different forms of UAV are available, ranging in price, stability and performance.

- Fixed wing. These tend to be heavier and more expensive, but can be more stable, hence easier to ortho-rectify, and used to cover larger areas (e.g. 10 square miles). They do require an open flat surfaced area for launch and landing
- Rotary Wing. These are normally cheaper, with vertical take-off and landing capability, hence easier to launch, for example in a dense forest area or built up area. However, they are less stable, and use more batter power, hence they are conventionally used for imagined smaller areas (e.g. not more than 1 square mile per flight). However, because they fly more slowly than the fixed-wing alternatives they can hover closer to the ground, thus they can obtain very high resolution) should it be needed.

Of the more expensive fixed-wing drones, most now come with an option of an on-board GNSS device that operates in real-time kinematic mode, so that with a fixed reference GNSS receiver (or access to a CORS network), very reliable orthophotomaps are possible.

Software for such systems has also improved, and modern versions permit:

- Control of the UAV to ensure full coverage, with suitable image overlap (e.g. 80% front, 70% sideways), at a suitable height to ensure optimum GSD
    - A number of fixed wing UAVs can also be coordinated so that they fly in tandem and ensure full coverage
    - On-board sensors monitor battery performance so can return to base if running low
    - On-board detectors can detect obstacles and avoid them
    - Drones can be tuned to fly at an optimum height ensuring a set distance above undulating land (a rough DTM, such as one of the globally available free products such as the Shuttle-derived Shuttle Radar Topography Mission at 30cm resolution) will suffice for flight planning purposes.
- Processing of the acquired imagery to make continuous ortho-images, as well as 3-D representation, including incorporation of any possible ground control points (GCPs) from a conventional survey. GCPs are fixed points in the project, which are used to physically adjust the project in 3 dimensions to align it with the GCPs, and therefore create both global and local accuracy. Check Points are used as an independent accuracy check. GCPs are essential to provide project accuracy and Check Points are used for verifying that the data and solution is indeed correct.

To improve the resolution of topographic mapping, GCPs should be randomly distributed all over the study area. Key recommendations for GCOP location include:

- Random – Distribute well throughout the study area, and not bunched them together or put them in a straight line
- Die Face – Ground Control Points should be in the center as well as near the edges, but not ON the edges.
- Tight – keep the Ground Control Points no more than 1,000-1,500 feet apart

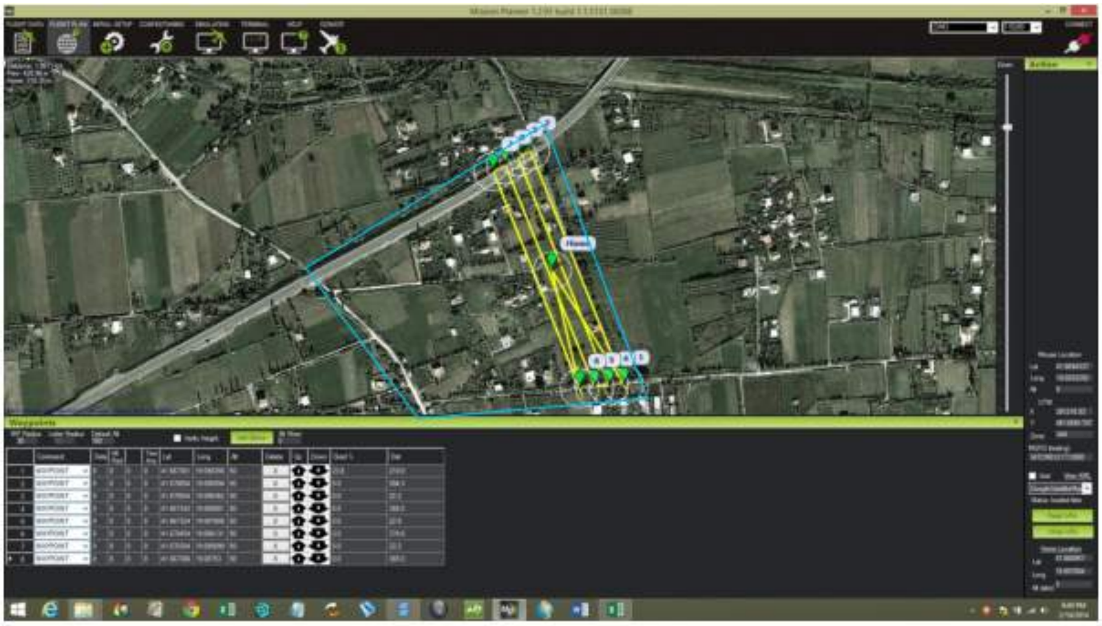


Figure 3: Mission planning software shows flight lines to cover study area

Drones can achieve GSD/spatial resolution of less than 2 - 3cm, flying at altitudes of less than 120 metres. Most small drones may be exempt from Special Flight Operating Certificate (SFOC), although permission must always be obtained.

The UAV is controlled by software that allows the operator to use a laptop in the field to prepare the flight plan, monitor one or more aircraft's exact positions at all times, and control the unit(s) while in the air. The software also acts as an interface between the UAV and the GPS base station if one is established.

In the Kosovo Case Study, for small areas, extremely detailed images at very high resolutions (2 – 3cm) have been captured in different lighting and weather conditions. Using a GPS base station, extremely high geometric accuracy was achieved. This is sometimes enhanced by pre-flight marking and differential GPS reading of these control points to be used in subsequent image processing.

Cameras can be fitted with different filters, so that parts of the electromagnetic spectrum are also available (e.g. thermal, near infra-red, etc.).

Drones can also be mounted with video cameras and LiDAR.

Because the technology necessitates local launching and flight, it provides an early opportunity for local sensitisation and awareness raising (informing for example village dwellers and elders, maybe even getting permission, to carry out the drone survey.

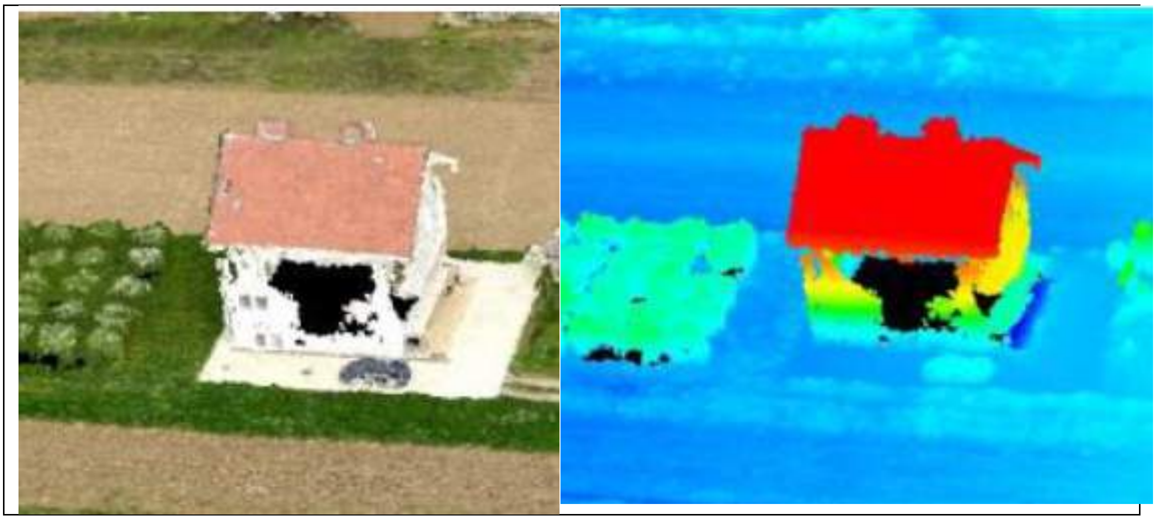


Figure 4: Dense point cloud for cottage and plants in Krusha (Kosvo pilot)

Post-processing software provides aero-triangulation facility for the imagery, which can configure the coordinate system to the one used in the original topographic ground survey, and the adjustment of the geoid separation of the base to orthometric elevations. The post-processing copes with the image overlap and generates orthophoto-mosaics and 3-D models. Because of the large overlap in image acquisition (conventionally 60%) and automatic image-to-image correlation, it is possible to obtain a set of "point clouds", which will indicate the approximate height of objects on the ground.

However, much more reliable and useful "point clouds" are those provided by LIDAR. UAS LiDAR mapping is available in the geospatial market but it is not as mature as UAS photogrammetry due to the high price tag for high-accuracy, low-weight LiDAR scanners, as well as the need for a precise GNSS/IMU. UAS-LiDAR mapping does not require large overlapped scans, and a single flight can cover a much larger area than UAS photogrammetry. However, the flight time is usually much shorter due to the heavy payload (typically 2kg) compared with a compact camera (typically 200g). UAS LiDAR mapping usually uses on-board RTK GNSS for heading and IMU for pitch and roll. Heading accuracy still needs to be improved to achieve comparable point cloud accuracy at the same flight height as UAS photography.

The Kosovo Case Study (section 4.2) provides some useful metrics:

- 2 drones were flown in tandem for 4 days to cover a study area of 5 square kilometres
- 44 500 images from 53 flights
- Considerable computing power to complete mosaics.

New advances for drones

Solar-powered versions.

Airbus recently announced the successful maiden flight of its Zephyr T aircraft, a drone powered only by sunshine, joining NASA and Facebook in a race to build high-altitude drones that combine the advantages of a satellite and the flexibility of a plane. “You don’t have to go through the rigor that current space-based satellite systems use,” says John Del Frate, an aerospace engineer at NASA’s Armstrong Flight Research Center. These “high altitude pseudo satellites,” will do many of the things satellites do and return periodically for new batteries or new tech. One day, swarms of solar-powered drones could provide communications and imagery, and at far lower than satellites, drones could provide sharper imagery of Earth. They could provide high-bandwidth links, using lasers to relay information to other drones or receivers on the ground, providing the sort of line-of-sight communication isn’t possible with satellites that orbit the planet and disappear over the horizon.

Large airship-plane hybrids

Large airship-plane hybrids are also being developed and will be commercially available soon. These hybrids – more than 90 metres long and holding a million cubic feet of helium – are capable of payloads of several tons, and could carry imaging systems, or even be used as a base for launching drones for rapid detailed image capture.

D. Limitations of Solution

- Regulatory limitations- it is important to consider the legal regulations before flying
- Wind and rain may make it difficult to fly
- There have been reports of some crow and eagle attacks on black fixed wing drones
- Battery life is a limitation to the period of flying, as also will be local/national requirements to keep any drone job within eyesight of the operator.

E. Costs of Technology

a) Capital Cost Items

Capital Item
Drones, including battery packs
Cameras
Software, including hard-drivers and servers

b) Revenue Cost Items

Revenue Item
GIS workstation maintenance (per annum)
Salaries for skilled operators/analysts (per annum)

F. Sustainability of Solution

Drone technology is undergoing rapid growth, particularly in terms of payload capacity, battery performance and size. Typically users should find that hardware will last for the duration of a project, but may seek to upgrade hardware after 2-5 years. Improvements in battery technology are making drones more viable for larger areas.
The key sustainability concern of drones is perhaps the ability for users to handle the resulting large amounts of data, including geoprocessing. Whilst contractors/consultants can be brought in to undertake this task, some capacity development is necessary in-house to ensure sustainability.

G. Capacity Level and Training Required

Activity	Skill Level
Drone operation	Surveyor / Drone operator
Data processing	GIS analyst/Photogrammetrist
Data maintenance	Data administrator

H. Supporting Documents and Reviews

Anderson, C. (2006). The Long Tail, Hyperion. New York, NY Anderson, C. (2012). Makers: The New Industrial Revolution. Random House, New York, NY

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Cunningham, K., G. Walker, E. Stahlke and R. Wilson (2011). Cadastral Audit and Assessments Using Unmanned Aerial Systems.' Proceedings of ISPRS and UAV-g, Zurich, Switzerland. http://www.teamconsulting.cc/images/uav-geomatics.pdf

Devriendt, L. (2014). 'Low-Speed and Low-Altitude UAS.' GIM International, 1(28)

Eisenbeiss, H., M. Sauerbier , Ch. Wildi (2013). Presentation at UAV-g Conference, Rostock University, Rostock, Germany. http://www.uav-g.org/Presentations/UAVg_2013_%20Eisenbeiss_Web.pdf

Everaerts, J. (2009). Unconventional Platforms (Unmanned Aircraft Systems) for Remote Sensing. Research Report No. 56, European Spatial Data Research, 57-102

Jazayeri, I, A. Rajabifard and M. Kalantari (2013). 'A Geometric and Semantic Evaluation of 3D Data Sourcing Methods for Land and Property Information.' Land Use Policy, 36: 219-230

Kelm et al (2013). 'Multi-purpose Spatial Data Capture.' ECA Region 2013 Innovation Grant Proposal, World Bank, Washington, D.C.

Manyoky, M, P. Theiler, D. Steudler and H. Eisenbeiss (2011). 'Unmanned Aerial Vehicle in Cadastral Applications.' Proceedings of ISPRS and UAV-g, Zurich, Switzerland. http://www.geometh.ethz.ch/uav_g/proceedings/manyoky

Neitzel, F. and J. Klonowski (2011). 'Mobile 3D Mapping with a Low-Cost UAV System.' Proceedings of ISPRS and UAV-g, Zurich, Switzerland. http://www.geometh.ethz.ch/uav_g/proceedings/neitzel

Rijsdijk, M. et al. (2013). 'Unmanned Aerial Systems in the process of Juridical Verification of Cadastral Borders.' Presentation at UAV-g Conference, Rostock University, Rostock, Germany. http://www.uav-g.org/Presentations/UAS_

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A.4 Feature Extraction from Imagery

- Efficient land registration requires the delineation of boundaries, which can be time consuming and costly using traditional ground survey techniques.
- As the volume of imagery increases exponentially with improvements in revisit times and resolution, automated methods are being sought to rapidly process the extraction of feature boundaries from imagery. This process is intended to eventually replace manual digitization by computer assisted boundary detection and conversion to a vector layer in a Geographic Information System

A. Description

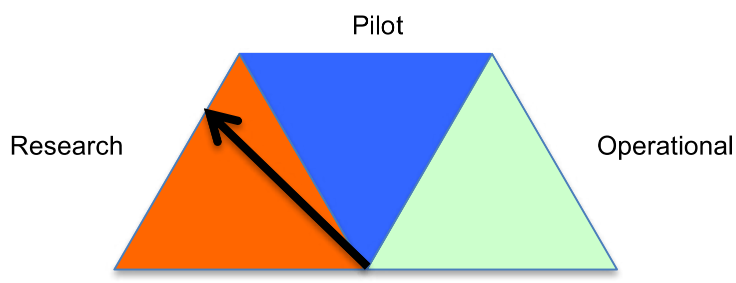
Two of the principles under the FFP Spatial Framework are:

- Visible (physical) boundaries rather than fixed boundaries
- Aerial / satellite imagery rather than field surveys

Humans are extraordinarily adept at identifying and digitising features in remotely sensed data sets thanks to our cognitive abilities. The wide use of printed orthophotomaps and participatory methods of drawing and agreeing property rights boundaries on them, has been shown to be very successful in Rwanda and moved operationally to Ethiopia. However, one of the limitations is that the drawn boundaries then have to be digitised in order to formulate the rights boundaries. Automatically extracted boundaries would not need digitising, but would still require overlaying and checking by citizens in the participatory approach.

Globally, as the volume of imagery increases exponentially with improvements in revisit times and resolution, automated methods are being sought for automated feature extraction, which can be used as boundaries to rights. Progress in Artificial Intelligence, sometimes linked to crowdsourcing is also driving this approach.

B. Maturity of Solution



Automated feature extraction has long been considered the Holy Grail of remote sensing, but for decades there has been relatively little to show for the significant sums that were invested in this technology, with many of the failings being attributed to the limitations of the sensors at the time. Advances in spatial and radiometric resolution, along with advances in processing of big data and artificial intelligence, are showing more promise.

C. Technology Details

The technology effectively aims to convert raster (picture) to vector (linear) data, and just for those features that may delimit property boundaries. The methods are either pixel-based or object-based.

(i) Pixel-based approaches analyse single pixels, optionally taking into account the pixels' context, which can be considered through moving windows or implicitly through modelling. These data-driven approaches are often employed when the object of interest is smaller or similar in size as the spatial resolution, or

(ii) Object-based approaches that are employed to explicitly integrate knowledge of object appearance and topology into the object extraction process. Applying these approaches becomes possible, once the spatial resolution is finer than the object of interest when pixels with similar colour, tone, texture, shape, context, shadow or semantics are grouped to objects. It is the method used for example for face detection on Facebook and others, and also made available through Google Cloud Vision API that quickly classifies images into thousands of categories, detects individual objects and faces within images, and finds and reads printed words contained within images. The technology is based on continuously evolving machine learning models and image processing algorithms, so improvements can be expected over time.

Specifically, edge detection can be divided into first and second order derivative based edge detection. An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location. First order derivative based methods detect edges by looking for the maximum and minimum in the first derivative of the image to locate the presence of the highest rate of change between adjacent pixels. Algorithms include Gaussian smoothing, gradient filtering, non-maximum suppression and hysteresis thresholding. Second order derivative based methods detect edges by searching for zero crossings in the second derivative of the image to find edges. The most prominent representative is the Laplacian of Gaussian, which highlights regions of rapid intensity change. The algorithm applies a Gaussian smoothing filter, followed by a derivative operation. Straight-line extraction is mostly done with the Hough transform.

Figure 5: Edge Detection

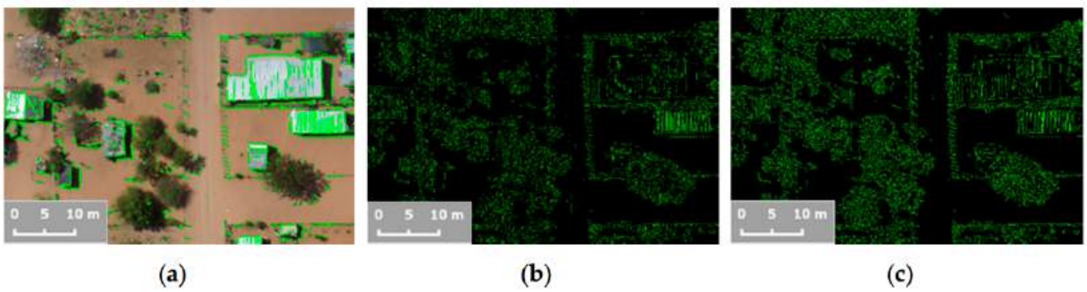


Figure 9. Edge detection applied on the greyscale UAV orthoimage based on (**a**) Canny edge detection and (**b**) the Laplacian of Gaussian. The output is a binary image in which one value represents edges (green) and the other value represents the background (black); (**c**) Shows the line segment detector applied and imposed on the original UAV orthoimage.

Feature detection can be improved by:

- Semi-automatic approaches that combine the interpretation skills of a human operator with the measurement speed of a computer. Semi-automatic approaches that include editing capabilities seem indispensable for cadastral mapping approaches that focus on the participation of local stakeholders and the integration of local knowledge

- Using multi-sensor approaches, especially the combination of airborne laser scanning (ALS) with imagery which yields accuracies that far surpass those that were achieved using pixel-based approaches on imagery alone. The LiDAR data provides three-dimensional point from which boundary features such as hedges, walls, can be semi-automatically determined with high accuracy and reliability.
- Keep improving feature detection and embrace machine learning/artificial intelligence with relevant imagery of relevant terrain and property boundaries. Even if a fraction of the effort that is put into face detection is put into feature extraction for property boundaries there is likely to be significant progress in the next few years, especially for very high resolution imagery
- Facebook reported that it has been using artificial intelligence software to scan 14.6 billion satellite images covering 20 countries in order to identify human-built structures. This has resulted in 350TB of data, a final global dataset with a spatial resolution of 5m
- A novel approach of combining human interpretation skills with a mass approach, is Tomnod, which is a team of volunteers who work together to identify important objects and interesting places in satellite images provided by Digital Globe. Current projects including asking volunteers to identify herds of livestock, permanent and temporary dwellings in South Sudan in support of the Famine Early Warning Systems Network to identify most vulnerable populations. Similarly, www.missingmaps.org (putting the world's vulnerable people on the map).has had nearly 30m edits (including over 9m buildings, and 1.16m roads) from remote volunteers tracing satellite imagery into OpenStreetMap (a crowdsourced system built by a community of mappers that contribute and maintain data about roads, trails, cafés, railway stations, and much more, all over the world.

D. Limitations of Solution

- There is as yet no operational, reliable approach to feature detection
- It is very computer-intensive
- Artificial intelligence and computer learning efforts have so-far been focused on commercial things such as illicit content and face recognition in social media imagery, rather than boundary or environmental detection.

E. Costs of Technology

Unknown at this stage

F. Sustainability of Solution

The solution has potential to be sustainable by offering an 'off-the-shelf' solution, however is not yet available.

G. Capacity Level and Training Required

Unknown at this stage

H. Supporting Documents and Reviews

MWC 2016: Facebook uses AI to map people's homes. Accessed at: http://www.bbc.co.uk/news/technology-35633915.
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Sohn, G.; Dowman, I. Building extraction using LiDAR DEMs and IKONOS images. Proc. ISPRS 2003, 34, 37–43.
Ünsalan, C.; Boyer, K.L. A system to detect houses and residential street networks in multispectral satellite images. Computer. Vis. Image Understanding. 2005, 98, 423–461.

I. Contact

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A.5 Paper Orthophotomaps

- Scaled paper copies of orthophotomaps are taken to the field and citizens / communities draw their visible parcel boundaries on the paper orthophotomaps.
- The boundaries are subsequently digitized from the paper orthophotomaps to create a digital cadastre.
- This is the most popular, scalable and successful participatory approach to capturing parcel boundaries.
- The best examples of applications in large-scale rural areas can be found in Rwanda and the on-going LIFT program in Ethiopia.

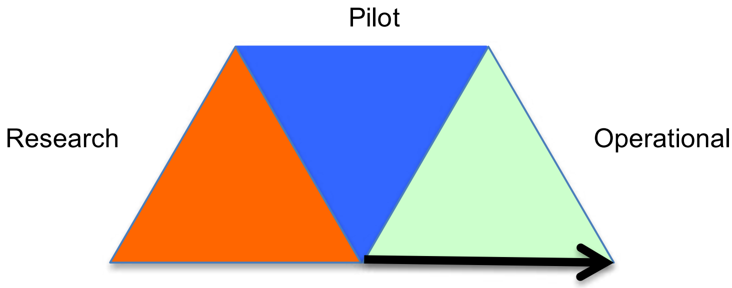
A. Description

Figure 6: Example from Rwanda showing and aerial imagery (left) from which the parcel boundaries are easily identified (right). Source: Didier Sagashya, Rwanda

To significantly accelerate the process of recording land rights, the FFP Land Administration approach advocates the use of a range of scales of satellite / aerial imagery as the spatial framework to identify and record visible boundaries. This fast, affordable and highly participatory approach is appropriate for the majority of land rights boundaries. The most important aspect of security of tenure for the majority of unregistered land parcels, is the identification and recording of the land object and its relation to neighbouring objects, in relation to the connected legal or social right. The absolute precision of the survey is less important, except perhaps in high value land and properties, and non-visible or contested boundaries, where higher accuracy, but more costly conventional ground survey methods and monumentation are more necessary.

In cases of high land values or intensive land use, the field surveys can be conventional land surveys using high-precision total stations or GNSS.

B. Maturity of Solution



In Rwanda 10.4 million parcels were registered and 8.8 million of printed land lease certificates had been issued over a five-year program. The unit costs were about 6 USD per parcel. See case study for more details.

C. Technology Details

The overall implementation process relates first to identifying the mapping technology and scales to be used for various areas according to topography, land use and building density. The imagery, after certain processing (geometric correction, sharpening, etc.,) can then be used to generate hard-copy, usually A1 colour, which can then be used directly in the field to determine the visible boundaries according to the actual occupancy and use. The scale must be constant within regions, so that relative distances and measurements can be made.

This must be a participatory process that involves all local stakeholders. This approach allows less skilled personnel from communities to be trained and used in the field. Importantly, this lets the FFP approach be highly scalable and supports the aim of secure land rights for all in much shorter timeframes. Rwanda provides an excellent example (see case study).

The FFP approach directly supports pro-poor recordation and the continuum of rights to ensure a fully inclusive methodology. The results can be drawn directly on the imagery and the parcels numbered for reference to the connected legal or legitimate rights. The resulting boundary framework can then be digitised and used as a basic layer in the national land information system, and can support the production and issuance of land rights documentation. This overall process may, of course, vary according to any specific local context.

When producing the spatial framework, the requirements for scale and resolution of the mapping will vary according to the topography and density of development. The criteria in selecting satellite, aerial or drone based imagery and the resulting accuracies is detailed in Section 4.3 of the Guide. It must be noted, though, that decisions will always depend on local circumstances. It is recommended that a national atlas be produced to show the various types of mapping and scales used in the different topographic areas with different kinds of land use.

D. Limitations of Solution

- The use and storage of paper is vulnerable in tropical climates, especially in the field with many people handling the material. Lamination is costly and also hinders easy marking up in the field.
- Since other land rights information needs to be captured, e.g. copy of ownership documents, finger-prints, photo of rights-holder, video of boundaries etc., some new approaches are being made to use tablets, projectors/screens, mobile cameras, etc.
- Facilities for printing large format, colour paper orthophotomaps are required.
- Trusted intermediaries need to ensure all stakeholders understand the interpretation of the imagery, since not everyone is spatially enabled.
- Several subsequent steps are needed after the field data capture, including scanning of the field maps, possibly geo-rectification and digitisation. Recruitment / management / paying of highly skilled GIS operators is required.
- The interpretation of the hand-dawn parcel boundaries has to be made by the GIS operators during the parcel digitising process and may introduce errors.

E. Costs of Technology

a) Capital Cost Items

Capital Item
Orthophotomaps
GIS workstation and software for digitising and managing land rights data
Printers for creating orthophoto hardcopies

b) Revenue Cost Items

Revenue Item
GIS workstation maintenance
Salaries for GIS editors/digitisers

Evidence shows that this approach is three to five times cheaper than field surveys and much less time and capacity demanding.

The Rwanda experienced US$6 / parcel (subject to specific country conditions).

F. Sustainability of Solution

This is a simple, highly participatory and sustainable solution. However, there are specific factors for its success:

- Full governmental and ministerial support;
- A strategy to overcome any resistance from professional groups, including from vested interests;
- Suitable land cover for parcel demarcation (parcel size suitable for satellite imagery, and well demarcate by visible field boundaries, e.g. walls, hedges, terrace boundaries);
- No legal impediments to recruit and train trusted intermediaries;
- A ‘green-field site’ makes the process more manageable. Any existing poor quality maps / documents complicate the process. For example, Ethiopia, had green books, though no maps and in Bangladesh the maps were so old and not maintained that the process basically started again.

G. Capacity Level and Training Required

Activity	Skill Level
Data capture and adjudication	Trusted Intermediary
Digitize demarcated boundaries from paper orthophotomaps.	GIS Operator

Quickly developed, highly participatory land registration programs involve a lot of resources. A strategy for recruiting and training para-professionals (locally trained land officers) is crucial for success. In Rwanda, for example, over 100,000 people were employed over the lifecycle of their program and a community driven process of demarcation meant that someone who was known in the community was responsible for defining the boundaries and not someone from outside the village. Given the sheer scale of the number of field teams operating, around 800 local land officers were employed by the Rwandan program at any one time. Once local districts were completed, the local land officers from completed districts were recruited to train the new land officers in the new districts.

The recruitment process for local land officers can be very simple: those who apply have to demonstrate that they can understand the aerial images, find their position on an image and have the attention to detail to draw boundaries.

H. Supporting Documents and Reviews

‘Rwanda Land Tenure Regularisation Case Study’, Dr Polly Gillingham and Felicity Buckle, Evidence on Demand, March 2014. Retrieved from 5th May 2017 https://www.google.co.uk/search?client=safari&rls=en&q=rwanda+ladn+registration+project&ie=UTF-8&oe=UTF-8&gfe_rd=cr&ei=uzQMWd64Isr38Aesk6HwBw

Byamugisha, F., T. Burns, V. Evtimov, S. Satana G. Zulsdorf (2012): Appraising Investments and Technologies for Surveying and Mapping for Land Administration in Sub-Sahara Africa. World Bank. Report.

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Case Study: Land Tenure Regularization in Rwanda

Rwanda implemented a well-functioning Land Information System through a program called Land Tenure Regularization. Nationwide systematic land registration started after piloting in 2009. The goal was to provide legally valid land documents to all rightful landholders and the program was completed in 2013. A general/visible boundaries approach was used and data were collected in a highly participatory manner. For provision of geospatial data high-resolution orthophotos and satellite imagery was used. Teams of locally recruited and specially trained local staff outlined the parcel boundaries on the imagery printouts that were scanned, geo-referenced and digitized. Printouts of the parcel plans became part of the legal parcel ownership document. The non-spatial data relating to owners' rights and particulars were captured in claim registers by legally constituted adjudication committees.

The information from the registers was entered into the Land Tenure Regularization Support System, from which titles were processed and printed for first issuance. A Land Administration Information System is used for processing transactions and for updating the register. In May 2013 about 10.4 million parcels were registered and 8.8 million of printed land lease certificates had been issued. The unit costs were about 6 USD per parcel (that is of course subject to specific country conditions).

The expected achievements for Rwanda are social harmony arising from reduced land conflicts and secure tenure, increased investment in land, greater land productivity and an increased contribution of land as an economic resource towards national development. There were not many qualified surveyors in the country. However, a land surveying program to train Geomatics engineers is underway.

Implementation was a shared responsibility between a wide range of stakeholders, with Rwanda Natural Resources Authority taking the lead. Development partners led by the United Kingdom´s Department for International Development were involved and other partners included Swedish International Development Cooperation Agency, European Union, Royal Netherlands Embassy and IFAD.

(E. Nkurunziza and D. Sagashya, Rwanda Natural Resources Authority)

Field data acquisition in Rwanda

A.6 Field Papers

- A tool to print maps from OpenStreetMap or imagery to take to the field to record boundaries and notes with pencil and paper. A scanned image of the marked up map can be easily georeferenced to support the manual update of the database. Primarily used within the OpenStreetMap community.
- Cadasta Foundation is customising Field Maps (it is FOSS) to support the capture of land rights and an interface to upload the land rights to their cloud platform.

A. Description

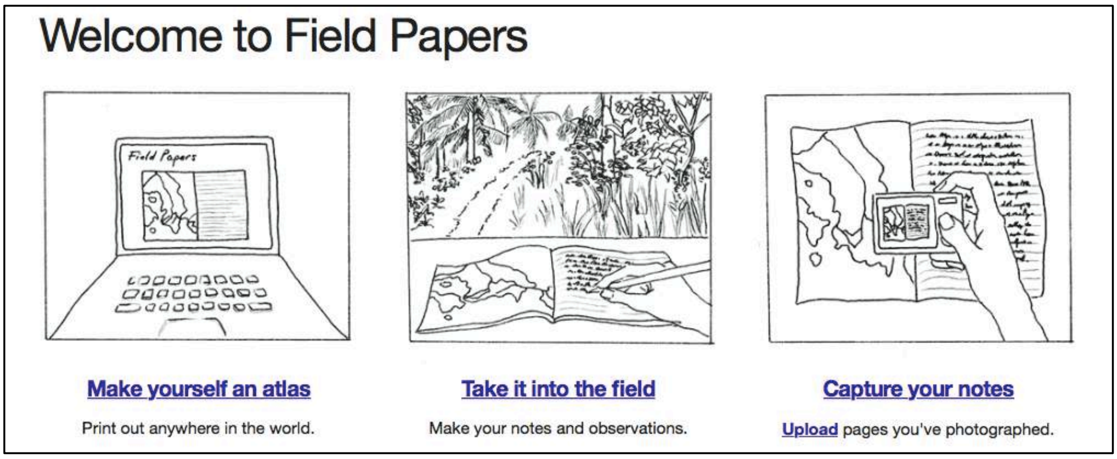
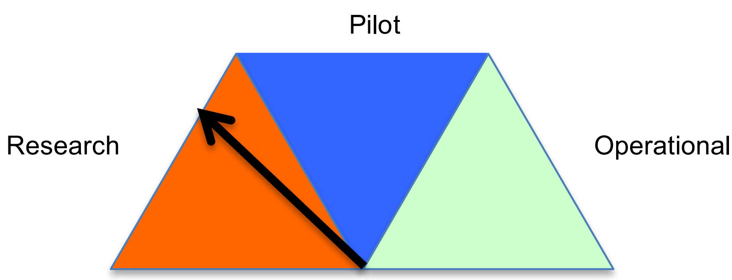


Figure 7: Field Papers Home Page (http://fieldpapers.org)

Field Papers is a tool that allows a user to print a map (with a backdrop of OpenStreetMap data or imagery) and then take into the field for recording notes, sketching boundaries, etc. Later, the user can photograph / scan each printed page and upload – and here is what makes Field Papers so interesting – because of the QR code embedded in the bottom corner of the printed sheets, the image will then be geo-referenced within your database, and the user can then trace any boundaries and transcribe notes as needed.

Although Field Papers is primarily a tool for updating OpenStreetMap, the Cadasta Foundation are customising the tool to support the capture of land rights on paper and an interface to digitise the land rights upload them to their cloud platform.

B. Maturity of Solution



Although Field Papers is fully operational, the Cadasta Foundation adaptation is still in the early stages of development and piloting. Solution most likely operational at the end of 2017.

C. Technology Details

Field Papers was designed and developed by Stamen (https://stamen.com). Here is the recommended procedure to use Field Papers (http://learnosm.org/en/mobile-mapping/field-papers/):

1. Locate the area you want to map on the Field Papers website. Print out a map of this area. You can choose to print the current map of the area on OpenStreetMap, or you can choose to print aerial imagery, if it is available in your area.

2. Use your printed map to survey the area. Add more places by drawing them on the map. Draw lines for roads, shapes for buildings, and so forth. Write notes about each location directly on the map, or write numbers on the map that relate to numbers in your notebook, where you can write more detailed information about each object.

3. Scan your paper into the computer. If you don't have a scanner, you can take a photograph of the paper, if your camera is able to take high quality pictures. Upload the image to the Field Papers website. When you printed a Field Paper, the paper comes with a QR code on the bottom of the page. This bar code allows Field Papers to determine the exact location of the map that you are using to survey. Later, when you load the paper back into Java OpenStreetMap Editor, all the objects that you drew will be shown in their actual locations. It's like using a GPS to collect precise coordinates, except all you need is paper!

Figure 8: Marked up printed map with QR code to support georeferencing

4. In the Java OpenStreetMap Editor, load the Field Papers. Use the objects you drew as a reference to add them digitally into OpenStreetMap.

All the OpenStreetMap software tools and associated Field Papers tools are FOSS. The Field Papers open source is on GitHub at https://github.com/fieldpapers.

D. Limitations of Solution

- It is assumed that the availability of OpenStreetMap data in remote, rural areas will be limited. Therefore, imagery (orthophotomaps) will have to be printed.
- The use and storage of paper is vulnerable in tropical climates.
- Facilities for printing large format, colour paper orthophotomaps are required.
- The interpretation of the hand-dawn parcel boundaries has to be made by the GIS operators during the parcel digitising process and may introduce errors.
- The Java OpenStreetMap Editor has limited functionality to handle topologically correct parcels, for example. It is unknown what level of editing functionality will be provided by the Cadasta Foundation solution.

E. Costs of Technology

a) Capital Cost Items

Capital Item
Orthophotomaps
Printers for creating Field Papers orthophoto hardcopies

b) Revenue Cost Items

Revenue Item
Access to Cadasta Foundation cloud platform

The Cadasta Foundation Field Papers solution is not operational and there are no figures for cost / parcel.

F. Sustainability of Solution

This is a simple, highly participatory and sustainable solution. Since it is primarily based on OpenStreetMap FOSS it should be highly sustainable. It requires little training.

G. Capacity Level and Training Required

Activity	Skill Level
Data capture and adjudication	Trusted Intermediary
Digitize demarcated boundaries from paper orthophotomaps.	GIS Operator

The recruitment process for trusted intermediaries can be very simple: those who apply have to demonstrate that they can understand the aerial images, find their position on an image and have the attention to detail to draw boundaries.

H. Supporting Documents and Reviews

Surveying with Field Papers, LearnOSM, Retrieved 6th May 2017 from http://learnosm.org/files/Field_Papers_en.pdf

I. Contact

Frank Pichel, Chief Programs Officer, Cadasta Foundation (info@cadasta.org)

A.7 Smart Sketchmaps

- Conversion of hand drawn sketch maps of non-metric spatial representations into topologically and spatially corrected maps.

A. Description

Figure 9: Community Creating a Sketchmap[1]

Whilst the use of sketch mapping itself is not new in land administration, smart sketchmaps' technologies and processes allow for conversion of hand drawn sketch maps of non-metric spatial representations into topologically and spatially corrected maps. Smart sketchmaps can provide qualitative spatial information in areas where conventional cartographic and geospatial knowledge is often limited. Including these maps in the land administration system not only adds to existing data about visible boundaries, but also importantly introduces records of those less obvious socially or temporally constructed de facto boundaries that are significant in customary tenures.

Smart sketchmaps can be seen as the next generation of hand drawn mapping that fully embraces the age of digital interoperability, automated processing, and fit-for-purpose land administration. Since recording certain land tenures is extremely difficult, if not impossible, using conventional technical survey prescriptions, smart sketchmaps may be the fundamental key in removing these barriers. This will be

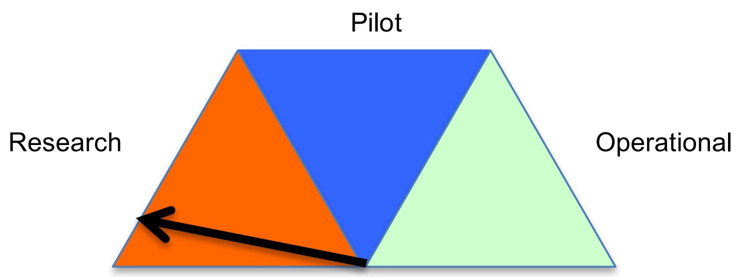
[1] Global Namati, 2016. Introducing the Community Land Protection Facilitator's Guide.

particularly beneficial for public-, private-, or grassroots mappers who cannot always adhere to those technical requirements.

its4land[2] is a research project, funded by the EU, with the aim to develop an innovative suite of land tenure recording tools inspired by geo-information technologies, that responds to end-user needs and market opportunities in sub Saharan Africa. Its4land will co-design, adapt, integrate, demonstrate, and validate a land tenure recording suite based on small unmanned aerial vehicles (UAV1s), smart sketchmaps, automated feature extraction, and geocloud services.

A tool for extracting spatial information from sketchmaps will be developed for the purpose of land tenure recording and to enable the capture of descriptive land tenure information from sketchmaps for incorporation and extension of the Land Administration Domain Model (LADM). LADM provides a standard for describing land administration systems worldwide based on quantified geometric information. its4land aims to extend the LADM with a shared vocabulary for sketching qualitative spatial information.

B. Maturity of Solution



Technology is currently in early research stage and probably three years away from being operational.

C. Supporting Documents and Reviews

Carline Amsing, Author of Dissertation on Smart Sketchmaps, University of Twente. (carlineamsing@gmail.com)

Schwering, A., Wang, J., Chipofya, M., Jan, S., Li, R., & Broelemann, K. (2014). SketchMapia: Qualitative Representations for the Alignment of Sketch and Metric Maps. Spatial Cognition & Computation, 14 (3), 220–254. http://doi.org/10.1080/13875868.2014.917378

Jan, S., Schwering, A., Schultz, C., and Chipofya, M., (2017), Cognitively Plausible Representations for the Alignment of Sketch and Geo-referenced Maps In: Journal of Spatial Information Science (JOSIS-2017) 14 (2017), DOI: 10.5311=JOSIS.2017.14.297.

Chipofya, M., Jan, S., Schultz, C., and Schwering, A. (2017), Towards Smart Sketch Maps for Community-driven Land Tenure Recording Activities (submission to AGILE 2017, accepted).

[2] https://its4land.com

D. Contact

its4land, Hengelosestraat 99, Enschede 7500AE, Netherlands.
Phone: +31-534874532

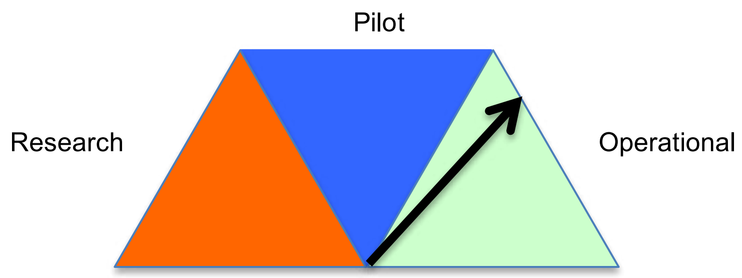
A.8 Mobile Applications to Secure Tenure (MAST)

- Participatory capture of land rights using smartphones (spatial, alphanumeric, and multimedia)
- Cloud platform to manage land rights
- Support government-issued certificates
- Going to scale in Tanzania and Burkina Faso

A. Description

USAID's Mobile Applications to Secure Tenure (MAST) uses an easy-to-use, open-source smartphone application and inclusive methods to capture the information needed to inventory and document land and resource rights. Mobile application is coupled with a cloud-based data management system to store geospatial and land information. This application suite is designed to lower costs and time involved in demarcating and documenting land rights, and most importantly, make the process more participatory, transparent, and accessible to local people. The MAST technology platform is based on a flexible data model, which allows it to be customized and applied to different contexts. With the support of the Tanzanian Government, the first MAST pilot resulted in government-issued Certificates of Customary Rights of Occupancy (CCROs) to rural Tanzanians for their land. The CCROs, paired with USAID-delivered training on land laws and women's land rights, are increasing tenure security, empowering women, and reducing conflict.

B. Maturity of MAST framework



2015 **Pilot**: Three (3) villages in Iringa District, Tanzania (MAST Pilot -Tanzania) – Data capture and field adjudication took place over a three (3) week period and resulted in the capture of a total of nine hundred and thirty-seven (937) parcels. This represented an average of fifty-five (55) parcels per day, or an average of six (6) parcels by each of the eight (8) trusted intermediaries. Technical assistance was provided by Cloudburst and implemented by CARE International.

2016 **Pilot**: Burkina Faso – pilot (MAST Pilot- Burkina) in four (4) villages within Boudry Commune, close to the national capital Ouagadougou. Within two months, 2,368 parcels in four villages (4) have been registered. The MAST app was translated into French and higher accuracy Global Navigation Satellite System (GNSS) support was used. Technical assistance was provided by Cloudburst and was implemented by Observatoire National du Foncier (ONF). The pilot was completed in 2017. Under the RISE Initiative, planning for the expansion of the MAST pilot into the East Region by ONF is underway.

2016 **Pilot**: Eastern Zambia – pilot (MAST Pilot - Zambia) in 134 villages with five (5) chiefs and two (2) local NGOs to record boundaries and certify customary land rights for 6,305 parcels in Chipata District. In the last quarter of 2016, the pilot expanded to Petauke District to test the technology in a new more rural environment. The project was run by Chipata District Land Alliance and Petauke District Land Alliance and is expected to be completed in 2017. Tetra Tech provided technical assistance.

2016 **Operational**: Tanzania (MAST Phase 2 -Tanzania) – Scale up of MAST to cover 41 villages with over 70,000 Certificates of Customary Rights of Occupancy to be issued. This project will significantly upgrade the existing modules and develop a new MAST component, Technical Register Under Social Tenure (TRUST), that allows for on-going management and maintenance of village and district land registers. The project will run for three (3) years finishing in 2019. Technical Assistance is provided by DAI, who are managing the project.

2017 **Operational:** USAID launched Land Technology Solutions (LTS), a new program designed to refine the MAST framework and support its expansion into new countries. LTS is an integrated knowledge transfer, capacity building, and technical assistance program that helps eligible countries rapidly deploy a customized version of MAST either as a stand-alone pilot project or an integrated activity supporting an existing donor funded program. This program is being implemented by SSG-advisors.

C. Technology Details

The MAST technology is an integrated application suite consisting of two principal components: (1) an android-based data capture application specifically developed to capture of land rights information and (2) a cloud-based data management infrastructure.

The MAST Mobile Data Capture Application captures land rights information (spatial, alphanumeric, and multimedia) in the field. Data is collected and stored on a user's device, and once the user is within the influence region of a mobile network or Internet, data is uploaded to the cloud-based data management infrastructure.

The MAST Data Management Infrastructure is a cloud-based web application providing tools to ingest, manage, and store captured information. It facilitates the intake and validation of data into a relational database management system that is configured on the Land Administration Domain Model/Social Tenure Domain Model. It processes and validates data according to predefined rules, facilitates the visualization and editing of data, and allows for the configuration and generation of formal land rights documentation.

Several versions of the MAST technology stack exist on Github, which mirror various deployments. The technology is currently undergoing a revamping of its underlying components, update of its data model, and improvements of key software functions related to both the capture and the processing and validation of data. Key functions of the initial version of MAST deployed for Tanzania and updated for Burkina Faso's context are provided below:

MAST Mobile Data Capture Application

- Parcels' boundaries captured using GNSS on mobile phone, using external GPS devices or by tracing boundaries on satellite imagery; and
- Captures data related to land parcel in off-line mode and transfers data to cloud-based data management server when a connection to Internet is available.

MAST Land Rights Data Infrastructure Web Application

- Provides administration tools that allow for customizable set-up and security of collected data;
- Facilitates intake and validation of data into a relational database management system that is configured on the Land Administration Domain Model (LADM) / Social Tenure Domain Model (STDM);
- Configures the database, including the addition of customized fields, and porting of attributes to mobile devices;
- Processes and validates geospatial and attribute data according to predefined rules;
- Visualizes and edits spatial data that has collected in the field, via a Web-based GIS; and
- Allows for the integration of statistical and template reports to support land rights documentation.
- Land rights data is managed on the cloud platform and access to the data is restricted through security.
- Access to the cloud platform is not provided to land rights holders or beyond, so there are no privacy issues around the dissemination of the land rights data.

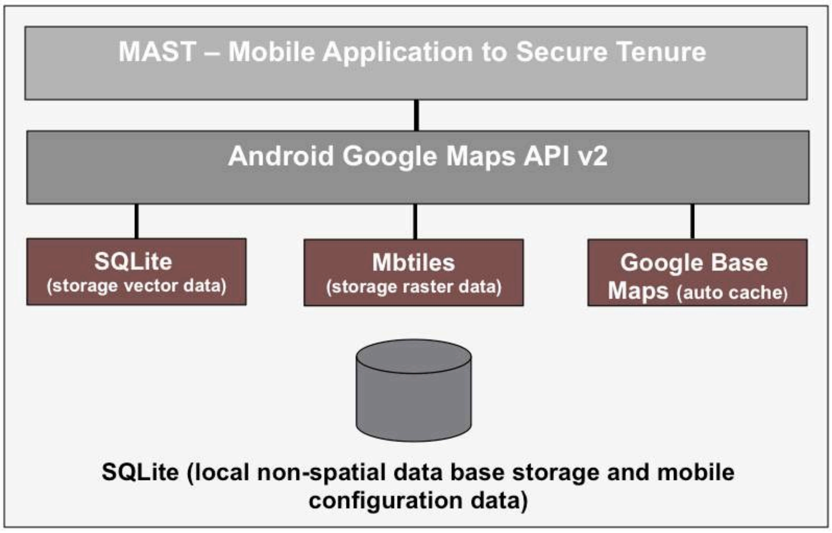


Figure 10: Architecture Mobile Data Application

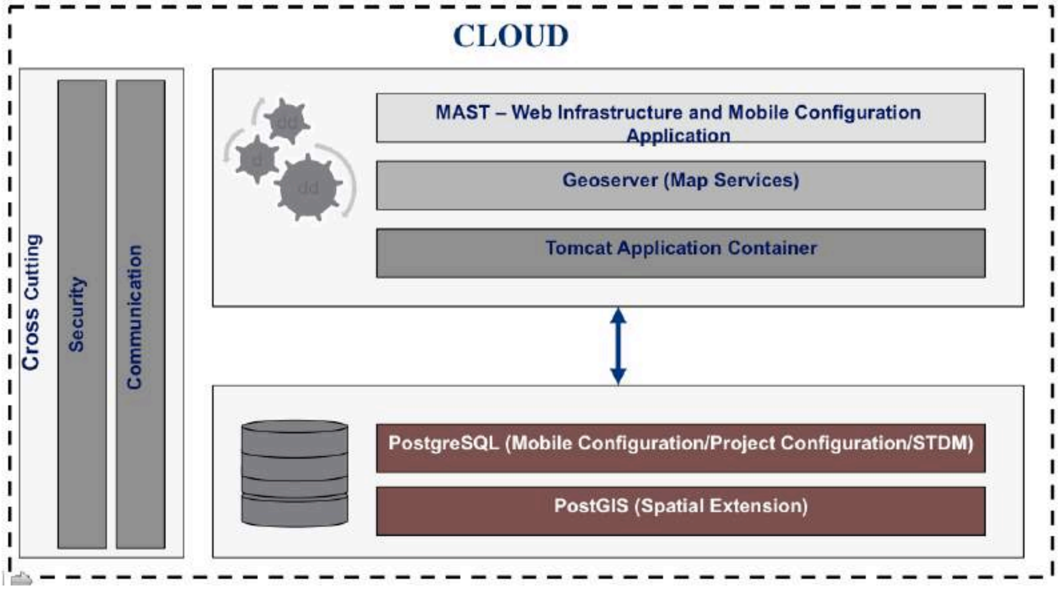


Figure 11: Land Rights Data Infrastructure Web Application

In line with USAID's September 2016 Open Government Plan, USAID will share source code and ensure that new code developed under its projects is shareable whenever possible. Under MAST, USAID has provided all source code from its implementation on GitHub. Under LTS, a major update of the technology platform is contemplated and will be made available on GitHub as well.

D. Limitations of MAST framework

- The implementation of MAST has been limited to rural, agricultural parcels. There has been no direct experience of using MAST in dense urban environments, although the application tools have been extended to allow for use of more accurate GPS devices.
- Some users have complained of poor visibility of mobile phone / tablet screens in daylight.
- Processing and validation of data on the data management infrastructure has been documented as being time-consuming and expensive. This can be

improved by a stable Internet connection, documenting processes, and by providing training related to parcel management.
- Spares of mobile phones / tablets need to be available in projects since no local maintenance service is normally available.
- Customization and deployment of MAST requires people with considerable technical knowledge and computer programming skills.

E. Costs of Technology

a) Capital Cost Items

Capital Item
An Android smartphone, e.g. Samsung Galaxy XCover 3 Ruggedized SIM Free Smartphone
GIS workstation for editing and managing land rights data
Satellite imagery
FOSS

b) Revenue Cost Items

Revenue Item
Internet access service
Cloud service
GIS workstation maintenance

The cost related to the deployment and implementation of MAST will vary from place to place based on requirements that are defined as part of the implementation program. In Tanzania pilot programs, the estimated cost per parcel was estimated to be US$ 30/per parcel. This was due to costs associated with utilizing government stationaries, which introduced a cost of approximately US$ 11/per parcel. Other costs included technical and logistical support for implementation as well as lengthy processes related to the processing and registration of CCROs. It is necessary to note that while these costs were similar to land registration campaigns implemented with traditional surveying and GIS technologies, an independent evaluation found that MAST was inclusive, and more impactful than traditional land demarcation and documentation approaches.

F. Sustainability of Solution

The software is based on FOSS, which makes it more sustainable. It is also supported by standard Android phones, supports STDM/LADM accepted standards, and allows for the customization of the software, which is downloadable from GitHub.

However, once the software/platform is customized, users/implementers will need to ensure that there ample resources to sustain the deployment of the technology on a cloud platform and that there are ample technical and financial resources to facilitate further implementation. Sustaining a cadre of trained users/operators with the skills necessary to undertake the implementation will also be key.

The requisite data management and interoperability skills are also needed.

G. Capacity Level and Training Required

Activity	Skill Level
Project Management	Project Manager
Data capture and adjudication	Trusted Intermediary
Data upload to cloud	Trusted Intermediary
Data editing and management	GIS Operator
Customisation of applications	Software Developer and DBMS Developer

H. Supporting Documents and Reviews

An independent review of MAST Pilot-Tanzania can be found here: (https://www.land-links.org/wp-content/uploads/2016/09/USAID_Land_Tenure_MAST_Workshop_Performance_Evaluation.pdf. This performance evaluation concentrates on the first of three (3) sites in which MAST was implemented: the village of Ilalasimba, in the Iringa district in Tanzania. MAST was implemented there from January to June 2015 and was intended to ground-truth the methodology that USAID and its implementing partner plan to use in subsequent pilot sites under the MAST project.

The following open source code and documentation is available for MAST Phase 1 on GitHub (https://github.com/MASTUSAID/):

- MAST Android Application Source Code (August 2015)
- MAST Data Management Infrastructure Source code (August 2015)
- PostgreSQL Scripts (August 2015)
- Installation and Deployment Guides (August 2016)
- MAST phase 2 Data Management Infrastructure repository (Apr 2016)
- MAST phase 2 android source code (March 2016)

I. Contact

Ioana Bouvier, Sr. Geospatial Analyst, USAID (ibouvier@usaid.gov) and Silvia Petrova, Geospatial Analyst, USAID (spetrova@usaid.gov).

A.9 Cadasta Platform

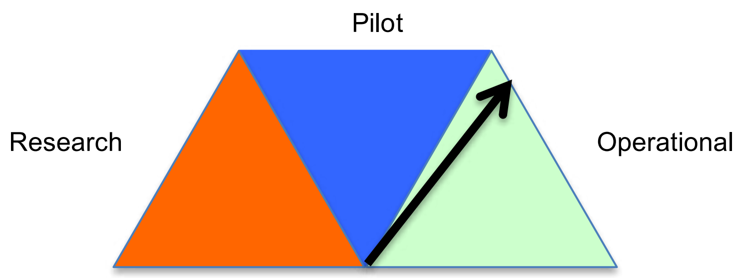
- The Cadasta Platform is a secure, hosted suite of mobile and web based tools designed to help organisations to collect, analyse, store and share data on land and resource rights.
- The Cadasta Platform prioritizes security and data ownership by system users, and is inclusive of granular roles and permissions.
- A key component of the platform is the streaming of a global base map from the DigitalGlobe API to offset challenges accessing satellite imagery; and the cloud-based hosting of private user workspaces on Amazon Web Services.
- Cadasta platform also offers a **public API** so third parties can integrate their existing infrastructure with Cadasta platform.
- Cadasta Platform is hosted by the Cadasta Foundation, a not–for-profit established with funding from Omidyar Network and DFID.

A. Description

The Cadasta Platform aims to support the creation of an accessible digital record of land, housing and resource rights. It is hosted by the Cadasta Foundation which was founded on the premise that documenting land rights and opening land records up to the public increases tenure security, with documentation creating an evidence base and advocacy case for vulnerable communities' claims to the land. Cadasta Foundation develops and promotes the use of simple digital tools and technology to help partners (including Namati, Landesa, Justice and Empowerment Initiatives Nigeria, Habitat for Humanity and Uttaran, Bangladesh, amongst others) efficiently document, analyze, store, and share critical land and resource rights information. Cadasta was launched in 2014 with funding from Omidyar Network and UK aid.

Key aspects that set the Cadasta Platform apart from alternatives include the user-driven (co-design) project establishment, cloud-based hosting of data and streaming of imagery, adherence to a data model consistent with the Social Tenure Domain Model and stringent privacy protocol with rights retained by the partnering organisation.

B. Maturity of Solution



The Cadasta Platform has been piloted in several country and regional contexts, but will continue being refined Based on input from partners in the field

2017 **Projects:** Cadasta is currently working to document smallholder land rights with partners in Indonesia (Daemeter) and Tanzania (Seed Change). Recent programs started include collaboration with Habitat for Humanity in the US where household tenure information is being collected, and with Tata Trust in

India collecting information regarding social and economical situation of families in Cuttack and Bhubaneswar.

2017 **Projects**: Cadasta is collaborating in Bangladesh with Uttaran, documenting land rights of small landowners in rural communities, aiming to provide some kind of formal recognition of their properties, with data for approximately 12,000 households captured.. Collected more than 12,000 records. Cadasta is also supporting Landesa in documenting household level land information in Odisha and Telengana States of India.

2016 **Pilot**: Pilots undertaken in Kenya (Turkana and Tana River with Kenya Land Alliance, Mau Forest complex with Ogiek People's Development Program; Isiolo County with Kivulini Trust), Zambia (Petuake District with Petuake District Land Alliance), Uganda, Nepal, and Myanmar. Cadasta has partnered with Namati to undertake these pilots together with local community groups (Namati partners) and gather lessons, reported in Brinkhurst et al. (2017).

2015 **Pilot:** Kosovo. Cadasta commenced a pilot project collaboration with the Kosovo Cadastral Agency, under the World Bank funded Real Estate and Cadastre Project.[3] The pilot sought to adapt the technology-driven solution to improve efficiency of registry and cadastral operations for field documentation of property rights claims. The village chosen, Krusha e Madhe, was selected due to the vulnerability of the population with regards to property rights and the presence of successful cooperatives (whose future growth was largely restricted by a lack of access to credit). The Cadasta platform was seen as an intermediate step for documentation prior to full registration.

C. Technology Details

Cadasta Foundation works to empower local partners to undertake mapping and related work for land documentation and/or registration. Support is twofold, comprising of the development and establishment of the Cadasta Platform, and support provided by the core staff of Cadasta, who are available to provide expert guidance, questionnaire development, training, etc. The Cadasta Platform is designed primarily for organizations working to document land and resource rights for individuals and communities. Core technical elements of the Cadasta Platform and support provided by the Foundation (where relevant) are discussed below under the headings of project preparation, data collection and data storage.

Project preparation

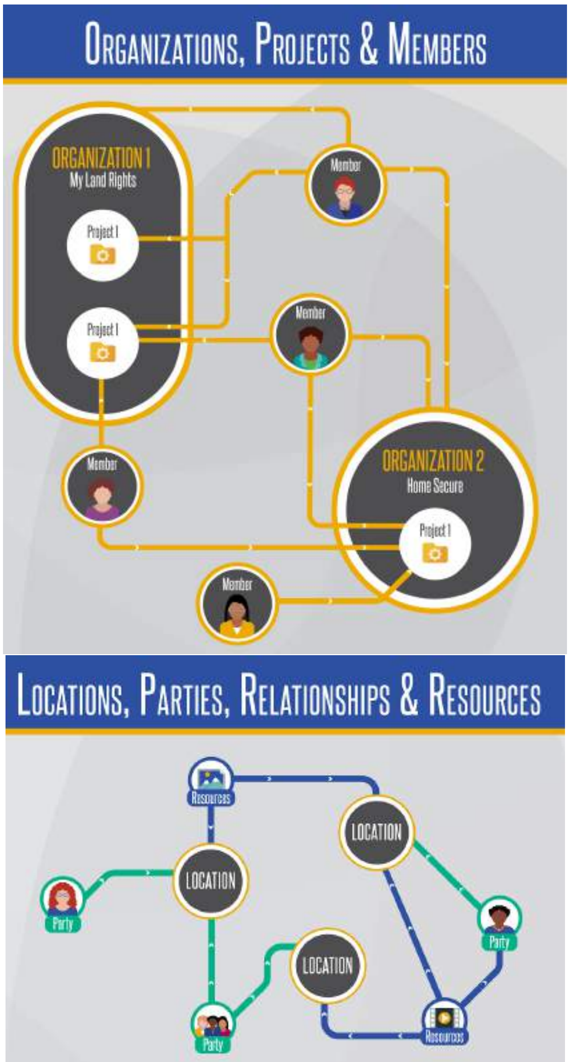
The fundamental ethos of Cadasta Foundation is people over data, and a key finding of the pilots undertaken with Namati in 2016 was a need for greater ownership and control by organisations and communities' over their projects and data (through, e.g., co-design methodologies).

In support of this, the Cadasta platform is adaptable according to user needs, and all source code and help information is available online (either on the Cadasta website, or GitHub). Users (typically NGOs assisting communities to document land rights) are supported to register as Organizations on the Platform, with each Organisation able to set up one or more projects. A project covers a specific geographic area, from a small parcel of land to the entire globe. Within the specified project area, there can

[3] Information obtained from Cadasta blog post, dated 22 June 2016. http://cadasta.org/kosovo-real-estate-and-cadastre-project-2/

be numerous project **locations**. A project may also have multiple **project members**, each of whom will have permissions specific to the project. This structure is shown in Figure 12 and can also be summarised as follows:

Figure 12: Overview of Cadasta Platform Structure (for users)



- Organization
    - Organization Members
    - Project
        - Project Members
        - Project Data Schema Cadasta XLSForm (which determines the structure of your data collection)[4]
        - Project Locations
            - Relationships (to People or Parties)
            - Resources (external attachments that support the documentation process, ranging from pictures or scanned files to audio or video testimonies)

[4] An upcoming release will get away from the XLS form, allowing the data schema to be designed within the project data schema natively in the platform

A key component of project preparation, in addition to co-design, is the definition of a data collection schema specific to the project. These should be customized around specific themes that address the core needs of the project, and may include text fields of a respondent's contact details, a drop down list of village names or a multiple select option of how the land was acquired.

The Cadasta Platform enables the preparation of data collection using XLSForm templates. XLSForm is a lo-fi database schema representation – it is a form standard that allows the creation of a custom questionnaire using a spreadsheet (or Google sheet) instead of a database. With XLSForm, different types of fields can be added including integers, radio questions, checkbox questions, text fields, etc.

Current Cadasta XLSForm templates have been made for:

- Documenting customary rights of a single group of people using a single parcel or piece of land;
- Documenting land that's being used for sustainable agricultural production (Sustainable sourcing);
- Documenting farmers' rights to use one or more plots of land (Smallholder Agriculture Form);
- Documenting urban informal settlements.

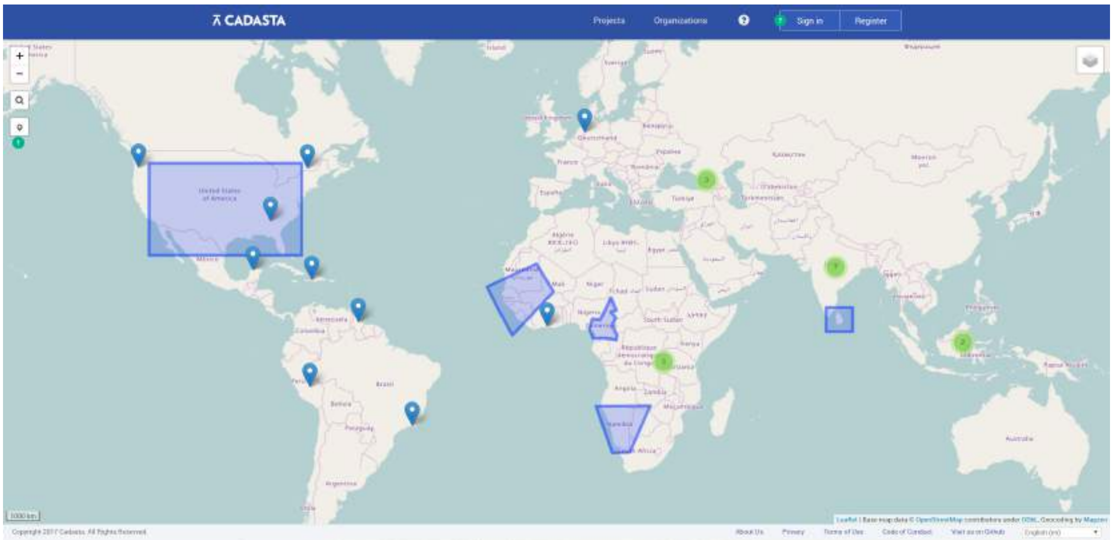
Data collection

Data can be uploaded to the Cadasta Platform from an existing source and/or can be entered via a web interface or using mobile applications (see Figure 13). Typically, data for each project is collected in the field, which may be done by using mobile applications or paper questionnaires. The Cadasta Platform currently supports two mobile data collection platforms, which are both available for use on Android devices, being Open Data Kit (ODK Collect) and Geographical Open Data Kit (GeoODK Collect). Both of these applications integrate with the Cadasta XLSForm and allow data to be uploaded to and stored on the Cadasta Platform. Mobile devices can be augmented with external GNSS or similar to improve accuracy if necessary.

Many organisations – and even national, regional or local governments – have difficulties accessing satellite imagery for mapping exercises. Cadasta acknowledges this and has established an agreement with DigitalGlobe to stream a global base map from the Digital Globe API that is free of charge for platform users, and ensures that all derived data from imagery reminds solely with the partner in terms of data ownership.

Field Papers, documented elsewhere, is also currently being integrated into the application, allowing the printing of the base map (either the DigitalGlobe satellite imagery or the basemap from OpenStreetMap) with a QR code that allows the print-out to be scanned back and geo-referenced into the platform along with any notations or sketches made on the imagery.

Figure 13: Cadasta Platform web interface showing existing international project locations



Data storage

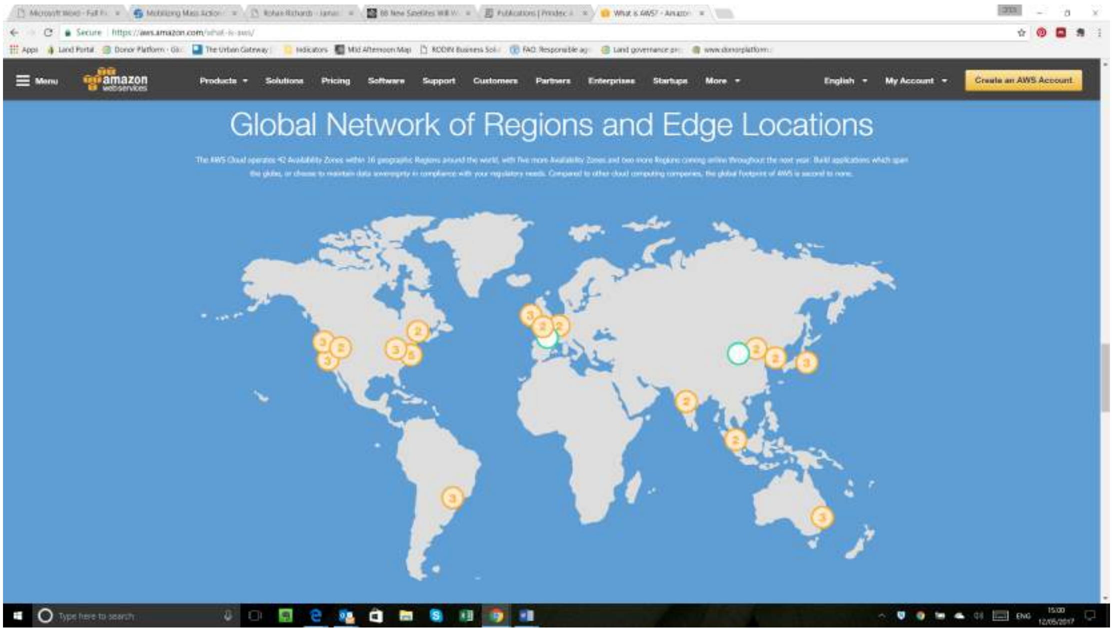
Cadasta seeks to offset the need for large government IT infrastructure and data storage support is a key step to achieving this. As under 'project preparation' above, Users create an account on the Cadasta Platform at platform.cadasta.org, create a new project, create and upload a Cadasta XLSForm and then gather data via ODK Collect or GeoODK Collect. All project data is hence stored on the Cadasta Platform, which is cloud-based and hosted on Amazon Web Services.

Amazon Web Services is a secure cloud services platform, offering computing power, database storage, content delivery and other functionality to help businesses scale and grow. The use of Amazon Web Services supporting 'land registry as a service' is likely to only increase, following adoption by Advara (providing services to the Western Australian government) and organisations like Cadasta.

A key data storage consideration is that many government land agencies do not, or legally cannot, have their data hosted offshore. Ultimately, Cadasta Foundation plans to support local instances of their platform, however with the rapid pace of releases, is not currently supporting local instances maintained by partners. However, conversely, some NGOs may be specifically interested in hosting data in the cloud off-shore, in order to best protect from government encroachment (as in the case of eviction or documentation of illegal settlements).

Privacy and the retaining of intellectual property and data ownership by users is seen as a fundamental need by Cadasta Foundation. Users choose their own privacy settings, are enabled to make projects publicly viewable or private depending on preferences, and all data and resources can be downloaded as necessary. Cadasta Foundation makes no claims to the data on its platform.

Figure 14: Amazon Cloud Based Storage Locations



Next Steps
Currently all Cadasta Platform code and documentation is open source and available via the Cadasta website and on GitHub. The open source licensing uses an AGPL license, which allows others to modify and distribute, but only where such changes are made available under a similar license.

A QGIS plugin is currently under development with release scheduled for Q2 of 2017.

Improvements in reporting capabilities are under development, including the possibility of printing map reports or obtaining more advanced statistical information.

Improving the usability of the platform is another key objective, and evolved dashboards for new and returning users, organizations and projects are being designed. In the same direction, a development of a more user-friendly data schema design is also on-going.

Accuracy

The Cadasta Platform supports the upload of data of all accuracies, however using the typical model promoted by Cadasta, users will likely achieve the following accuracies:

a) A mobile device augmented with external Bluetooth antenna.
b) A mobile device with no augmentation.
c) In the case of sketchmaps using Field Papers accuracy will be defined by the resolution of the imagery, how well it has been georeferenced, and data collection decisions.

D. Limitations of Solution

- There is limited experience of integration between community mapping initiatives and formal/government land registries. This presents both positives and

negatives – whilst some organisations that have piloted the platform may have preferred to maintain ownership of data as a form of 'counter-mapping' and local control, without an interface with government processes or systems there is potential for duplication of effort, dual-systems and limited opportunity for formal recognition of rights. Additionally, the pilots noted some opportunity for local powerful interests (e.g. local chiefs) to manipulate the process of mapping of rights and boundaries.
- Cadasta Foundation advocates a co-design process for designing the mapping activity, which can require a reasonable amount of training and early expert support. This is likely to be difficult to scale.
- NGO or other community-led processes must consider the challenge of long-term maintenance (and ownership) of mapping data
- If national standards are unclear, this may limit the functionality and application of community land registration applications (i.e. minimum required accuracy of coordinates, process by which coordinates are collected and validated, symbols used in and design of maps, acceptability of 'general boundaries' etc.)
- Some users may prefer hosting of data within their own country, which may not be possible using Amazon Web Services hosting.
- Cadasta team initially provided the training directly through hands-on face-to-face interactions. As the training has been refined, Cadasta has begun to utilize a train the trainer approach through partners like Namati and Daemeter, training via video webex, and the production of a detailed user guide (q4 2016) and launch of a Cadasta YouTube Channel which will include more training videos, recognizing that Cadasta is a small team and is difficult to scale up training.

E. Costs of Technology

a) Capital Cost Items

Capital Item
An Android mobile tablet
PC for editing and managing land rights data
Differential GNSS device

b) Revenue Cost Items

Revenue Item
Internet access service
Cloud service
PC maintenance

Estimates from Cadasta Foundation partner Namati suggest that even with free software and satellite imagery, the cost of the participatory community mapping process (that includes use of handheld GPS) is approximately US$1800 "per community"[5].

F. Sustainability of Solution

[5] They do not clarify the extent of 'community' however it is assumed this is equivalent to village or similar, and likely the size of the pilots conducted. See Brinkhurst, M., Pichel, F. and Ogina, H. 2017 *Mapping as Empowerment – Lessons from a Year of Participatory Community Mapping* Paper presented at 2017 World Bank Conference on Land and Poverty. Washington D.C. March 20-24, 2017.

The Cadasta platform is dependent on the on-going support of Cadasta Foundation, and in turn continued funding/support for the Foundation.

Too often community mapping exercises are conducted as one-off exercises and whilst the Cadasta Foundation has provided a solution for data storage, there remains a challenge of data maintenance over the long-run, including update. Cadasta Foundation addresses this by ensuring training is a core component of implementation – communities will need to ensure that this capacity is maintained.

G. Capacity Level and Training Required

Activity	Skill Level
Data capture and adjudication	Community mappers, with training from Cadasta and/or partners
Data upload to cloud	Community mappers, with training from Cadasta and/or partners
Data editing and management	Community mappers, with training from Cadasta and partners
Customisation of applications	GIS or programming technician

H. Supporting Documents and Reviews

Cadasta website (http://www.cadasta.org)

Brinkhurst, M., Pichel, F. and Ogina, H. 2017 *Mapping as Empowerment – Lessons from a Year of Participatory Community Mapping* Paper presented at 2017 World Bank Conference on Land and Poverty. Washington D.C. March 20-24, 2017.

I. Contact

Frank Pichel, Acting CEO, Cadasta Foundation 1110 Vermont Avenue, NW Suite #500, Washington, DC 20005 info@cadasta.org

A.10 Landmapp (now called Meridia)

- A cloud platform and mobile application that provides smallholder farmer families (earning less than US$5 a day) with documentation of their land.
- Provision of a profile with which smallholder farmer families can access services that are precisely tailored to their circumstances.
- The service is going to scale in Ghana and initiating operations in Indonesia.
- Landmapp provides a service not the underlying technology.

A. Description

Many of the world's 500 million smallholder farmer families face two interrelated challenges: they hold little, if any, rights to their land and, being restricted to the informal sector, they often cannot access technical and financial services to improve their livelihoods.

For smallholder farmers securing their land is very complex and an enormous challenge. Landmapp is a company that aims to make this simple, by providing an end-to-end service from when the farmer signs up till they hold a legal land certificate in their hands. Landmapp educates farmers on the importance of land tenure, verifies their identify, validates the land claim with neighbours, submits the claim to the authorities for legalisation and places the final product in their hands. This allows smallholder farmer families to more effectively access technical and financial services.

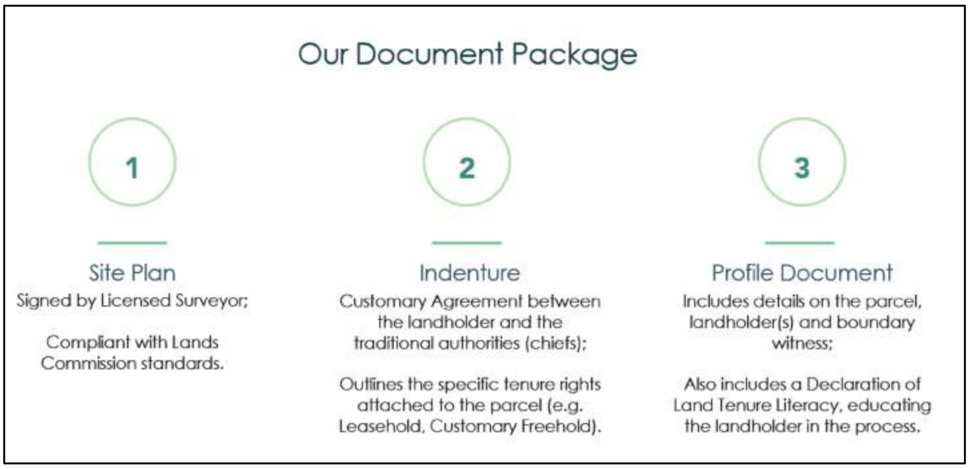
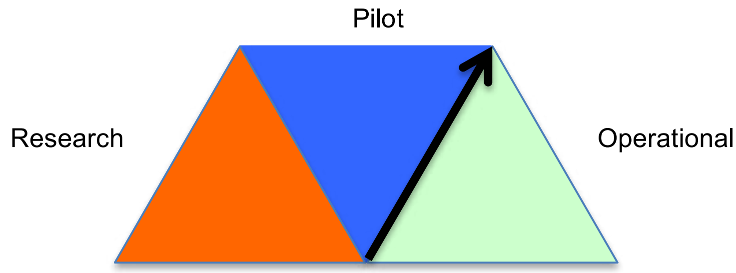


Figure 15: Landmapp's approach to providing land rights documentation

B. Maturity of Solution

2016 **Pilot**: Landmapp field teams operate in Western, Eastern and Ashanti region of Ghana to improve the security of tenure with smallholder farmer families. They work extensively with key stakeholders across Ghana, including Ghana Lands Commission, Stool Lands, Paramount and Divisional Chiefs to ensure full legal compliance with required land legislation and local authorities and best practices.



Early fieldwork also undertaken in Golaj, Albania (2014) and Lampung, Indonesia (2015). Other countries the company is taking an interest in include Cote d'Ivoire, Tanzania, Uganda and Ethiopia.

C. Technology Details

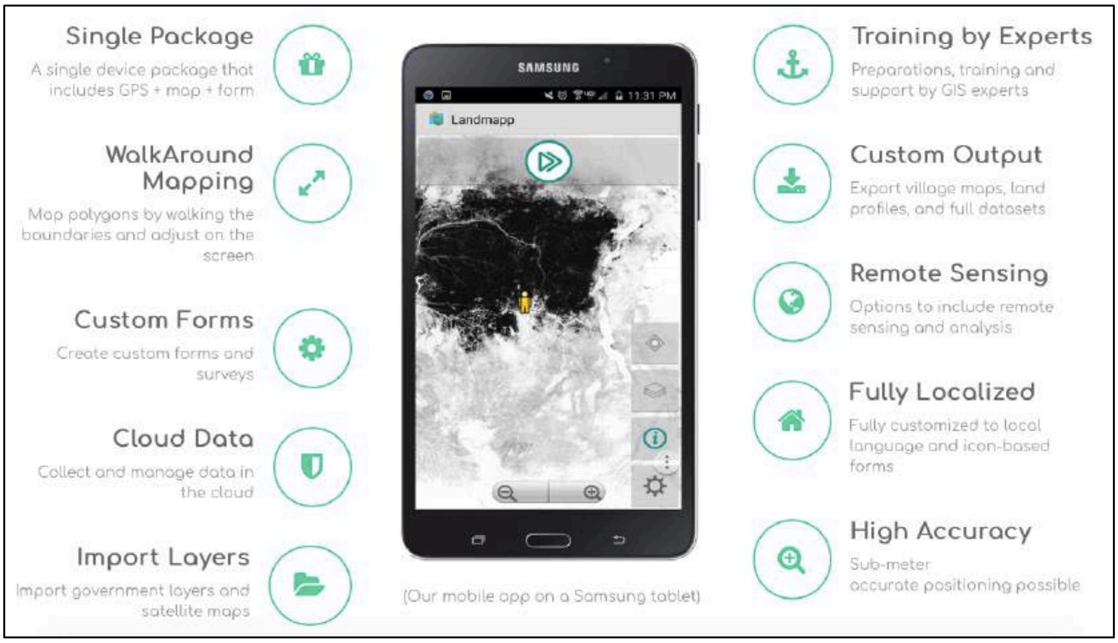


Figure 16: Landmapp range of functionality

The Landmapp process for supporting smallholder farmer families involves the following:

- **Campaign**: Visit farmers, meet with community leaders and provide information on radio and posters.
- **Sign-up**: Farmers are educated on Land Tenure and sign up.
- **Map**: Map the farm boundaries with mobile technology and interview the farmer, the farmer's spouse and the neighbour. Landmapp in Ghana is set up to document 10,000+ parcels per year.
- **Analyse**: Data are analysed for errors or anomalies.
- **Validate**: Make the data to the farmer and ensure 100% data accuracy and verified by neighbours.
- **Sign**: Land tenure document is signed by the relevant authorities and delivered to the farmer.

Landmapp's approach in Ghana symbolises their approach to providing security of tenure. Their field teams operate in Western, Eastern and Ashanti region of Ghana, providing the following solutions to their customers:

- **Farmseal** is a customary land document including a Farm Plan and Indenture, providing farmers with a long-term lease in traditional areas, validated by neighbours, witnesses and signed by a licensed surveyor, the traditional authorities (divisional and paramount chiefs) and legalised by the high court.
- **HomeSeal** provides rural homeowners with peace of mind through a land document that includes a Cadastral Plan, signed by a licensed surveyor and the Regional Surveyor, an Indenture signed by the traditional authorities (Divisional and Paramount chiefs) and legalised by the high court.
- **CropSeal** is a lease agreement between a landholder and a sharecropper (caretaker farmer) that allows full integration and clarity of the traditional Abunu and Abusa agreements, providing both parties with a higher degree of tenure and financial security.

Their teams visit villages and towns educating customers on the importance of land documentation and how Landmapp provide it at affordable prices and ensure final delivery to farmers.

Landmapp work extensively with key stakeholders across Ghana including Ghana Lands Commission, Stool Lands, Paramount and Divisional Chiefs to ensure full legal compliance with required land legislation and local authorities and best practices. Landmapp is also registered with the Ghana Data Commission to ensure their data collection practices conform to required status. This approach of working closely with chiefs in customary areas and officials within the National Cadastre and Land Registration Agency strengthens the security of tenure being provided to clients. Landmapp believes farmers should control their data and Landmapp's privacy policy ensures this.

Landmapp provides a legal verified data product where they meticulously check each land parcel claim and data record to ensure the highest quality data before submitting it for legalisation. Landmapp seeks to simultaneously collect biographical, agricultural and geographical date to create a farmer profile that is useful beyond tenure security, to support credit scoring, farming inputs procurement and ICS processes.

Mapping with a hand-held GPS receiver is fast and easy, but the accuracy is limited, especially if the satellite signal is blocked by vegetation. While this method is sufficient for documentation of farm plots in the customary system, Landmapp have been providing higher accuracy to their customers through differential GNSS, and also giving them the option to register parcels in the national cadastre. Landmapp have been using low-cost GNSS the Emlid ReachRS. It is an affordable and fully integrated differential GNSS system that is ready for field application. The ReachRS relies on single frequency GNSS, which limits the operation radius around the base station, but the accuracy is close to what systems of ten times the price can achieve.
The ReachRS has a fully integrated design, with inbuilt battery, WIFI, Bluetooth and radio. The ReachRS was fully integrated with the data-collection on the GeoODK based Landmapp app. See Figure 17 for Landmapp's data architecture.

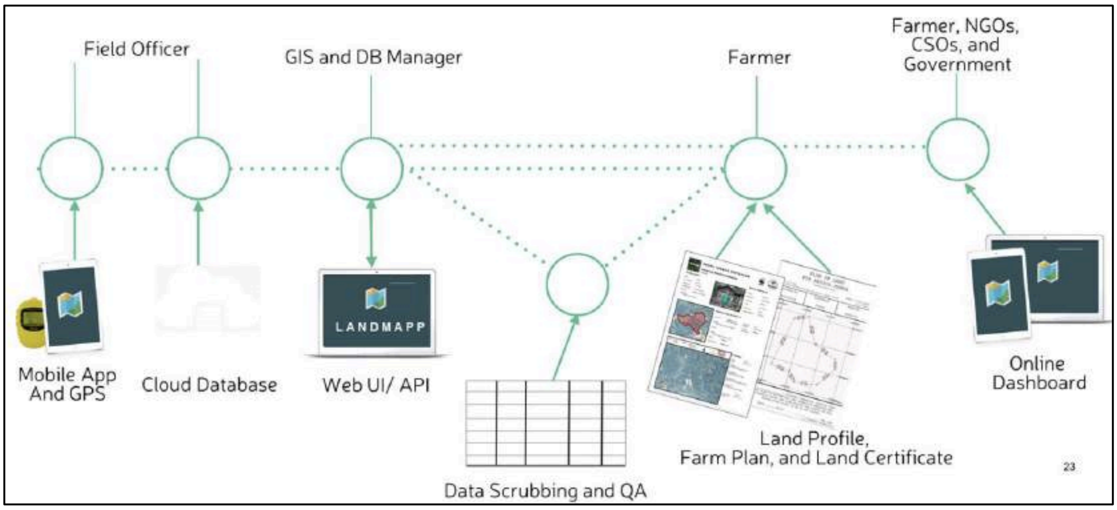


Figure 17: Landmapp Data Architecture

Landmapp uses three options for recording the location of parcel boundaries:

a) Direct use of the GNSS capability on the mobile device.
b) Integration of differential GNSS.
c) Use of the orthophoto image to trace the boundary.

D. Limitations of Solution

- The use of Landmapp has been limited to rural, agricultural parcels. Although there has been no direct experience of using Landmapp in dense urban environments, their use of differential GNSS proves that this will be possible.
- Some users have complained of poor visibility of mobile tablet screens in daylight.
- Spares of mobile tablets need to be available in projects since no local maintenance service is normally available.
- The inadequacy of using the GNSS capability of the mobile tablets in dense vegetation, e.g. cocoa, has been overcome by using extended poles on external GNSS devices.

E. Costs of Technology

The Landmapp technology is currently used internally within Landmapp operations and is not available externally. They provide a range of services that smallholder farmers pay for.

F. Sustainability of Solution

Omidyar Network announced in February 2017 that it had invested in Landmapp, an Amsterdam-based property rights company that enables smallholder farmers to document and protect their land holdings. The investment will help Landmapp to grow its customer base in Ghana, where the company is providing this unique service primarily to cocoa farmers. The transaction also involved participation by HERi Africa, an existing investor in the company.

Given that Landmapp provides their service directly to landholders, resulting in the landholder receiving some form of certificate of title, there is a clear lifecycle to the process and it appears sustainable.

G. Capacity Level and Training Required

Activity	Skill Level
Data capture and adjudication	Landmapp field personnel
Data upload to cloud	Landmapp field personnel
Data editing and management	Landmapp GIS Operator
Customisation of applications	Landmapp GIS / DBMS Developer
Obtaining documentation of registered parcel	Landmapp personnel

H. Supporting Documents and Reviews

Landmapp website (http://www.landmapp.net)

I. Contact

Landmapp, New Energy Docks, Distelweg 451, 1031 HD Amsterdam, The Netherlands. +31 20 43 57 548 (info@landmapp.net)

A.10 Solutions for Open Land Administration (SOLA) – Open Tenure

- Crowd sourcing approach to the collection of tenure relationship. Developed as a tool for communities to assess and clarify their tenure regimes so to protect the individual and collective rights of their members.
- Mobile devices provide for in-the-field capture of legitimate tenure rights with boundary mapping. Data are then uploaded to a web-based community server.
- Open Tenure has been successfully adapted to allow for formal recording of customary and informal rights where recognized by law.
- A UN-FAO development that has been piloted in Uganda, Nigeria, Guatemala, Myanmar and Cambodia.

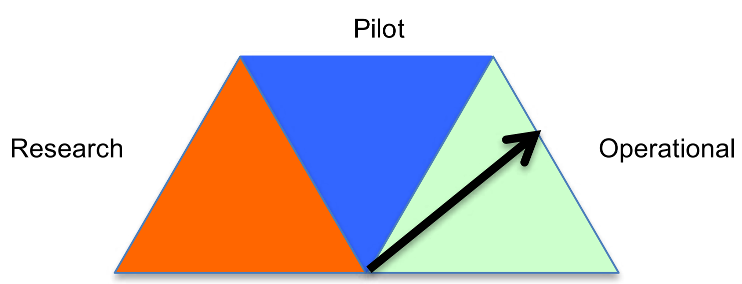
A. Description

Open Tenure is a mobile application developed for both Android and iOS devices that allow citizen recording of tenure rights. People designated as Community Recorders use their mobile device in the field to record details of a tenure right claim describing the tenure right and all owners (right holders) and a map of the boundaries of the land claimed. Photos of the owner(s), the land claimed and supporting documents can be captured and linked directly to the claim.

When the recording of a claim is complete, the Community Recorder uploads a claim to the Community Server for community based review and moderation. The Community Server web application also publishes “community recognized” tenure rights and can generate a certificate for owners of a recognized tenure right. Open Tenure is designed to work where Internet connections are unavailable or unreliable. Likewise, Community Server can be implemented for Internet access (typically through an IaaS Cloud Server) or on as a stand-alone PC connected to a wireless router allowing mobile devices loaded with Open Tenure to upload and download claims/recognized tenure rights and imagery data wirelessly.

The UK Department for International Development financially supported the development of Open Tenure, with the technical support of FAO.

B. Maturity of Solution



2015 **Pilot**: Cambodia – The Monks Community Forest covering 18,000 hectares in Oddar Meanchey Province was the site of the first field test of Open Tenure. The monks are responsible for the sustainable management of the forest. For the Open Tenure field test, monks and villagers living within the forest were provided with mobile devices. The monks supervised the villagers in recording the land they farmed within the forest. The monks were also interested in recording other rights, restrictions and responsibilities associated with the management of the forest including incidents of unsanctioned forest clearance, forest fires, hunting and fishing.

2015 **Pilot**: Guatemala – Using the improved software and manual, a second Open Tenure field test was held involving La Bendicion community in Guatemala. This community consists of 48 families who were resettled by the government following their return from Mexico after the 1998 Guatemala Civil War. The community area boundaries had been surveyed by the government's cadastral agency, the Registro de Informacion Catastral. Open Tenure was used to map and record individual housing areas as well as agricultural and communal land holdings within the community.

2016 **Pilot**: Uganda, Kasese District - Digital record of Certificates of Ownership: digital system to record and manage information on customary land as prescribed by the Uganda law. The system was developed through customization of Open Tenure to respond to local legal requirements, while converting the existing paper-based records and validating the information on owners and land. The customized version of Open Tenure and the information of the database will be integrated with the Land Information System under development.

C. Technology Details

<u>Background to SOLA</u>

The pilot implementations of the first SOLA software application, SOLA Registry, were completed in December 2012. This marked the successful completion of a 2.5 year FAO project (funded by the Government of Finland) that involved the design and development of the generic SOLA Registry software and then 3 pilots. These pilots utilized local software developers to customize the software for each country (trained and mentored by the FAO developers) and implement the customized versions of SOLA registry. The aim of this project was to make affordable and sustainable computerized systems that supported integrated cadastre and registration functions of a typical district land office available to all countries. The fact the SOLA Registry software was open source was but one element in ensuring it was affordable and sustainable. It was also designed to be customizable, ease of language localization and incorporate international good practice for service delivery and responsible governance of tenure. SOLA Registry supports transparency of tenure records and related land office processes, robust data management and the need for enterprise scale software. The underlying data structures used by all SOLA software are also based on the Land Administration Domain Model (LADM), now published as ISO 19152.

With the various SOLA implementations that occurred in 2013 and 2014 (Lesotho, Nigeria and Tonga), the software was customized for use in these countries and extended to include support for systematic registration, lease management, the inclusion of orthophoto layers and an interface to finance systems. The language localization features were also utilized to provide Arabic, French, Russian, Spanish, Portuguese and Chinese translations of SOLA Registry. Khmer (Cambodia) and Albanian translations of SOLA Open Tenure and Community Server and an Amharic (Ethiopia) translation of SOLA State Land were also created.

<u>Current SOLA Software Applications (including Open Tenure)</u>

In 2015 as a result of the more specialized nature of some of these early SOLA software extensions, it was decided to package the SOLA software as a series of software applications. Each application supports a different aspect of tenure (including land) administration. These software packages are:

Registry - providing enterprise wide support for registration and cadastral functions in a typical district land office including case management of applications through a client desktop application and network server based software.

Open Tenure (in combination with Community Server) - designed to support community and citizen based tenure relationship recording outside of formal land administration. Open Tenure is for mobile devices (Android and Apple iOS) providing for in-the-field capture of tenure rights (including identifying all right holders (owners), mapping, scanning of supporting documents and photos of owners). Boundary mapping is possible using both the built-in GPS and through defining boundaries relative to aerial or satellite imagery. Once all the details have been captured for a property (or other tenure right) and the mobile device is connected to a community server (such as SOLA Community Server) either through the Internet or wirelessly. Once the connection is made, the property details can be uploaded.

Existing tenure data and aerial (and satellite) imagery for a particular community can also be downloaded from the community server to Open Tenure for offline field capture. When Open Tenure is connected to the Internet, imagery sources (such as from geo-portals and Google Map) can also be used as the reference imagery layer when these sources have high-resolution imagery covering the community's land.

Although Open Tenure was designed for community tenure recording it has also been used for land administration purposes including title capture, gazetted reserve mapping and systematic registration. Its basic functionality, dynamic data field definition and the alignment of the Open Tenure data package with LADM also make it relevant in land administration.

Community Server - designed to support community and citizen tenure relationship recording. Whereas Open Tenure deals with field capture, Community Server hosts Open Tenure captured data and provides web access (and comprehensive searching) to tenure related map and attribute data. It also provides the community with the ability to review and moderate tenure rights collected using Open Tenure. This leads to these rights being recognized by the community and that can be marked with a certificate customized specifically for each community. Community Server is a web-based application typically involving a cloud-based server, a SOLA database and the use of GeoServer. Community Server also makes any tenure data it holds available for download onto mobile devices running Open Tenure. Another feature of Community Server is that it allows for community members to record tenure rights in an Internet café although obviously mapping boundaries this way is not as direct as with Open Tenure.

Systematic Registration - supports systematic (first time) registration through a project office with a simple local area network (LAN) including the production of public display listings and maps, the generation of title certificates and the digital transfer of this data to a district land office.

Admin - provides system administration functionality to all SOLA software applications including the configuration of a SOLA application for its specific environment. Admin is a web-based application.

State Land - provides enterprise wide support for state land tasks including lease administration, acquisition and disposal of land and property and the management of state land and properties. Solution uses a client desktop application, server side software and a SOLA database.

Further SOLA Software Applications being Considered for Development

Mass Valuation – to support the systematic valuation (and re-valuation) of particular categories of properties including the formulation of appropriate valuation models, the calculation of values, generation of listings of proposed new property values, dealing with objections to new property values and the dissemination of finalized property values for uses such as land or property taxation systems.

Addressing – to support street naming and property number assignment and updating for systems such as civil registries, emergency service response and general government administration systems.

Public - a web based portal allowing the general public to view a range of tenure information (read only) as well as obtain tenure details through an Open Data compliant interface.

Open Tenure Application

Typically the recording of tenure rights will include these stages:

- Community information dissemination;
- Community Recorders download details of existing tenure rights and fit-for-purpose map imagery;
- In-the-field recording of claim details including mapping of claims and the collection of document images and photos;
- Upload claims to Open Tenure Community Server;
- Display of claims and the potential submission of challenges to claims on Community Server;
- Review of claims (and associated challenges);
- Moderation of claims (community endorsed) including modification of claims based on community based consensus;
- Issue of certificates acknowledging the community recognition of ownership (or other tenure rights) over a mapped area of land;
- Publishing of community endorsed tenure rights on Community Server.

The same Open Tenure functionality has been implemented in all 3 types of client devices providing Open Tenure land rights data entry:

- Record contact details for person or organization claiming tenure rights (including images of collaborating ID/registration documents and photos);
- Record shares and details of other right holders (where there are multiple right holders);
- Recording of images of documents supporting claim;

- ''Fit for Purpose'' mapping of tenure right using down-loaded map imagery on the mobile device augmented by GPS position fixes and a selection of map edit tools;
- Selection of map imagery sources;
- Recording Challenges to tenure right claims;
- "Open Data" downloads of previously recorded tenure rights from Open Tenure Community Server;
- Claim uploads (direct or as encrypted file by email) to an Open Tenure Community Server;
- Tenure right claim Map generation;
- Tenure right claim Summary generation;
- Claim status updating; and
- Easy software language localization (Arabic, French, Spanish, Portuguese & Russian Language.

The recommended minimum specifications for each Open Tenure client options supported are:

a) An Android Tablet
   - 7'' tablet
   - Android version 6.0 (and upgradeable)
   - 1GB RAM
   - 8GB of disk available
   - Rear camera
   - GPS sensor (able to provide position fixes without SIM or outside mobile coverage)
   - Wi-Fi connectivity
   - Battery capacity of 4,000 mAh
   - Compass sensors

b) iPad
   - iPad 2 (iPad mini recommended)
   - iOS 9.0 or later
   - Wi-Fi & cellular/SIM model
   - 16GB of disk available

c) Internet Connected PC
   - Internet connection **or** Wi-Fi connectivity between PC and mobile devices
   - One of the common web browsers

Open source components have been used to create the initial Open Tenure Server based on Geoserver and the FAO SOLA system that has been suitably modified to be web-based. The database schema is a LADM (ISO19152) compliant variation of the SOLA database schema, imagery map layers utilize WMS and data is exchanged with Open Tenure clients by way of JSON packages. Functionality includes:

- New user registration and user role definition;
- "Open Data" uploading from and downloading to Open Tenure client devices for the community's area of interest;
- Community based tenure rights claim review;
- Community based tenure rights claim moderation;
- Web access to submitted tenure right claims;

- Email notifications of claim submission and processing;
- Internet Café Claim recording (replicating Open Tenure client functionality).

The following open source code and documentation is available for SOLA at https://github.com/SOLA-FAO and for Open Tenure at https://github.com/OpenTenure.

Open Tenure uses two options for recording the location of parcel boundaries:

a) Directly use of the GNSS capability of the mobile device.
b) Use of the orthophoto image to trace the boundary. More important to clearly identify boundaries from features visible on the imagery.

D. Limitations of Solution

- The use of Open Tenure has been limited to rural, agricultural parcels. There has been no direct experience of using Open Tenure in dense urban / peri-urban environments.
- Some users have complained of poor visibility of mobile device screens in daylight.
- Spares of mobile devices need to be available in projects since no local maintenance service is normally available.

E. Costs of Technology

a) Capital Cost Items

Capital Item
A ruggedized Android or IOS tablet - essential
PC for editing and managing land rights data - optional
Wi-Fi Hotspot – essential (for wireless model)
Satellite imagery where recent high-res imagery is not publically available - optional
Software purchase (FOSS)

b) Revenue / Operating Cost Items

Revenue Item
Internet access service
Cloud service
PC & Tablet maintenance

F. Sustainability of Solution

- Standard Android and iOS mobile devices are supported (Open Tenure).
- ISO (LADM) standard are supported.
- Software available on GitHub and is FOSS.
- SOLA software developer and user resources are available through FLOSSOLA open source community website (www.flossola.org)
- UN-FAO continues to support SOLA (including Open Tenure) software
- SOLA software solutions can be customised.

The original SOLA software development team established in Rome in UN-FAO was disbanded in 2016 when the project funding from the UK Department for International Development concluded. It is not yet clear as to whether the SOLA open source development community has a critical mass of knowledge and skills to continue the development and support of SOLA and Open Tenure software.

G. Capacity Level and Training Required

Activity	Skill Level
Data capture and adjudication	Trained Trusted Intermediary
Data upload & download to community server	Trained Trusted Intermediary
Data updating, editing and data management	Trained Operator
Customisation of software applications	Java / DBMS Developer

Key manuals are available on the FLOSSOLA website (www.flossola.org - Solutions and Resources tabs):

a) Manual for Community Recording of Tenure Relationships Using Open Tenure

This is a non-technical manual for community facilitators working with a community contemplating whether to take on community tenure recording and, if they do, how they would like to approach tenure recording within their community. It is assumed the facilitator is either a member of the community or a trusted individual who is familiar with the community. The manual goes through the three levels of engagement for a community before taking on tenure recording. To begin with it explains tenure concepts through stories and simple illustrations from the fictitious community of "Gawa" and encourages the community to tell their equivalent stories. Secondly a proposed 8-step process for tenure recording is outlined as a starting point for discussions on an appropriate process for the community in question. Once the process has been agreed to it is documented along with some of the details such as key roles and responsibilities. These understandings are documented in what is called the "Community Protocol". Finally, the community prepares a plan to get tenure recording underway in their community. An annex to the manual provides links to both the associated training material and to the technical training material for using the Open Tenure software.

b) Technical Guide for Enabling Technologies for Land Administration

This guide is from the series of technical guides that FAO has prepared to assist in the implementation of the Voluntary guidelines on the responsible governance of tenure (VGGT). It offers guidance on how certain technologies and methodologies can be utilized to implement many of the guidelines' provisions including the definition and recording of tenure rights and related processes and improved service delivery. The context for this guide is land administration and the target audience is senior staff and managers in land administration agencies of countries with incomplete, emerging land administration systems.

The technical guide focuses on the application of technologies in land administration agencies, how these agencies can better meet their statutory requirements, the obligation to their clients to provide an excellent level of service and to meet society's increasing expectation of greater transparency in how they operate and being able to provide improved access to the tenure records. The guide draws upon excellent examples from land administration agencies around the world on how technology and computerized systems can result in dramatic improvements in efficiency, service delivery, transparency and in general, better governance of tenure. The premise of this guide is that the introduction of enabling technologies in land administration is a very tangible and measurable way whereby improvements in tenure governance can be achieved. The goal is that this technical guide will facilitate the achievement of such benefits across all countries.

H. Supporting Documents and Reviews

Pullar N., 2016. 'Mainstreaming Open Source Tenure Software'. Proceedings of the World Bank Land & Poverty Conference, March 2016.

Solutions for Open Land Administration (SOLA) website: http://www.flossola.org

I. Contact

VG-Tenure@fao.org and community@flossola.org

A.12 STDM Software

- The STDM software is a FOSS software distribution to set up with visual installer, customize and maintain a wide range of people to land relationships.
- STDM ships with the multi-user database Postgresql, with PostGIS extension to manage spatial objects, to manage the land rights data, the desktop GIS QGIS product for spatial management and maintenance, and a variety of tools for reporting.
- STDM can be run as a standalone workstation or as a fully network-enabled spatial data infrastructure scalable to national level (although not tested at this level).
- STDM is used to enumerate persons, groups and households and map them to buildings, agricultural plots (called "gardens") or land lots. A wizard guides the end user through the customization needed to address one of the three distinct use cases: rural areas, local governments and informal settlements.
- It is designed as an easy-to-use solution, which does not require highly technical people to customize and deploy.

A. Description

The Social Tenure Domain Model (STDM) land information system (not to be confused with STDM the model that is a 'specialization' of the ISO-approved Land Administration Domain Model (LADM) has been developed to bridge the gap between formally registered land and land that is not registered. It is a pro-poor, participatory and affordable land information system for representing a person-to-land relationship along the land rights continuum. The land tool has been developed by UN-Habitat through Global Land Tool Network (GLTN) and other partners in recognition of the need for legal pluralism and a broader recognition of person-to-land relationships.

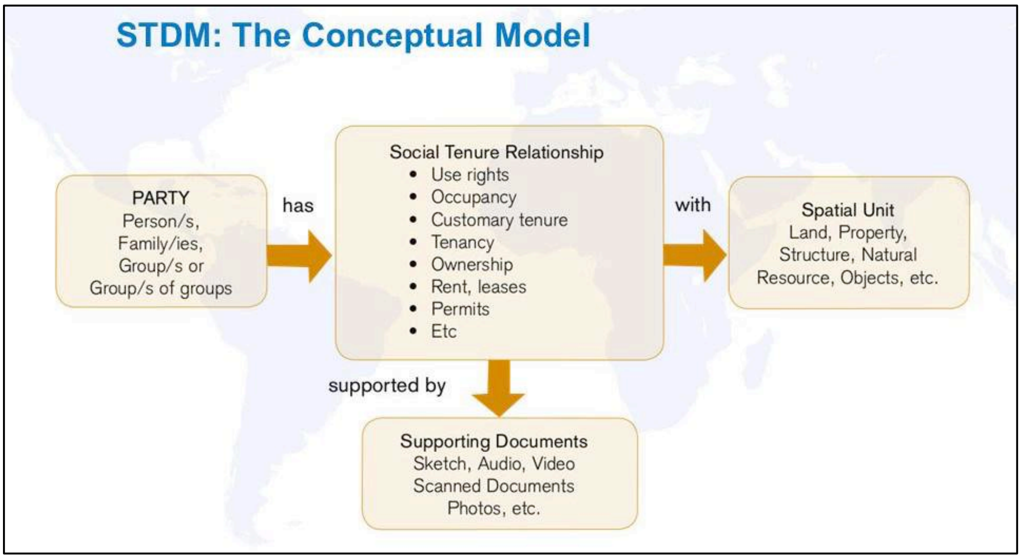


Figure 18: STDM Conceptual Model

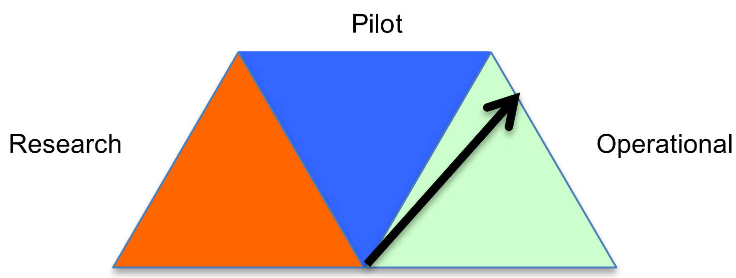
STDM has two major components: i) the multi-user database Postgresql, with PostGIS extension for spatial objects, to manage the land rights data; and (ii) the desktop GIS QGIS product for visualization of spatial units and related attribute data such as party information and supporting documents.

The STDM system can be implemented in two different architectures: 1) The STDM QGIS plugin is primarily used in local installations without the need for Internet access. It forms the basic tool to collect survey data and questionnaires and is designed to run in standalone scenarios and is also well suited to run on older hardware. 2) The architecture is based on a client/server design, which builds on network-enabled components such that STDM can also be extended for LANs where several users share the same database. This can improve productivity, but also requires more operational know-how (networking, security).

The FOSS database Postgresql is fully scalable and lends itself to any large-scale system. Many national registries and cadastre systems completely rely on Postgresql as the primary DBMS production system for nationwide data. The STDM data model, which has been developed in parallel to the Land Administration ISO standard LADM, has been implemented in three basic profiles catering for rural scenarios, informal settlements and for local governments. All three profiles are available as predefined Postgresql databases shipping with the system and can be heavily customized through an intuitive easy-to-use user interface that does not require programming of the database to reflect the data profile of any given application context.

An STDM Advisory Committee composed of international Land Administration experts, sociologists and open-source ICT experts governs and advises on the direction of STDM developments.

B. Maturity of Solution



The STDM QGIS Plugin is currently available in stable version 1.5 and the development version 1.6. The software has been developed and maintained for 5+ years. It builds on the highest quality database Postgresql 9.5 (used by IBM, Amazon, the Ordnance Survey UK, and many others), PostGIS 2.2 and QGIS 2.18 (the premium OSGeo Desktop GIS). The maturity of the STDM QGIS Desktop is:

- Operational with several sources of options in market.
- STDM will be complemented by Online components, which are currently in evaluation. The STDM Desktop architecture lends itself easily to add Online components. The primary fields of application will be for results dissemination, collaborative work and in a future phase online data acquisition. A small number of pilots have been conducted. It is aimed at NGO's who want to get going quickly, but lack the know-how or infrastructure to run their own regular STDM installation. All that is needed to get started with STDM Online is an Internet browser.
- STDM Online will be provided as a service: http://metaspatial.net/en/stdm.

A summary of key pilots and implementations can be found on the STDM web site and documentation at: http://stdm.gltn.net/.

C. Technology Details

This section describes the technology in more detail:

- Minimal hardware requirements for the STDM Desktop version: it can run on a 4+ years old laptop hardware with 2+GB RAM and 160 GB hard disk on Windows and Linux operating systems.
- The architecture can scale up to several redundant and replicated databases run in a cloud environment (e.g. Amazon S3).
- Well-know standards are integrated, including OGC WMS, WFS-T, WMTS, and the modern standard OGC GeoPackage and GeoJSON.
- The GeoODK technology has recently been integrated in the development version for prototyping and field testing.
- Workflow of data capture includes:
  - Questionnaires developed with the STDM desktop tool;
  - Enumeration with physical hardware (phones) on site and data transfer, e.g. CSV and shape files.
  - Enumeration on paper and subsequent transfer with the STDM QGIS environment.
  - Generation of individual registration documents, for example certificates of occupancy and water registration certificates for farmers, and of statistical reports, for example, ratio of tenure status based on gender, computation of land value based on land use and area.
- An experimental linkage with the Cadasta.org platform has been created and import and export has been successfully tested.
- On-going work focuses on including more languages (currently English, French, German and Portuguese are supported with more to be incorporated).
- STDM is designed to follow a FFP approach and can handle simple point data with low precision up to high cadastre precision (sub-centimetre).
- Data security is of primary importance for STDM, especially the Online components that will initially only handle generalized and anonymized data.
- The stack is built exclusively on FOSS components. Additionally, STDM itself is maintained as an FOSS project. This means that the source code is freely available and can be further customized to meet an organization's requirements, such as linking it to a persons' registry system or integration with a financial system as part of a land rates management system.

D. Limitations of Solution

- The current state of development is geared towards local installations and offline data acquisition due to the fact that the data requires a high level of privacy. Networked environments require appropriate know-how regarding data security (including facility and building security, backup, maintenance).
- To date the STDM Online acquisition components are in an experimental state and cannot be used in a production environment.

E. Costs of Technology

a) Capital Cost Items

Capital Item
Laptop/desktop workstation
Handheld GPS Device (optional)

b) Revenue / Operational Cost Items

Revenue Item
e.g. Internet access service
e.g. Cloud service
e.g. Laptop maintenance

A report on the current costs (per parcel) experienced in pilots is planned to be produced by the end of 2017.

F. Sustainability of Solution

Key sustainability considerations:

- Standard Android phones are supported.
- STDM / LADM standards are supported.
- Software is freely available on STDM website and source available on GitHub.
- Software solution can be customised without the need for programming, i.e. data attributes and report templates.
- A local (currently mostly African) developer community has emerged with regular commits from the region (Kenya, Ethiopia, DRC, Angola, others).
- New versions are released at least every 6 months with new features and bug fixes.
- The core components Postgresql, PostGIS and QGIS are with thousands of productive installations worldwide.

G. Capacity Level and Training Required

Activity	Skill Level
Data capture	Anybody
Adjudication	Trusted Intermediary
Data upload to cloud (optional)	Trusted Intermediary
Data editing and management	Low skills requirement, GIS Operator optional
Customisation of data model	Any land expert with 1 day STDM workshop
Customisation of background data	GIS Operator
Customisation of application	Software Developer

It is recommended to attend a one or two day introductory STDM workshop for regular operation. There is an active mailing list offering 24/7/356 help for both users and developers. Response time is typically less than 24h. There is a comprehensive English language manual covering all aspects of STDM. Message boxes and descriptive texts in the user interface guide users in a growing number of languages. YouTube videos, slide sets, tutorials and a wealth of accompanying literature have been created over the past five years.

H. Supporting Documents and Reviews

STDM website http://stdm.gltn.net

Applying Open-Source approaches in STDM. Accessed at http://gltn.net/home/2017/05/03/applying-open-source-approaches-in-stdm/

Enhancing Community Development Initiatives using STDM in the Philippines. Accessed at http://gltn.net/home/2016/12/19/enhancing-community-development-initiatives-using-stdm-in-the-phillipines/

Locations where STDM is being implemented. Accessed at http://stdm.gltn.net/applications

I. Contact

Arnulf Christl, Metaspatial (Arnulf.Christl@Metaspatial.net)
John Gitau, GLTN, UN-HABITAT (John.Gitau@unhabitat.org)

A.13 Mapping For Rights

- A robust participatory mapping methodology, using mobile technology, to accurately map forest communities' land tenure and resource use.
- To date supported 300 forest communities to produce maps of their lands and resources covering over 2,000,000 hectares, primarily in the Congo Basin.
- Allows remote and marginalised communities to represent themselves spatially, bringing their local knowledge and perspectives to the attention of governmental authorities and decision-makers.
- Community-based real-time monitoring (RTM) project launched in 2015.
- Rainforest Foundation UK provides a service not the underlying technology.

A. Description

The Rainforest Foundation UK's (RFUK) participatory mapping programme aims to promote recognition of communities' rights to access, control, and use forests in legislative, political and strategic processes of Congo Basin countries. More specifically, it seeks to ensure that forest communities, civil society groups and relevant government agencies have the capacity and resources to accurately map community land tenure and resource use, in order to inform decision making and planning related to forests and forest communities.

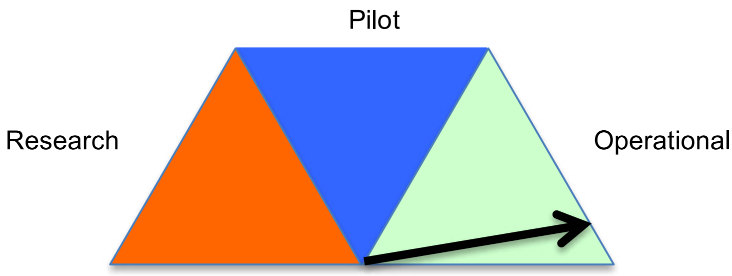
Figure 19: Early stages of participatory mapping

RFUK and its partners have pioneered participatory mapping in the Congo Basin since 2000, first supporting a pilot mapping exercise with Baka (often referred to as "Pygmy") communities documenting their presence and forest use in order to inform the development of national forest policy in Cameroon. Since then, our regional mapping programme has extended to the Central African Republic, the Democratic Republic of Congo, Gabon and the Republic of Congo, involving members of local civil society and government agencies. In each of the countries, specialist mapping laboratories have been equipped and staff trained in GIS (geographic information systems), along with an extensive network of community mapping facilitators. This has helped to support some 300 forest communities to produce maps of their lands and resources covering over 2,000,000 hectares to date. This work has played an important role in giving remote and disenfranchised forest-dependent communities a voice concerning natural resource management. The participatory mapping involves the use of mobile devices, GPS-enabled tablets of smartphones.

In recent years, there has been a growing effort to promote community engagement in decision-making processes concerning natural resource management. Participatory mapping has emerged as a powerful tool that allows remote and marginalised communities to represent themselves spatially, bringing their local knowledge and perspectives to the attention of governmental authorities and decision-makers. For this reason, participatory mapping is commonly used to create maps that represent land and resource use patterns, hazards, community values and perceptions, to gather information on traditional knowledge and practices, to collect data for assessments or monitoring, to present alternative scenarios and to empower and educate stakeholders. The methodology has been particularly effective in documenting the impacts of logging, mining, strictly protected areas other ‘land grabs' on forest based communities.

The community-based real-time monitoring (RTM) project was launched in 2015 and has helped train dozens of community observers in rainforest communities across Cameroon, Ghana and the Democratic Republic of Congo (DRC) to send increasing numbers of real-time alerts on illegal felling operations. This uses SMS technology.

B. Maturity of Solution



2000	**Pilot**: Rainforest Foundation UK and its partners pioneered participatory mapping in the Congo Basin in 2000 by supporting a pilot mapping exercise with Baka (often referred to as "Pygmy") communities documenting their presence and forest use in order to inform the development of national forest policy in Cameroon.
Since 2000	The regional mapping programme has extended to the Central African Republic, the Democratic Republic of Congo, Gabon and the Republic of Congo, involving members of local civil society and government agencies. In each of the countries, specialist mapping laboratories have been equipped and staff trained in GIS, along with an extensive network of community mapping facilitators. This has helped to support some 300 forest communities to produce maps of their lands and resources covering over 2,000,000 hectares to date.

C. Technology Details

The Mapping For Rights methodology formulated by Rainforest Foundation UK involves 8 inter-related stages, as illustrated in Figure 20. Each field team working with a community is supplied with a fully equipped mobile mapping laboratory comprised of:

- 8 to 10 GPS-enabled tablets (or smartphones)
- Motorbikes with helmets and spare parts
- 2 field laptops
- 1 mobile projector
- 1 semi-professional video camera
- 1 still camera
- 1 2.5 KVA portable generator
- Field equipment (tents, sleeping bags, backpacks, torches, boots, waterproof jackets etc.)
- Training kits (paper in different sizes, pencils, coloured pens, and copies of official and community maps, official mapping data).
- Copies of relevant laws related to community rights over land and resources.

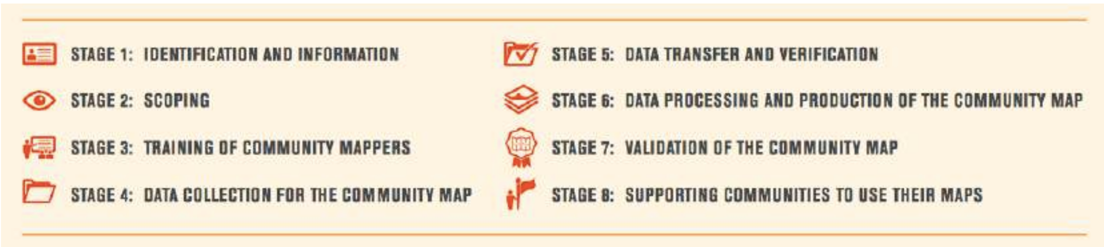


Figure 20: The mapping process is carried out through 8 inter-related stages

The Mapping For Rights methodology also uses GNSS handsets, such as the Garmin e-trex range.

The recorded coordinates are then uploaded to the GIS environment to produce the community map. The open source Quantum GIS (QGIS) on a laptop is used within Mapping For Rights.

Community data can also be uploaded to a global platform where authorized users are able to access community and other geo-referenced data from the Congo Basin via an interactive map interface. The database consolidates participatory mapping work that has been carried out in the region to build a picture of community land tenure and resource use, in order to promote effective collaboration and to inform planning, policy and decision-making processes. The aim is to continue to build the database so as to create an ever more comprehensive record of community forest tenure and use in the Congo Basin and elsewhere.

Community Based Real-Time Forest Monitoring

This ForestLink system aims at enabling communities anywhere in the world to capture and transmit accurately geo-referenced reports of forest illegalities to a central database in real-time, even from areas where there is no mobile phone or internet connectivity. It uses reporting tablets, which use a simple, icon-based recording and transmitting system. ForestLink is supported by satellite-based technologies, which help overcome the absence of data exchange networks in remote forest areas. Data is collected using Open Data Kit (ODK), coded for reduced data sizes through the Python programming language and transmitted to a satellite by the Raspberry Pi transmitter. Transmitted data is stored in a central geographical database. Once data reaches the database, it can be analysed by specialists and/or be retransmitted to local partners for verification.

Figure 21: Real Time Monitoring Kit

a) Directly use of the GNSS capability of the mobile device.
b) The use GNSS handsets, such as the Garmin e-trex range.

D. Limitations of Solution

- The use of the Mapping for Rights is focused on use within remote forest communities where accuracy of boundaries in not demanding.
- Dense forest vegetation is challenging for GNSS devices to receive sufficiently strong signals fro the satellite configuration.
- Spares of mobile devices and GNSS handsets need to be available in projects since no local maintenance service is normally available.

E. Costs of Technology

a) Capital Cost Items

Capital Item
Fully equipped mobile mapping laboratory for Mapping my Rights
FOSS

b) Revenue Cost Items

Revenue Item
Internet access service
Maintenance contracts for components of mobile mapping laboratory

Financial support is required for travel and living expenses in the forest. Actual costs depend on location, but in DRC, for example, field teams spend between US$780 and US$930 per village for all the work leading up to and the production of a community map.

F. Sustainability of Solution

Rainforest Foundation UK has been working with forest communities in the Congo Basin since 2000 in participatory mapping projects to safeguard their land and resource rights. In recent years, there has been a growing effort to promote community engagement in decision-making processes concerning natural resource management. Participatory mapping has emerged as a powerful tool that allows remote and marginalised communities to represent themselves spatially, bringing their local knowledge and perspectives to the attention of governmental authorities and decision-makers. Rainforest Foundation UK is well established and respected in supporting indigenous forest communities.

G. Capacity Level and Training Required

Activity	Skill Level
Data capture and adjudication	Facilitation Team and Community Mappers
Data editing and management	GIS technician
Making best use of their maps and other related data as powerful advocacy tools	Community Mappers

Resources needed for participatory mapping in forest communities include Facilitation Teams and Community Mappers.

- The facilitation team is composed of a Geographic Information System (GIS) technician and a mapping facilitator. They sometimes work together and sometimes separately, according to the stage of the process, and have clearly defined roles.
  - The GIS technician coordinates all activities of the mapping process and ensures the successful collection of cartographic data and the production of geo-referenced community maps.
  - The mapping facilitator organises the logistics of field activities and assists the GIS technician in carrying out the various stages of the process whilst assisting the community members with participatory exercises.

  Facilitation teams work under the supervision of locally-based NGOs, which provide logistical support, monitor their work and help with the use of maps by communities and other advocacy work.

- Community mappers are selected by their own communities with support from the facilitation teams to ensure that they best represent the different components of the community, and the different types of knowledge about ownership, use and control of community land and resources as well as possible. Community mappers play a key role in making sure the community map is accurately presented, but also that other members of the community fully understand the final map. When the map is ready, community mappers or other members will then be trained in how to make best use of their maps and other related data as powerful advocacy tools.

A number of training toolkits are available on-line:

- Training Kit on Participatory Spatial Information Management and Communication. Retrieved from http://pgis-tk-en.cta.int
- Training videos. Retrieved from http://www.mappingforrights.org/video-training
  - How to Map, Part 1: Mapping for Rights
  - How To Map Part 2: Scoping of forest communities
  - How to Map, Part 3: Summary of the different mapping methodologies
  - How to Map, Part 4: Facilitating ground and sketch mapping

- How to Map, Part 5: Using GPS units
- How to Map, Part 6: Geographic Information Systems (GIS)
- How to Map, Part 7: Validating community maps
- How to Map, Part 8: Putting maps into action

H. Supporting Documents and Reviews

Mapping For Rights website (http://www.mappingforrights.org)

The Mapping For Rights Mapping Methodology: A New Approach to Participatory Mapping. Retrieved from http://www.mappingforrights.org/technical-guides

I. Contact

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A.14 Blockchain Based Land Administration

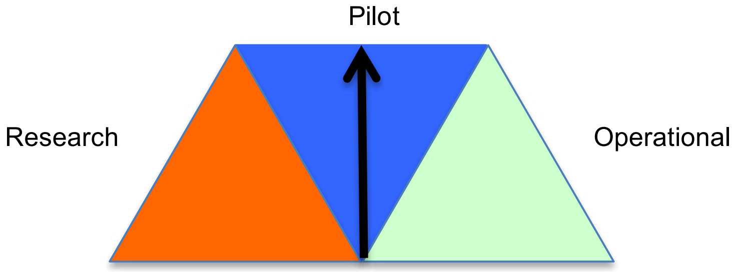
- Blockchain is a decentralized, distributed database holding a public ledger of contracts, transactions and records and is increasingly being considered for land registries.
- Blockchain could also potentially serve as a sort of virtual notary service and authenticate when precisely a transaction occurred.
- The technology's land registry application is being piloted in Ghana, Honduras, Sweden and Georgia.
- Benefits include the reduced reliance on trusted third parties, lowered costs (through automation), and greater security against fraud.

A. Description

In the simplest terms, the blockchain is a decentralized, distributed database holding a public ledger of contracts, transactions and records. What makes the blockchain so innovative is that every node has a complete or partial copy of the blockchain and all historical transactions, eliminating the need for a central database and ensuring that a single user is unable to fraudulently manipulate the data.

The concept of a transparent, decentralized public ledger could easily apply to land information management, where the land registry serves as a database of all property rights and historical transactions. The added benefit of using the blockchain technology is that you can get away from a centralized database, which too often could be vulnerable to hacking, misuse by system administrators, or even natural or man-made disasters destroying the data centre. Blockchain could also potentially serve as a sort of virtual notary service, authenticating when precisely a transaction occurred. Blockchain is predicted to be disruptive in the entire title insurance market and U.S. lending institutions may at some stage do away with title insurance.

B. Maturity of Solution



Honduras was one of the first countries to trial the blockchain technology, and started developing their pilot in 2015. However, due to political reasons, the pilot was not successful. More recently, blockchain based land-titling services are being piloted in Ghana, the Republic of Georgia, Sweden and Cook County in Chicago. No land administration systems using blockchain have yet gone live.

Only the Ghana initiative, BenBen, appears to use the blockchain at the core of the land administration, supporting transactions between citizens and banks. The other pilot programs use blockchain for its archiving functionality, for a track-and-trace function or in order to orchestrate the process of e-conveyancing. The land administration itself seems to be handled by more conventional systems.

C. Technology Details

In 2008 a paper was published on The Cryptography Mailing List at metzdowd.com by a member under the pseudonym of Satoshi Nakamoto, describing the bitcoin digital currency. In 2009 the first bitcoin software was launched. This used a technology called blockchain. It is often said banks, governmental parties and Land Registry authorities will be challenged (or even be replaced) by this ‘disruptive technology’. Various interested professional parties, including banks and Land Registry organisations, are examining and exploring the possible practical use of this technology (see Georgia case study). Changing or liquidating an organisation is not a matter of simply introducing new technology; it is also a matter of policy, governance, legislation and insurance. These matters are yet to be addressed by the blockchain community. Meanwhile, several organizations are conducting pilots to see how this technology could improve the current workflow and governance mechanisms.

The blockchain is a type of decentralized, distributed ledger that records transactions between parties, without the need for a trusted third party or trust within the group. All transactions of a certain time period are stored in a “block” and are connected (“chained”) to the previous block with the help of a complex cryptographic mathematical formula. This makes the ledger resistant to change or tampering and therefore ensures that all parties can trust the history as recorded on the blockchain.

Having a consensus mechanism makes blockchain invulnerable to localized attacks. No single participant can influence the blockchain by changing the stored transactions or by validating invalid transactions. To be able to do so, one has to have control of the majority of the network. In general, this is prevented in public blockchain applications since decentralised storage of information is performed by every node on the network. Each node maintains, and continuously verifies, a complete copy of all transactions. The consensus mechanism ensures that to take control over the blockchain, over half of the parties must be hacked, which is virtually impossible.

Compared with a ‘classic land registration system’, blockchain may even provide some additional certainty. The shared databases allow security of back-ups. Trust is added by cryptographic proof and a decentralised database, in stark contrast to a non-trusted current administrator (Registrar). Blockchain has the potential also to save costs because of removal of intermediaries (Notaries or licensed conveyancers) or administrators (Registrars). It, therefore, can be judged as a potential alternative for the classical Land Registers.

D. Limitations of Solution

- A land administration system is successful when all partners involved (owners, banks, Notaries, etc.) have trust in this system. This is independent from legal and technical solutions. In some countries people do not always trust the current system. In some cases there is fraud and corruption and in other cases there is a lack of quality. A blockchain-based Land Registry system may seem to offer a solution to these problems, although in reality it perhaps does not at this moment. The real challenge for these countries will probably be the initial identification of right holders and the creation of actual titles. Once it is known who is the actual owner of a certain parcel, the ownership of the parcel can be transferred. This initial phase will not be realised by using blockchain. Blockchain is designed as a ‘shared single source of trust’, to exclude (mistrusted) governmental parties and banks, but it demands trust from the very start when everyone can agree on the initial owners of title. This starting point may be the problem in the case of these countries, because there is no trust and so there will be no consent by all interested parties. In those cases a blockchain-based Land Registry will not work.

- Putting large documents (e.g. deeds) on the blockchain does not seem to be possible given the current capabilities. Storage of data in a transaction on the blockchain is limited and will require references to an external database, increasing vulnerability.
- Querying the data managed by the blockchain is highly complex and may be limited.
- Blockchain is meant to 'eliminate' the use of a Trusted Third Party. "It offers a way for people who do not know or trust each other to create a record of who owns what that will compel the assent of everyone concerned. It is a way of making and preserving truths." However, in terms of data quality and accuracy, just because something is recorded on the blockchain does not mean it is technically sound or verified. But what is to be trusted if the person does not have the (legal or surveying) expertise that is needed to fulfil the transfer of ownership of property? A man-in-the-middle, a Trusted Third Party, is still needed.
- Blockchain technology will not improve legal certainty with regard to the content and legal meaning of the first block. In a case where there is uncertainty with regard to the titleholder, blockchain will not bring any changes.
- Some transactions may be too complex to automate and check and cannot be supported by blockchain.

E. Costs of Technology

No financial figures associated with the blockchain investments have been publically released from the countries currently piloting the technology for land titling and registration.

F. Sustainability of Solution

A number of companies are applying the technology to land administration in a few early adopter countries. None have yet produced operational solutions. The sustainability of the technology within land administration will increase once operational solutions are created. The jury is still out.

G. Capacity Level and Training Required

Unknown at this stage.

H. Supporting Documents and Reviews

Mizrahi, A. 2016. A blockchain based property ownership recording system. Accessed at: https://chromaway.com/papers/A-blockchain-based-property-registry.pdf

Pichel, F. 2015. Bitcoin technology for land administration? Accessed at: https://www.devex.com/news/bitcoin-technology-for-land-administration-86362

Vos, J., Lemmen, C. and Beentjes, B. 2017. Blockchain-Based Land Administration Feasible, Illusory or a Panacea? Proceedings of the World Bank Conference on Land and Poverty, Washington DC, March 2017.

'The Land Registry in the blockchain – testbed'. A development project with Lantmäteriet, Landshypotek Bank, SBAB, Telia company, ChromaWay and Kairos Future. https://chromaway.com/papers/Blockchain_Landregistry_Report_2017.pdf

A.15 Advara

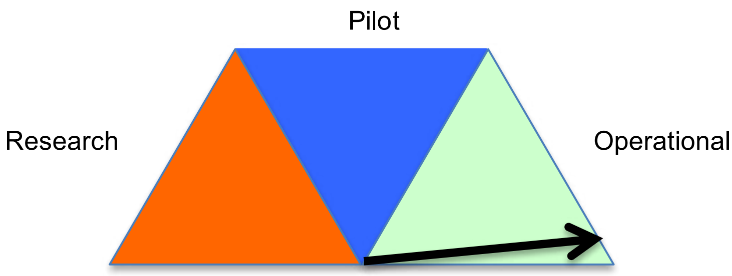
- Advara is a unique land registration platform implementing a cloud-based 'land registry as a software' solution.
- Advara claims to be the first universal, cloud-based land registration platform.
- Advara is 78% owned by Landgate, the Western Australian registry authority and 22% owned by Adecco, parent company to Ajilon (an advanced tier consulting partner with Amazon Web Services).

A. Description

Advara is a land registration platform, developed for Landgate – the Western Australian land registry authority. Advara is also the name for the company formed to develop and implement the Advara platform solution and has been established as a public-private partnership – 78% owned by Landgate and 22% owned by Adecco (parent company to Ajilon, which is an advanced tier consulting partner with Amazon Web Services, and the key business partner).

Advara is believed to have provided specialist consulting advice to the consortium of companies that successfully bid to operate the New South Wales land titles registry.

B. Maturity of Solution



The Advara platform is operational in Western Australia, but has not been implemented elsewhere and so it is not clear how transferable this solution is.

C. Technology Details

The following information has been taken from the Advara website and other promotional material; it has not been vetted by Advara staff.

The Advara platform has been designed to be scalable and cloud-based land registry solution that is adaptable to multiple jurisdictional circumstances. It was developed following a review of existing Landgate processes, which were streamlined as part of the process of development. A key innovation introduced by Advara is hence not simply the cloud-hosting, but also the quasi- business process engineering. Automation is a further key feature of what has traditionally been a paper-based, labour intensive process.

The stated intention of the Advara platform is that it has been designed to be adopted for other legacy land registry systems, with the following key efficiencies:

- Safe migration away from aging and inefficient legacy systems – with low cost and low risk
- Automation and expediting of a vast majority of paper and electronic registration lodgements
- Manual processing is minimized, as are associated labor costs
- Processing errors and delays are minimized and/or eliminated
- End user registration experience is improved, with an intuitive online interface
- Ongoing system infrastructure and management costs are minimized with either a Land Registry as a Service (LRaaS) solution or a concessional model.

When implemented for Landgate in Western Australia, Advara claims to have achieved the following improvements:

1. **Cost.** Per document costs significantly reduced.
2. **Speed.** Processing taking seconds rather than days.
3. **Productivity.** Automating the land registry process.
4. **Efficiency.** Significant reduction in rework.
5. **Flexibility.** Dynamic rules engine and skills based routing.
6. **Customer satisfaction.** The lowest 'Active Documents' (outstanding backlog cases) and significant reduction in 'Turn Around Times'.

Total savings of AUD$52 million over 5 years are anticipated.

D. Limitations of Solution

- Advara is currently only consulting with Australian land registries and has as yet shown no interest in international applications.
- Some countries may not wish to have their data stored in the cloud, particularly if the underlying server is not located in their country.
- Applications may be limited to cities/regions with strong Internet access.

E. Costs of Technology

Unknown at this time, however the implications of the NSW land registry privatisation are that there is significant opportunity for private sector engagement and/or revenue creation from the implementation of this technology, subject to streamlining of existing processes and or business re-engineering.

F. Sustainability of Solution

The solution shows strong promise for sustainability given adoption by the Western Australian land registry, one of the best regarded registries worldwide.

G. Capacity Level and Training Required

Significant training and in-house capacity may be required to adopt this solution, unless it is implemented in a PPP or via contract.

H. Supporting Documents and Reviews

Advara website, https://advara.com

I. Contact

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A.16 what3words

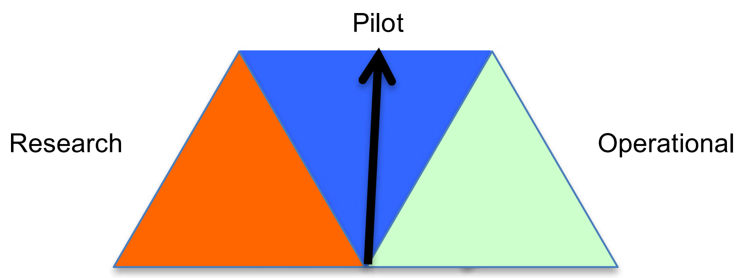
- what3words is a simple way to talk about location. The approach divides the world into a grid of 3m x 3m squares and each one assigned a unique 3-word address. There is a global grid of 57 trillion squares.
- It eases the sharing of location between non-professionals, with significantly less ambiguity and opportunity for error than alternatives (i.e. latitude/longitude)
- The service provides a platform in the form of a free mobile app or online map. It can also be built into any other app, platform or website, with just a few lines of code.

A. Description

Addressing around the world isn't suitable for everyday needs. Street addresses can be inaccurate or ambiguous. Road names are repetitive. Homes and businesses are often located far from the center of their zip / postcode. And much of the world simply isn't addressed – from informal settlements to the park where you've planned to meet friends, or the precise location where you're waiting for the cab to collect you. The UN estimates that 4 billion people lack a reliable way to address their homes. As such, they are denied access to basic social and civic services. They struggle to open bank accounts, register a birth or access electricity or water supplies. Without the ability to communicate where they live, these people become invisible to the state.

what3words is a global location referencing system based on a grid of 57 trillion 3m x 3m squares. Each square has been allocated a unique, fixed 3-word address. A person's ability to remember 3 words long enough to write them down is near perfect; trying to remember anything over 6 numbers or letters is very difficult. The use of words means non-technical people can find any location accurately and communicate it quicker, easier and with less ambiguity than any other system. Words can easily be written, spoken, printed or shared digitally. what3words is already built and ready to use, it is quicker and cheaper to implement than a new addressing system. The system converts long and complex latitude /longitude coordinates to 3 simple words and back. It works offline in over 20 languages.

B. Maturity of Solution



Although this solution is operationally mature in several market sectors, it is still immature in land administration. Hence the maturity being indicated as 'late piloting'.

C. Technology Details

The following what3words products are available:

- **On-line API**: The API is a few lines of code that can add 3-word address functionality to an existing app, map or site;
- **what3words map**: The free map tool, at map.what3words.com, lets yours discover and share 3-word addresses quickly and easily.
- **what3words app**: Free app for iOS and Android puts all the useful map features in a handy package for smartphones.
- **Mobile SDK**: This package provides the same service as the API, but it can be installed on a smart phone and works entirely offline.
- **Server SDK**: Businesses, NGOs and governments can use this service to run the what3words system from their own servers.
- **Batch Conversion**: This tool offers conversions from coordinates to 3 word addresses and vice versa.
- **GIS Plugins**: All the features of what3words can be used via plugins for GIS platforms, such as ArcGIS, QGIS and Hexagon's Smart M.Apps.

A wide range of third party products is available. Here are some examples:

- **UN-Asign**: Building on UNDP's use of what3words in the field in many regions across Africa, the regional security team in Turkey are using it to communicate across their teams. Drivers and security team members have downloaded the free what3words application, which enables them to simply describe the exact location of assets, people and even any incidents that arise. UN-ASIGN is available on Android and iOS.
- **Esri**: The what3words locator allows ArcGIS platform users to display the 3-word address for any location or search for a 3-word address, either individually or via batch conversion to and from coordinates. It makes full use of the Esri Geoinformation Model and is accessible online or offline, anywhere in the world.
- **Navmii**: Navmii gives you turn-by-turn driving and walking navigation. With traffic & hazard warnings, local search, driver analytics, downloadable maps and what3words, Navmii takes the hassle out of finding places.

The map site is available. Here is an example of a 3-word location (https://map.what3words.com/daring.lion.race), illustrated in Figure 22: example what3words on-line map site.

D. Limitations of Solution

- It is not a formal street address based system.
- What3words reserves the right to change their list of words and will not be responsible for the consequences.
- The grid is two-dimensional, so the addressing scheme does not distinguish between floors in a building.
- Resolution of 3m x 3m.
- 3-word addresses do not help directly with the creation or maintenance of land parcel boundaries. However, they can add value as follows:
  - Given an underlying Spatial Data Infrastructure (SDI), 3-word addresses can assist in easily communicating the coordinates for a location, i.e. is this point within this land parcel's polygon?
  - For a land parcel, what are the key access locations associated with the parcel, i.e. points of access, gates, rights of way bisecting the boundaries?

- For a land parcel, what is the main structure within the parcel's bounds, i.e. what is the location of the house or other property within the parcel?
- For a land parcel, what are the locations of the fixed assets within the parcel's bounds, i.e. outhouses, barns?
- In the absence of a formal Location Parcel Identification System (LPIS) e.g. for an informal settlement, there is a benefit from having 3-word addresses associated with structures, as this enables formal identification of a settlement's presence, and offers a usable location identifier for residents, businesses (e.g. postal addressing in favelas, townships etc.), and government authorities.
- Possibility to link what3words to point-based cadastre.

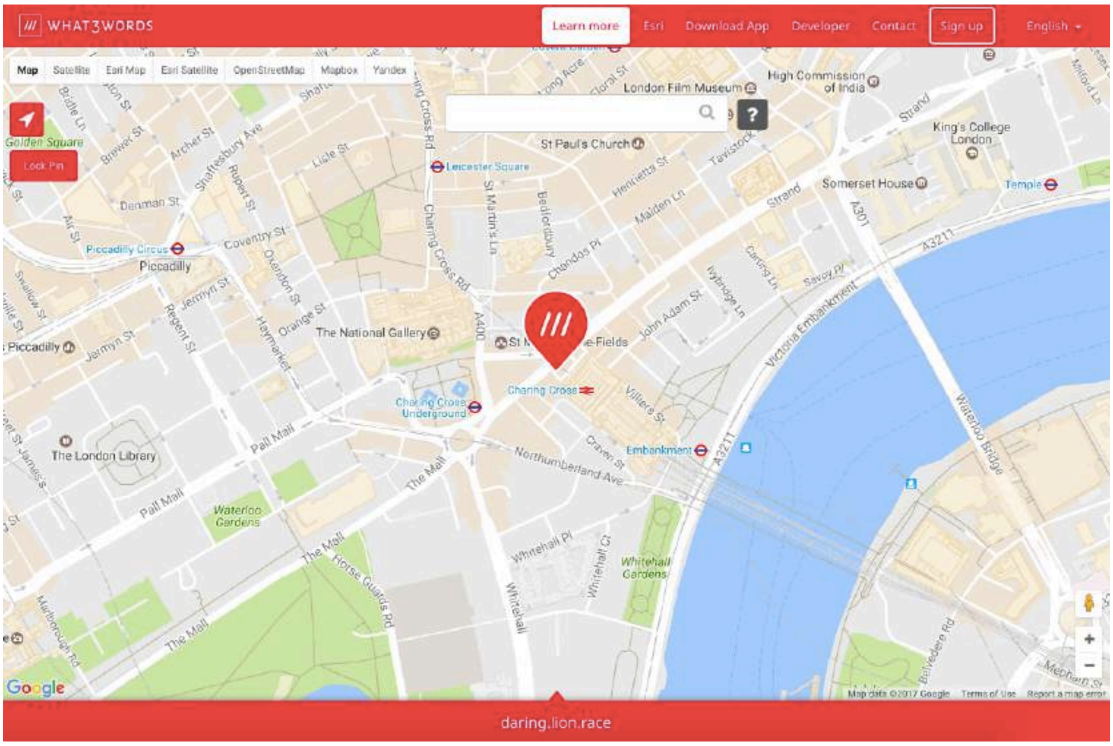


Figure 22: example what3words on-line map site

E. Costs of Technology

a) Capital Cost Items

Capital Item
Software is copyrighted and not freely usable.

b) Revenue Cost Items

Revenue Item

F. Sustainability of Solution

The what3words company has become well established with a wide range of customers in a diverse set of industries, including

- Navigation & Mobility;
- Automotive & Transportation;
- Deliveries, Logistics and E-commerce;
- Postal Services;
- Travel & Tourism;
- National Infrastructure and Government;
- UAVs;
- Humanitarian;
- Emergency Services;
- Events;
- Asset Management; and
- GIS.

APIs and tools make it easy to embed what3words functionality into apps and third party products. However, the software is copyrighted and not FOSS.

The company has managed to raise over $12 million capital within the past 4 years.

G. Capacity Level and Training Required

Activity	Skill Level
Use of what3words	Citizen

H. Supporting Documents and Reviews

what3words website: https://what3words.com

I. Contact

what3words, Studio 213 Westbourne Studios, 242 Acklam Road, London, W10 5JJ.

2 APPENDIX B: KEY CONSIDERATIONS

This appendix contains further information on key land administration topics that will help users of the Guide to understand the consequences and shape the decisions on the type of technology to use in land administration. This appendix provides more in-depth information about a supporting framework for decision support. It includes:

B.1 Costing and Financing Land Administration Systems - is essentially a decision-support tool for the costing and project design of land administration. It prompts discussion on a country's readiness for land reform, providing a series of templates to assist public agencies to identify the core needs and necessary minimum investment for land reform processes.

B.2 Role of Trusted Intermediaries - A key feature of these citizen centric approaches is the use of a network of locally trained land officers acting as trusted intermediaries and working with communities to support the identification and adjudication process. This approach builds trust with the communities and allows the process to be highly scalable. A strategy for recruiting and training trusted intermediaries is crucial for success

B.3 When to Capture Informal rather than Formal Land Rights – In countries where there is lack of political commitment or other constraints to recognize all legitimate rights then support may well build incrementally through the influence of local pro-poor recordation initiatives, which recognize and record legitimate rights in communities.

B.4 Customary (Social) Tenure - While many tenure rights are defined in formal law, there are often other rights that are not similarly defined, but yet people use them every day because they are recognized by the local community and others. These rights have a social legitimacy even if they lack legal recognition.

B.5 Public Awareness - Good public awareness is a critical success factor in many international projects to register rights. Campaigns to promote public awareness impact greatly reduce the length of time needed to systematically identify, adjudicate and register rights and the participation rate of landholders in these activities

B.6 Imagery Sources and Comparisons - The selection of technology for cadastral survey depends upon a wide range of factors. There are about a dozen commercial satellite operators that provide imagery of 1m or better. This section provides comparison of different imagery and when to use them.

B.7 Emerging Standards in Land Administration - It is essential that land administration programs adopt international standards wherever possible, e.g. LADM. This section provides an overview of existing and emerging standards in land Administration.

B.8 NSDI and Land Administration - Increasingly, geospatial information within a country is becoming an integral part of the national data infrastructure that promotes data sharing and consumption. Similarly to other infrastructures, it is a structure needed for the operation of a society as well as underpinning the services and facilities necessary for an economy to function effectively. This section argues that land administration information needs to be an integral part of a NSDI.

B.9 Capacity Development - Implementing a FFP land administration system at a countrywide scale is demanding in terms of both financial and human resources, and will take years. The need for human resources and skills must be assessed up front with regard to developing the various aspects of the land administration system and also with regard to the capacity for running and maintaining the system. Therefore, a strategy for capacity development is critical

B.10 Factors Influencing the Design of the FFP Spatial Framework - The FFP spatial framework for a country is not a homogeneous framework with the same approach to capturing and recording land rights being adopted across all regions of a country. Instead the spatial framework will be a patchwork of different approaches depending on local circumstances. Legal, social and geographical factors influencing the design of the spatial framework are discussed to help guide the decision support.

B.11 Legal & Regulatory Framework Considerations - To allow a country specific strategy for FFP land administration to be implemented, changes will have to be made to the Legal & Regulatory Framework to accommodate full recognition of all tenure types in a country and to allow new approaches and technologies in the capture and recording of land rights to be adopted.

B.1 Costing and Financing Land Administration Systems (COFLAS)

(CoFLAS): a tool for project preparation, budgeting and decision-making.

UN-Habitat and the Global Land Tool Network, having observed the land sector reform reliance on international development funds, identified Modernizing the Budgetary Approach of Land Agencies as a key area for tool development. The thinking is underpinned by the challenge of public agencies internationally to rationalize the cost and quality of public service provision, particularly during repeated cycles of financial crises. In developing countries, public resources are subject to competing critical priorities including health, education, water and infrastructure – not to mention the less visible land sector.

Available as a download from the GLTN website, CoFLAS is essentially a decision-support tool for the costing and project design of land administration. It prompts discussion on a country's readiness for land reform, providing a series of templates to assist public agencies to identify the core needs and necessary minimum investment for land reform processes.

Methods used to establish or reform LAS will have cost implications for the eventual operation and maintenance of the LAS, as well as impacting any potential for revenue generation. Core components of LAS establishment which are addressed under CoFLAS include:

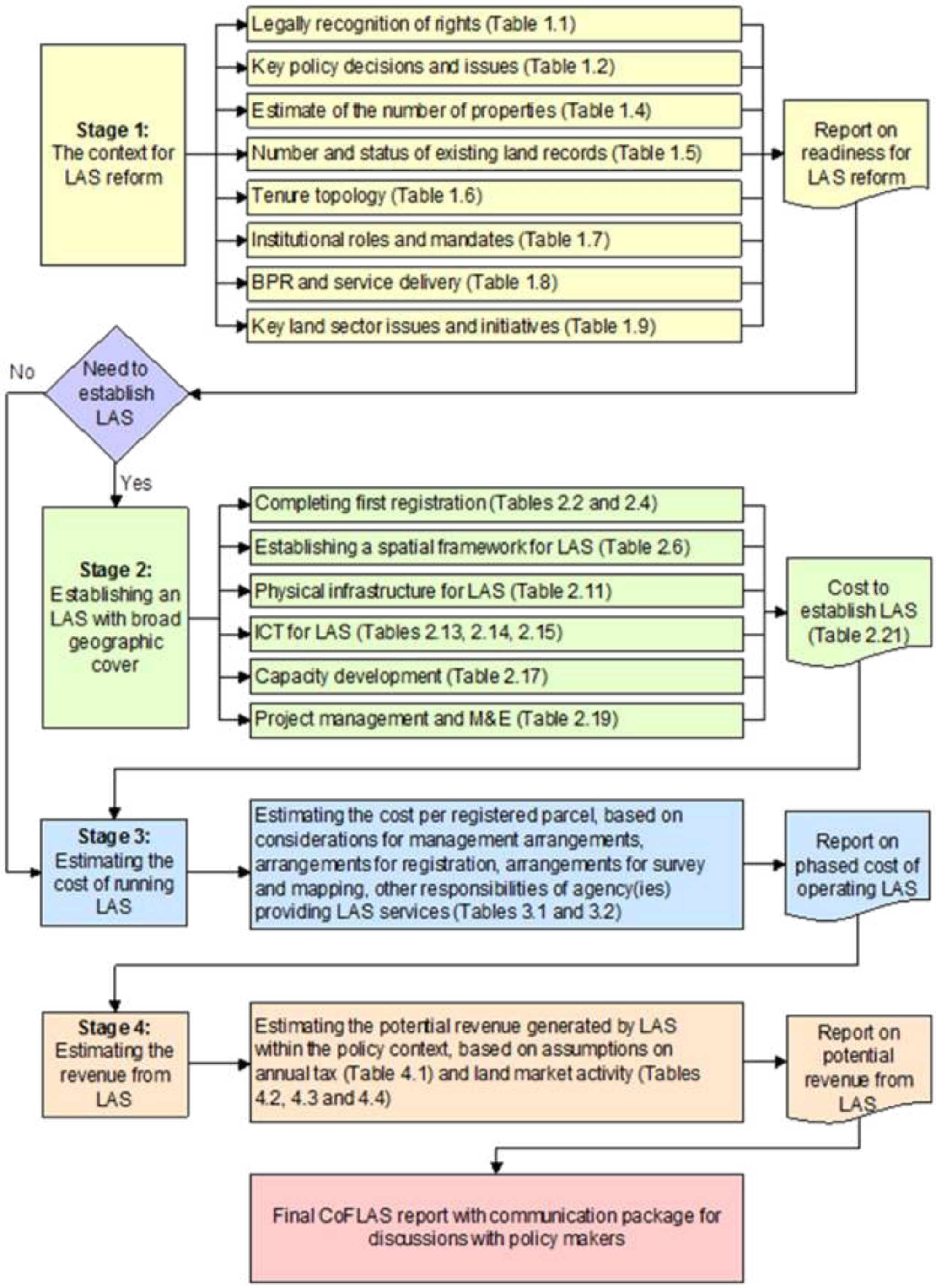
- ✓ Completion of first registration or formal recognition of rights.
- ✓ Establishing a spatial framework for land administration
- ✓ Acquiring and setting up the physical infrastructure for land administration
- ✓ Implementing ICT to support LAS
- ✓ Developing human resource capacity
- ✓ Project management.

Figure 23 provides the schematic of the CoFLAS process, referencing some 39 table templates for countries to complete to support their evaluation.

Stage 1 sets the context of land reform. To establish or reform a LAS, there will need to be demonstrated political will, clear leadership, strong stakeholder engagement and clarity around the context for land administration reform. This context can be established by consulting relevant stakeholders and undertaking investigations to:

- ✓ Establish an overview of the existing tenure rights recognized by law
- ✓ Estimate the number of properties/land holdings/parcels (registered and unregistered)
- ✓ Identify present institutional arrangements and any overlaps/gaps present
- ✓ Understand service delivery procedures and discuss opportunities
- ✓ Identify key issues to be addressed, and aims of the land reform
- ✓ Identify relevant initiatives and any development partner support

Figure 23: Schematic of CoFLAS stages



[Source: Burns, T. 2015 *Costing and Financing of Land Administration Services in Developing Countries* UN-Habitat Global Land Tool Network Secretariat. Accessed on 13 Feb 2018 at https://gltn.net/home/download/costing-and-financing-land-administration-services-coflas-brief/?wpdmdl=11282

Stage 1 hence assesses the readiness of a country or region to move forward, ultimately identifying key policy issues that may impact land reform, preparing a tenure typology and estimating the number and type of properties to be registered, identifying key institutional actors and overlaps/gaps, and identifying opportunities for business process re-engineering and streamlining.

Stage 2 identifies the major cost elements of establishing an LAS or LAS reform program, ensuring broad geographic coverage: generic costing steps include completing first registration, establishing a spatial framework and physical infrastructure to support the LAS, and implementing ICT and capacity development measures to support reform.

Stage 3 evaluates the likely annual operational costs of an LAS based on decisions made explicitly or implicitly in the earlier stages: it includes salary and recurrent costs, including equipment and software upgrade and maintenance as well as general office costs.

Stage 4, the final stage, provides a basis for estimating the potential revenue generation resulting from potential annual land and property taxes and potential taxes, fees and charges levied on transactions or LAS services: noting the tension that exists between the objective of recovering costs and ensuring accessibility and affordability.

B.2 Role of Trusted Intermediaries

Quickly developed, highly participatory land registration programs involve a lot of resources. A key feature of these citizen centric approaches is the use of a network of locally trained land officers acting as trusted intermediaries and working with communities to support the identification and adjudication process. This approach builds trust with the communities and allows the process to be highly scalable. A strategy for recruiting and training trusted intermediaries is crucial for success.

The training, support and supervision of these trusted intermediaries require new strong partnerships to be forged with land profession associations, NGOs, CSOs and the private sector. The land administration institutions need to introduce strong supervision of these partners with an associated quality monitoring program. The recruitment process for these trusted intermediaries can be very simple: those who apply have to demonstrate that they can understand aerial images, find their position on an image and have the attention to detail to draw boundaries. Over time, the trusted intermediaries should be encouraged to self-organize into collaborating networks and resources may be shared with other information services, e.g. health and agriculture.

A good example of this approach is the BRAC's 'Property Rights Initiative' in Bangladesh (BRAC 2014). A key component of this program was the creation of a new class of government-certified BRAC *amins* or land entrepreneurs. These entrepreneurs were trained by BRAC to measure land and certify property rights, as well as deliver a range of other services and human rights monitoring for their local communities. Land entrepreneurs have the opportunity to earn an income from their survey work while also carrying an obligation to provide free surveys and services to the local poor.

In Rwanda over 100,000 people were employed over the lifecycle of their program and a community driven process of demarcation meant that someone who was known in the community was responsible for defining the boundaries and not someone from outside the village. Given the sheer scale of the number of field teams operating, around 800 local trusted intermediaries were employed by the program at any one time. Once local districts were completed, the local trusted intermediaries from completed districts were recruited to train the new trusted intermediaries in the new districts. The recruitment process for local trusted intermediaries was very simple: those who applied had to demonstrate that they could understand the aerial images, find their position on an image and have the attention to detail to draw boundaries. The use of local people to support the program also had significant socio-economic benefits across communities in Rwanda. Many staff used their earnings to partake in master level courses and many of those used were recruited in government positions at the end of the program.

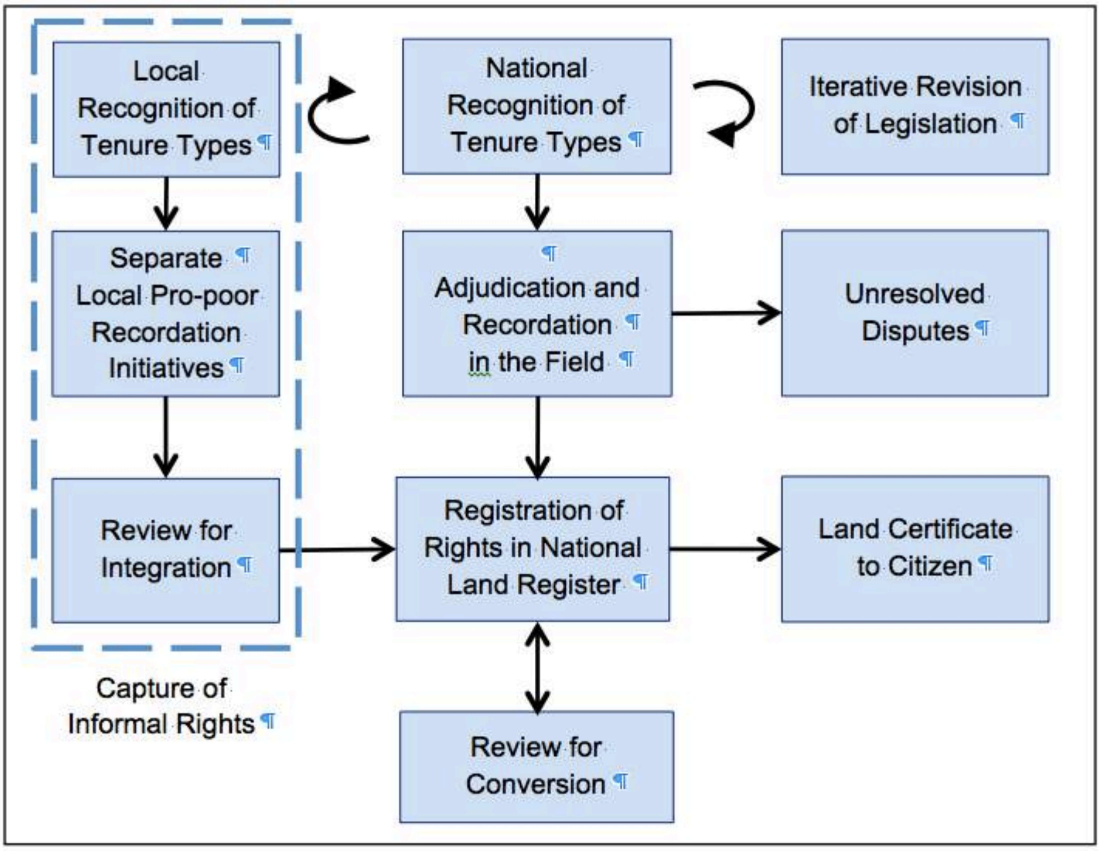
It is essential in the FFP approach to land administration that processes and resources to maintain the land information is an integral part of the initial program design. Maintenance is required from the first day of operation. The importance of this is often neglected, and once titles are issued there is often little pressure to keep the registry information up to date. Resources and processes must be in place to at start of the program to validate and maintain the land rights information. A network of trusted intermediaries must be retained to adopt this crucial role. It is estimated that on average 5% of all land rights will require maintenance annually.

Land professionals have a key role to play in this new resource model through the provision of training for the trusted intermediaries, ensuring that the appropriate data capture approaches are adopted in the designated regions of the country, monitoring the quality of the captured land rights data, and efficiently and securely managing the significant, amounts of land rights data within the national program. This new, enhanced role for land professionals will raise the profile of the profession and provide new revenue streams.

B.3 When to Capture Informal Rather than Formal Land Rights

The processes of recording and registering land rights under the FFP approach is illustrated in Figure 24. The processes within the dashed line box represent the informal capture of land rights.

Figure 24: FFP Process for Recognizing, Recording and Reviewing Land Rights



The FFP approach to land administration is primarily aimed at implementing national programs at scale to deliver security of tenure for all. It is a pro-poor approach that recognizes and legalizes all legitimate rights. This requires political commitment, as witnessed in Rwanda, Ethiopia and other countries, to roll out these national programs in short timeframes and at affordable costs.

However, in countries where there is lack of political commitment or other constraints to recognize all legitimate rights then support may well build incrementally through the influence of local pro-poor recordation initiatives, which recognize and record legitimate rights in communities. The local pro-poor recordation initiatives can therefore work in parallel and be a supportive component of the national recordation process or act as a driver for change. These local initiatives may gain sufficient momentum and acknowledgement to eventually trigger wider incremental change and eventually lead to national recognition with corresponding changes to the legal and regulatory framework and help countries adopt the FFP land administration approach.

Local Pro-Poor Recordation Initiatives

A number of pro-poor land recordation approaches and solutions have been developed and are active around the world. There are extensive initiatives for safeguarding the rights of indigenous communities (for example, the Aliansi Masyarakat Adat Nusantara (AMAN) and the Asia Indigenous Peoples Pact (AIPP) operating in Indonesia, and Rainforest Foundation UK operating in the Democratic Republic of Congo) and techniques to crowdsource land rights are also emerging. This Guide includes a number of emerging mobile-based solutions that are being used to capture land rights outside of the formal land administration system. These include:

- The Cadasta Foundation has a GeoODK based mobile application and an associated global cloud platform to securely manage the land rights of citizens and communities involved in their informal programs.
- STDM system from GLTN provides tools to capture land rights and from 2017 provides a cloud platform for managing the land rights, rather than just storing and managing them locally. This has been used successfully in informal settlements and with local governments to increase security of tenure and to empower citizens to engage in the planning process (see the Mashimoni, Nairobi case study).

The ultimate aim sought by these informal initiatives is to provide security of tenure for the citizens and communities by registering the legitimate rights within the FFP national land register in the formal land administration system. This will require engagement with the National Land Registration and Cadastral Agency in a due diligence process to determine whether legitimate rights, recorded under local pro-poor recordation initiatives, can be considered to meet a set of conditions to allow their integration into the national land register. This process is illustrated in Figure 24.

In contrast to these solutions operating outside of the formal land administration system, a number of emerging mobile solutions are directly engaging with the National Land Registration and Cadastral Agency to directly integrate the captured legitimate land rights into the national land register. These solutions include:

- In Tanzania USAID's Mobile Applications to Secure Tenure (MAST) project was implemented with the support of the Government of Tanzania and local people received government-issued Certificates of Customary Rights of Occupancy (CCROs) for their land.
- In Ghana Landmapp provide a customary land document including a Farm Plan and Indenture, providing farmers with a long-term lease in traditional areas, validated by neighbors, witnesses and signed by a licensed surveyor, the traditional authorities (divisional and paramount chiefs) and legalized by the high court.

The local pro-poor recordation initiatives can therefore work in parallel and be a supportive component of the national recordation process or act as a driver for change to help countries adopt the FFP land administration approach. Wherever possible, local initiatives should coordinate with the national level to plan for future national recognition of the legitimate rights – and National government should provide guidance for undertaking such local recordation.

Case Study: STDM Community Empowerment in Mashimoni, Nairobi

The Mashimoni informal settlement covers 9.5 ha and is located in the east of Nairobi. The site owned by the State was a former quarry and people have been squatting since 1975. The densely populated slum faced serious problems such as fire, inadequate infrastructure and health issues. People were also threatened by eviction due to close proximity to a business center with high associated land values. The community formed a Resident-Association in 2010 with the main focus on solving the land issue.

A first enumeration was organized in 2010 to obtain information on the settlement and the residents. The community then negotiated with the Ministry of Lands for the national government to hand over the land to the residents. The land was subsequently safeguarded through a cabinet resolution.

Community leaders helped to introduce STDM in 2011 with support of the Pamoja Trust and community members were trained. The community is using STDM for mapping and enumerations towards tenure regularization under the Kenya Informal Settlement Improvement Project (KISIP). Data on 'structures' ('slum houses') and 'users' was collected, linked, verified and digitized using STDM facilitated data access.

STDM has gathered evidence on land tenure and on the legitimacy of people to land relations in litigation and negotiation and helped to avoid evictions. Conflicts in cases of double or triple selling of structures has been reduced. Data has also been collected on utilities, sanitation and facilities to demonstrate the scale of problems. This has led to the installation of 75 toilets across the slum and supported negotiations to remove an open sewer.

STDM has empowered and enabled the community to have a say in planning issues and participation and transparency is encouraged. Electricity is now available across the slum and the community have a five year improvement / development plan. This STDM project has been sustainable and has successfully built and empowered a slum community to significantly improve their environment and security of tenure. The Mashimoni experience has resulted in the broader usage of STDM under KISIP.

[Source: Joseph Arthur, STDM Co-ordinator, Muungano Mashimoni Number Ten; Cyprian Selebalo and John Gitau, UN-HABITAT, Global Land Tool Network]

B.4 Customary (Social) Tenure

While many tenure rights are defined in formal law, there are often other rights that are not similarly defined, but yet people use them every day because they are recognized by the local community and others. In the majority of developing countries around 80 per cent of the land is held under some form of customary tenure, where the collective and occasionally individual rights are created by custom managed by traditional authorities. These rights have a social legitimacy even if they lack legal recognition.

In Africa, for example, over 60 per cent of urban areas are informal. Informal tenure rights are often created spontaneously in informal settlements and are not recognized by formal law. However, the informal rights can be used as the basis for the creation of legally recognized rights where the law allows. Informal settlement residents also need to be brought into the formal system.

And the VGGTs state: “Based on an examination of tenure rights in line with national law, states should provide legal recognition for legitimate tenure rights not currently protected by law.” Therefore, the recording of customary tenure rights in a land registry may not be possible until legal reform has provided legal status to the rights and an adjudication process has established the information needed for the records. This process should be managed through co-management between the traditional authorities and the formal governmental institutions, wherever possible. This approach has been successfully implemented in Kenya.

Communal lands with customary tenure can be included in the formal system by initially demarcating the outer boundaries while retaining the community institutions that allocate and manage individual and household plots, with the option to register these land rights as the need arises (Byamugisha, 2013). It should be noted that based on customary tenure, some stakeholders will be provided with temporary rights who may not be present all year round, such as pastoralists with seasonal use rights to animal corridors, pastures and water sources.

This Guide provides examples of technology and approaches that have been used to capture these categories of legitimate rights either informally or formally in partnership with land registration institutions. These technologies normally use the Social Tenure Domain Model (STDM) that introduces the social element into land administration systems It describes relationships between people and land in an unconventional manner in that it tackles land administration needs in hitherto neglected communities, such as people in informal settlements and customary areas. It supports development and maintenance of records in areas where regular or formal registration of land rights is not the norm.

References

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B.5 Public Awareness

Good public awareness is a critical success factor in many international projects to register rights. Campaigns to promote public awareness impact greatly reduce the length of time needed to systematically identify, adjudicate and register rights and the participation rate of landholders in these activities. The extent of uptake to register subsequent land right transactions is also typically positively impacted.

Core components in the public awareness process may include:

- Preparing and overseeing the delivery of ***public outreach messages*** prior to the land activity (whether via TV, radio, village area posters, community group meetings, etc.). Where there is a time element to messages, consideration of hosting messages outside work hours and on weekends is needed.
- **Consulting with and training local officials and leaders as project advocates.** In the case of technology use, local youth may also function as strong project advocates.
- **Meetings with key stakeholders to gain better access to owners of rental properties, and landholders residing overseas.** Stakeholders may include property managers and developers, community and representative groups, consular offices in neighboring countries, etc.
- **Hosting community meetings**, and ensuring sufficient advertising time prior to hosting, so that stakeholders attend.
- **Hosting targeted awareness campaigns for women**, including identifying and support local female figureheads as project advocates and ambassadors, and hosting specific meetings and focus group sessions for women to ensure strong social representation and to capture any gender-related issues as they arise.
- **Simultaneously performing rights adjudication and boundary demarcation** to increase completeness of regularization and the need for only one time participation of owners at the property.

Approaches to public awareness may include a range of activities such as:

- Paid advertisements and regular editorial content on formal television, radio and newspaper media;
- Advertisements on billboards and in key buildings/meeting areas,
- Mobile vehicles;
- Linking to local community groups such as churches and sporting groups,
- The production of posters;
- Village and community meetings including the use of play-acting presentations on key land sector issues and activities;
- The production of video-content and distribution through the internet; and
- The production and distribution of videos, leaflets and other material.

International experiences using these are shown in the case study box below. In addition to these there are emerging opportunities for public awareness through social media (see Appendix A.2 ‘Social Media for Land Administration’).

International Experience on Public Awareness and Engagement

A sound and coordinated public awareness strategy should be drafted prior to the commencement of land administration activities to promote local participation and engagement.

A localized awareness program can work well in areas with a high percentage of owner-occupiers. In this context, one of the most effective and cost-efficient methods to promote public awareness of land administration activities is the use of explanatory flyers, particularly when these promote a set date and time for either a public meeting or at which the demarcation team are coming. These flyers should be hand delivered to each landholding, usually about one week before the appointed time for demarcation (or public meeting). Poster advertisements placed about the same time as the mail handouts on telegraph poles, walls, shops, etc. in the locality can also help – but they should also be removed once activities (i.e. adjudication) are completed.

In Palestine, the implementation team hired university students to undertake the mail handouts and signage work, which proved quite successful. In Kyrgyz, adjudication teams undertook the work themselves, but made a point of wearing distinctive green uniforms when distributing flyers by foot, followed up with community meetings to explain activities and timelines. Advertisements were also placed on local buses.

Timing is a critical element of public awareness and engagement, with quick follow-up necessary to capitalise on efforts. Too many delays, or too long a time period between public awareness activities and demarcation will likely result in low public awareness. Attention should also be made to landholders who may not live in an area undergoing adjudication.

To address a wider audience (i.e. in the context of nation-wide or region-wide activities) several countries have used television advertising, including participation in talk show programs, and discussions on land issues on radio. During these programs, land adjudication would be a key message, but other questions could also be answered regarding land values, etc. In Montenegro, a local comedian made a short video that went viral.

B.6 Imagery Sources and Comparisons

Satellite Sensors

The selection of technology for cadastral survey depends upon several factors, such as: terrain conditions (hilly, undulating, plain); vegetative cover (dense, sparse); built-up areas (urban, settlements); size of survey area (state or region or project area); accuracy (required versus achievable); timeliness (short or normal); cost (budget requirement versus available); and weather (especially cloudiness).

Table 4 below shows categories of urban and rural land uses, preferred mapping scales for them, and the equivalent imagery spatial resolution (also known as ground sampling size (GSD)).

There are about a dozen commercial satellite operators that provide imagery of 1m or better (

Table 5). One of the biggest advantages of satellite data is that they cover large areas. The number and frequency of coverage, means that the chances of getting cloud-free suitable imagery is enhanced, although in tropical areas, with the necessary sun-synchronicity of polar-orbiting satellite, cloud and haze are still major problems. Thick tree canopy and shadows are other restrictions

The price for 1m pan-sharpened imagery is about US$ 15 per square kilometre. Tasking can be requested, where the satellite operators will prioritize acquisition of your requested areas of interest, by "pointing" the satellite during suitable orbits. The cost of tasked collections is normally about 15% more than archived imagery.

The prices shown are "raw" data, which have geometric distortions due to sensor orientation and varying terrain. The image displacements caused may be geometrically corrected to match the projection of map co-ordinate system using transformation techniques.

Ground control points (GCPs) are required, either from reliable maps or from in-field measurements, in order to geo-correct the imagery to obtained images with consistent scale and consistent with the national overall framework.

Especially in hilly terrain, more accurate geo-correction may be obtained if a digital elevation model (DEM) is used for the geo-correction. There are several crude global DEM that can be used, but if any local, more detailed ones are available, better accuracy would be achieved. Some satellite systems provide stereo pair from which a DEM can be generated by image correlation and stereo-model techniques.

A certain amount of image enhancement can also be carried out, in order to make the most suitable image composition for paper orthophotomaps or use as background imagery in mobile phones or tables such as for MAST.

Commercial satellite companies do not place their imagery into the public domain and do not sell their imagery; instead, one must be licensed to use their imagery. Thus, the ability to make legal derivative products from commercial satellite imagery is minimized.

Aerial photography methods

NMCAs have also traditionally focused on topographic mapping, initially with large expensive analytic through digital stereo plotters. Meanwhile, aerial methods have moved to fully-digital methods now, with sophisticated digital cameras, supported by GNSS-RTK and inertial monitoring units can be processed with modern software to produce highly accurate orthophotomaps at resolutions of up to 5 – 10 cm (equivalent to mapping scales of about 1/150) and 3-D models with x,y,z accuracies of a few centimetres (with sufficient ground control points). Aerial methods can be enhanced by adding additional sensors such as LiDARs on the planes when they make their runs.

Photogrammetry is the practice of determining the geometric properties of objects from photographic images. This involves estimating the 3-D coordinates of points on an object. These are determined by measurements made in two or more photographic images taken from different positions. Common points are identified on each image. A line of sight (or ray) can be constructed from the camera location to the point on the object. It is the intersection of these rays (triangulation) that determines the three- dimensional location of the point

Photogrammetry is more accurate in the x and y direction while range data is generally more accurate in the z direction. The range data can be supplied by techniques like LiDAR and laser scanners. Airborne LiDAR is a highly cost effective means of collecting detailed topographic survey information, and offers significant advantages over traditional forms of topographical survey in terms of speed, access, resolution, accuracy and canopy penetration, for a variety of applications.

LiDAR – Light Detection and Ranging is a method of detecting distant objects and determining their position or other characteristics by analysis of pulsed laser light reflecting from their surfaces. Basically, a laser pulse is reflected from a rotating mirror inside a laser scanner. By measuring the time delay between when the laser pulse is emitted, and when it returns to the scanner, the distance between the scanner and the object can be precisely determined. The scanner can also accurately measure angles. When all of the distance, angular and positional information is processed the scanner can produce highly accurate 3D data set, which is sometimes referred to a point cloud. Photos can clearly define the edges of buildings when the point cloud footprint cannot. Therefore, often the orthorectified images are draped on top of the LiDAR grid thus creating a 3D visual survey.

Radar sensors can also be used on survey planes. This can speed up such a ground survey and serve as a control method. In FFP approaches, radar imagery may also be considered as an effective way of collecting cadastral boundary data quickly and cheaply. Printed imagery can be taken into the field to compare automatically extracted features with actual cadastral boundaries. Those boundaries can be marked with a pen on top of the image. Back in office, the polygons for spatial units (parcels) can easily be identified and fed into the database with the required accuracy.

The biggest disadvantage of aerial methods is that they require availability of aeroplanes, trained pilots and the obtaining of permission. This can also make it uneconomical if only small coverage areas are required. Even with an area of say 250 square kilometres, the price of aerial imagery could be twice that of archive satellite imagery.

Table 4: Categories of urban and rural land, preferred mapping scale and imager resolution
(Adapted from Byamugisha et al., 2012)

Area	Description	Preferred Mapping Scale	Image Ground Sampling Distance/ Resolution (m)	Platform	Is LiDAR appropriate?
Urban central High density, high value	Dense development and very high land values require large scale mapping to be performed by conventional terrestrial surveys or large scale image maps	1/500 – 1/2,000	0.10 - 0.50m	Aeroplane Drone Satellite	Yes
Residential Urban Medium density, high value	In residential areas the dwellings and parcels are normally easily identified in image maps	1/1,000 – 1/2,000	0.25 - 0.50m	Aeroplane Drone Satellite	Yes
Peri-urban Mixed density, good value	Peri-urban areas include a mix of land uses depending on the density and complexity of developments.	1/2,000 – 1/5,000	0.50 - 1.25m	Aeroplane Drone Satellite	Possibly
Informal/slum Very high density	Slum areas can be mapped for many purposes. Ideally, the individual housing structures can be identified as a basis for various kinds of administration and service delivery.	1/500 – 1/2,000	0.10 - 0.50m	Aeroplane Drone Satellite	Possibly
Small towns, villages High density, low value	Rural villages may be mapped separately or they may be mapped as part of a major rural area	1/2,000	0.50m	Satellite Aeroplane Drone	No
Rural agricultural Medium density, good agricultural value	In rural agricultural areas the individual parcels will normally be visible on satellite image maps	1/2,000 – 1/5,000	0.50 - 1.00m	Aeroplane Satellite Drone	No
Rural remote, forest Low density, low value	Mapping more remote rural areas may serve various purposes, such as land rights, natural resource management, water catchment, etc.	1/5,000 – 1/10,000	1.00 - 2.50m	Satellite	No

Area	Description	Preferred Mapping Scale	Image Ground Sampling Distance/ Resolution (m)	Platform	Is LiDAR appropriate?
Rural mountainous	Mountainous areas can be covered by maps to a scale of 1/5,000 – 1/50,000 depending on the topography and settlement activity.	1/5,000 – 1/50,000	1.00 - 10.00m	Satellite	No

Table 5: Satellite sensors and prices for available imagery

Satellite	Sensor	Spatial Resolution	Price *
WorldView 4	Pan/MS	0.31m/1.24m	17.50
WorldView 3	Pan/MS	0. 31m/1.24m	17.50
WorldView 2	Pan/MS	0.46m/1.84m	17.50
WorldView 1	Pan/MS	0.46m/1.84m	17.50
Quickbird	Pan/MS	0.61m/2.62m	17.50
GeoEye-1	Pan/MS	0.46m/1.84m	17.50
Pleiades 1A/1B	Pan/MS	0.50m/2.00m	13.00
IKONOS (80cm)	Pan/MS	0.82m/3.28m	10.00
TripleSAT	Pan/MS	0.80m/3.28m	
Kompsat-3A	Pan/MS	0.55m/2.20m	
Kompsat-3	Pan/MS	0.70m/2.80m	
Gaoferi-2	Pan/MS	0.80m/3.20m	
SkySat 1/2	Panchromatic	0.90m	

*Approximate per square km for archived imagery. There is normally a minimum order of 25 sq.km for archive imagery (normally classed as 90 days or older). Licensing is for 1 – 5 users. Prices for tasked orders are about 15% higher.

B.7 Emerging Standards in Land Administration

Land Administration Domain Model

Alongside the push for the increased use of imagery, global standards such as the Land Administration Domain Model (LADM) and its specialization the Social Tenure Domain Model (STDM) focus on standardized modeling of information at the conceptual level. The design of LADM took place in an incremental approach with continuous expert reviewing from 2002 to 2006 within the International Federation of Surveyors. Then a design and development process for international standards was followed.

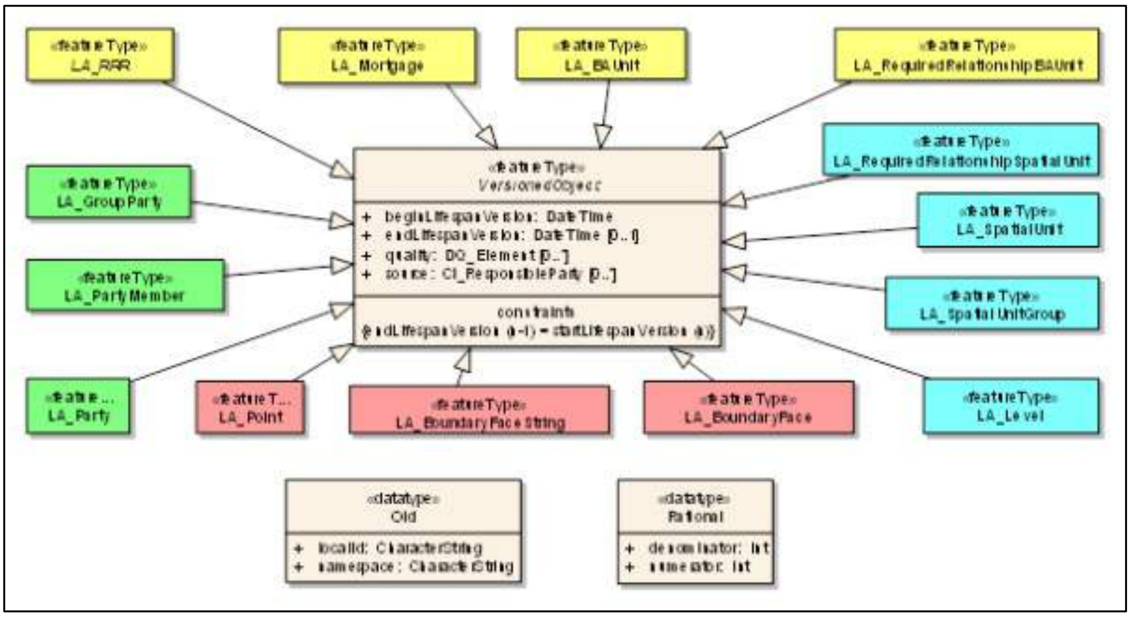
The Land Administration Data Model was a key development over many years over several countries, looking to rationalize the disparate ways that cadastral and land administration data was captured, stored and managed. LADM was adopted in 2012 as an International Standard, ISO 19152:2012. It:

- defines a reference Land Administration Domain Model (LADM) covering basic information-related components of land administration (including those over water and land, and elements above and below the surface of the earth);
- provides an abstract, conceptual model with four packages related to
    - parties (people and organizations); - shown in green in the Figure below
    - basic administrative units, rights, responsibilities, and restrictions (ownership rights); - shown in yellow
    - spatial units (parcels, and the legal space of buildings and utility networks); - shown in blue
    - spatial sources (surveying), and spatial representations (geometry and topology) for 2-D and 3D- shown in pink
- provides terminology for land administration, based on various national and international systems, that is as simple as possible in order to be useful in practice. The terminology allows a shared description of different formal or informal practices and procedures in various jurisdictions;
- provides a basis for national and regional profiles; and
- enables the combining of land administration information from different sources in a coherent manner.

All LADM elements are temporal objects (that is they have lineage through time).

The standard that a continuum of tenure exists in terms of social tenure relationships, such as occupancy, usufruct, informal rights, customary rights, indigenous rights and nomadic rights. In the same way, parties holding the rights may not only be natural or legal persons, but could be a family, tribe, community, village, or a farmers' cooperative. Also, the spatial unit may not only be a land parcel, but can also vary according to where the rights and social relationships apply, e.g. a point cadastre rather than a parcel boundary, or 3D volumetric parcel, or it could be text based or photo based. Similarly, one may talk about a continuum of data acquisition methods or technologies that will include what could be called “continuum of accuracy”. Another dimension could be a continuum of land recording and credit accessibility, ranging from informal land offices in an informal settlement to a governmental land registry.

Figure 25: LADM Conceptual Model



The model aims at standardization, in order to make it easier to support structuring data in single and distributed land administration environment and monitor the progress of global indicators relating to land tenure security. Flexibility is provided by ‘code tables’ that allow expansion by the inclusion of, for example, a broad range of (local) types of recognized land rights, types of restrictions, types of responsibilities, types of holders, types of spatial units (text, point, line, polygon and volume based). Several country profiles were included in the first publications, and may other have since been developed. Some of these have proceeded to the physical database design using model-driven architecture while others examine the implementation of a LADM-compliant 3D Cadastre. All of them however, have the common scope of improving their country’s land registers and to achieve interoperability. In addition, the implementation of country profiles based on LADM makes it is possible to compare cadastral management systems.

Land Administration & Standardization

All data in a land administration are supposed to be documented in authentic source documents. Those source documents are the basis for building up a trusted and reliable land administration, as basis for transactions and for the establishment of new land rights in a land administration. LADM is capable of supporting the progressive improvement of cadastres, including both the geographic and other elements and of supporting fit-for-purpose cadastral requirements. LADM can potentially be used to support organizational integration, for example, between often disparate land registry and cadastral agencies. LADM can help to reconcile superfluous government databases and reduce the large amount of data redundancy that currently exists.

LADM is of one of the first spatial domain standards within ISO TC 211. TC 211 is the Technical Committee on Geographic Information within the ISO. This knowledge domain specific standardization captures the semantics of this domain. This is required: for communication between professionals (and between professionals and grass root surveyors and citizens in participatory approaches); for system design; system development and system implementation purposes; and for purposes of data exchange and data quality management. Operationalization of such a standard as LADM has enabled Geographical Information Systems (GIS) and Database Management System (DBMS) providers and open source communities to develop products and applications, which, in turn, has enabled land registry and cadastral organizations to use these components to design, develop, implement and maintain systems in an even more efficient way.

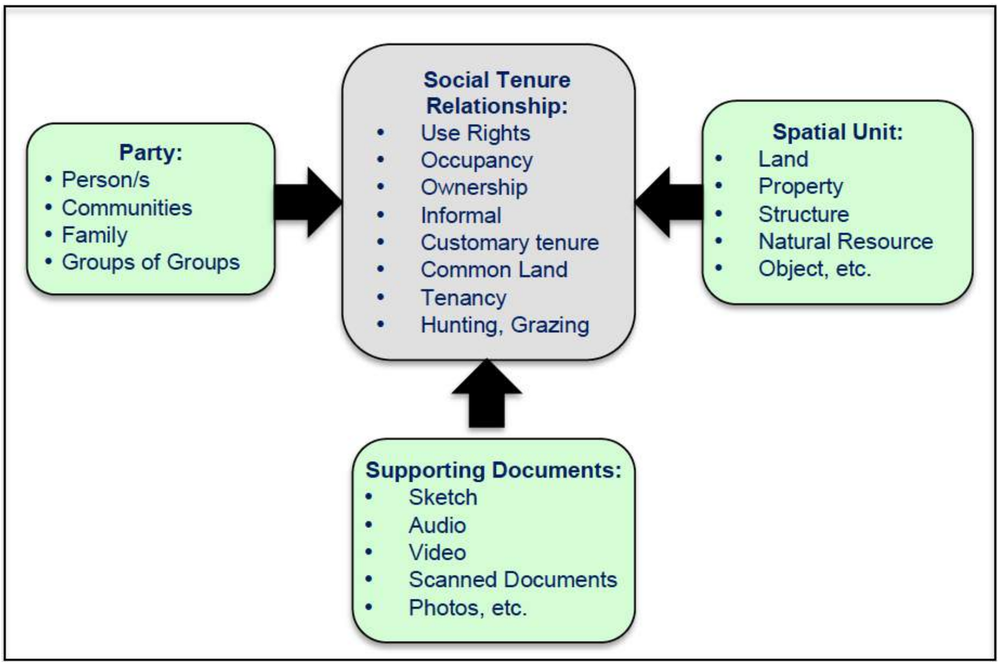
LADM provides a shared ontology, defining a terminology for land administration. It has greatly supported the development of application software for land administration, and facilitated data exchange with and from distributed land administration systems. An important aspect in the development of coherent Spatial Data Infrastructures (SDIs) is that the various standardized domain models are reusing the same model patterns as solutions for the same situations.

The standard also supports data quality management. Use of standards contributes to the avoidance of inconsistencies between data maintained in different organizations, by reducing or avoiding data duplication.

Social Tenure Domain Model (STDM)

Supported by UN-Habitat, and to support customary and informal tenure in developing countries, the Social Tenure Domain Model (STDM) was also developed as a specialization of LADM. STDM aims to support a range of 'rights': from informal (customary, indigenous) to formal persons (variety of types: groups, organizations, natural persons) and spatial units (from text to topology). See Figure 26.

Figure 26: The STDM Conceptual Model explains the interrelationship between parties, social tenure, and the spatial units supported by relevant documents



(Source: UN-HABITAT/ GLTN)

OGC Land Administration Domain Working Group

The Open Geospatial Consortium (OGC) has set up a domain-working group on land administration in 2016. OGC has standing liaisons with major players in the land administration domain, including Technical Committee 211 of the ISO TC211, World Bank Group, the Royal Institute of Chartered Surveyors, the World Wide Web Consortium, OASIS, the International Federation of Surveyors, and the Global Land Tool Network. OGC always strives to use, build on and complement existing standards. However, while there are some standards describing elements of an administrative system, such as in LADM and STDM, there are gaps in the way that they incorporate geographic descriptions of land records, and / or inadequate rules for defining and describing the quality of the records. The Land Administration Domain Working Group aims to assess the existing standards and address any gaps it finds.

The OGC members have drafted a charter for the domain working group for land administration. The charter describes how to improve the interoperability, effectiveness and efficiency of land administration systems by optimizing the use of OGC and complementary open standards. Improved interoperability will contribute to reduced deployment time, lower system lifecycle costs, improved flexibility and scalability, improved choice from the IT marketplace, and improved ability to share, exchange and integrate information related to land administration.

The domain-working group will examine the land administration process from the land survey organizations, up through jurisdictional levels. This will be done with partner organizations across industry, development agencies and others where necessary. The group will also pursue work to provide a common vocabulary for the locational aspects of land administration databases, and it will also provide a forum for connecting suitable technology for data linkage and quality assessment.

References:

ISO 19152:2012. https://www.iso.org/standard/51206.html
Peter VAN OOSTEROM, Christiaan LEMMEN and Harry UITERMARK, 2013. Land Administration Standardization with focus on Evidence from the Field and Processing of Field Observations, FIG Article of the Month - March 2013

Peter van Oosterom and Christiaan Lemmen, 2015. The Land Administration Domain Model (LADM): Motivation, standardization, application and further development, Land Use Policy
http://www.gdmc.nl/publications/2015/LADM_motivation_standardisation_application.pdf

B.8 National Spatial Data Infrastructure (NSDI) and Land Administration

Increasingly, geospatial information within a country is becoming an integral part of the national data infrastructure that promotes data sharing and consumption. Similarly, to other infrastructures, it is a structure needed for the operation of a society as well as underpinning the services and facilities necessary for an economy to function effectively. In the case of geospatial information, the term National Spatial Data Infrastructure (NSDI) has been adopted. The NSDI connects people to geospatial information services to make better-informed decisions.

Geospatial information can be an integrative solution to assist North-South, South-South and triangular regional and international cooperation. An example to this process is having a global geodetic reference frame. A geodetic reference frame allows precise observations and 'positioning' of anything on Earth, connected globally, and used many times by different countries and users for countless social, economic and environmental purposes. These include forecasting changes in sea level rise, earthquake fault movement and liquefaction, risk of river flooding and intelligent transport. Another example is having global standards for geospatial information so that in times of crisis, countries can share their information, knowledge and experiences. These standards allow interoperable and seamless use of information, to address and solve cross-border problems such as air pollution, earthquakes, typhoons, flooding, and other natural disasters. The global sharing will allow countries to spend less time on being reactive, and focus more on visionary sustainable development policy-making and implementation using evidence-based geospatial information for decision-making. A good example of a regional SDI is the European Union's INSPIRE (Infrastructure for Spatial Information in Europe) initiative. This European Spatial Data Infrastructure will enable the sharing of environmental geospatial information among public sector organizations, facilitate public access to spatial information across Europe and assist in policy-making across boundaries.

The World Bank Group (WBG) has embraced geospatial information and SDIs as key facilitators for clients to guide government or strategic investments and to meet the WBG's objectives of eradicating extreme poverty and increasing shared prosperity.

The WBG conducted a data gaps analysis of countries' needs through the Development Data Directors and identified geospatial information as one of the fundamental data infrastructures to be strengthened to support the development process. This conclusion was further confirmed through the role of geospatial information in achieving and monitoring the Sustainable Development Goals (SDGs). For example, in Goal 13 'Take urgent action to combat climate change and its impacts' the availability of geospatial information in areas of meteorology, topography, coastal marine, socio-economic information of the local population and disaster emergency facilities can assist in modeling, forecasting and production of evacuation routes, flood inundation scenarios, flood hazard and risk maps.

The land information infrastructure created to support the land administration system should not be seen as a separate information infrastructure, but Information produced and distributed by Cadastre and Land Registry organizations is an integral part of NSDI. This is very apparent within the EU INSPIRE initiative where the following INSPIRE geospatial themes are provided by the land information infrastructure:

INSPIRE, Annex I Themes:

- Coordinate reference systems
- Geographical grid systems
- Geographical names
- Administrative units
- Addresses
- Cadastral parcels

INSPIRE, Annex II Themes:

- Elevation,
- Ortho-imagery

INSPIRE, Annex III Themes:

- Buildings
- Soil
- Land use

The property-related data contained within the land information infrastructure, when combined the geospatial information contained within the wider NSDI, has great potential to provide many benefits across all sections of the community by adding value through the combining of data sets and making these widely available.

B.9 Capacity Development

- Review and baseline capacity within land administration institutions.
- Formulate and implement a capacity development strategy for land administration across the public land sector.
- Work with academic institutions to revise their curricula to embrace FFP Land Administration to produce a new generation of land professionals to support the public and private sectors.
- Encourage the establishment of land and property professional bodies.

Implementing a FFP land administration system at a countrywide scale is demanding in terms of both financial and human resources, and will take years, perhaps decades. The need for human resources and skills must be assessed up front with regard to developing the various aspects of the land administration system and also with regard to the capacity for running and maintaining the system. Therefore, a strategy for capacity development is critical: “Don´t start what you can´t sustain”.

The current implementation of land administration solutions in developing countries is severely restricted through the lack of capacity at all levels within the public sector and a normally, under-developed private sector. Within the context of FPP land administration key skill gaps in the public sector include, for example:

- Formulation and management of national level land administration policies and programs;
- Design and implementation of spatial frameworks;
- Modifications to the legal & regulatory framework to accommodate the flexibility required for FFP;
- Institutional reform required to create effective land institutions to implement FFP Land Administration;
- Building and sustaining Public Private Partnerships;
- Developing ICT strategy, investment and infrastructure management;
- Understanding and selection of appropriate participatory approaches and technology to support the capture of land rights;
- Creating and engaging with a network of trusted intermediaries.

In the short term, part of this capacity development can be achieved through training courses and twinning with land administration agencies in developed countries, for example. However, in the longer-term, a capacity development initiative is required to create a new generation of Land Professionals who have a wider understanding of the holistic and sustainable administration and management of land.

Capacity development must take place at the societal, institutional and individual levels, and provide advice for capacity development activities in support of implementing a FFP approach in the land sector. Capacity development has three stages: 1) capacity assessment, 2) development of a capacity strategy and 3) implementation of the capacity development strategy.

Capacity assessment provides a baseline of current capabilities across the land sector stakeholders, e.g. public sector land institutions, private sector, professional associations and NGOs. The baseline is then compared with the capacity requirements stated in the country specific FFP land administration strategy and gaps identified that have to be filled to support FFP land administration. This information is then used to create the capacity development strategy.

The capacity development strategy identifies a long-term capacity development goal. However, the implementation of the strategy has to be incremental with intermediate goals and strategic objectives that will contribute to achieving the long-term goal. This is part of an overall change management program.

A key change that has to take place is in academia. Land institutions need to challenge their local academic institutions to change their curricula and embrace FFP land administration principles in order to create a new generation of land administrators and managers.

Successful implementation of national FFP land administration programs also requires the support of a vibrant private sector working in partnership with the land institutions. Governments should encourage growth in the private sector through issuing contracts under Public Private Partnerships and establishing regulation of the private sector, through land and property professional bodies, to ensure standards and ethical and quality compliance.

References

Enemark, S., McLaren, R. and Lemmen C., 2016. “Fit For Purpose Land Administration: Guiding Principles for Country Implementation.” UN-HABITAT, GLTN, June 2016.

B.10 Factors Influencing the Design of the FFP Spatial Framework

The FFP spatial framework for a country is not a homogeneous framework with the same approach to capturing and recording land rights being adopted across all regions of a country. Instead the spatial framework will be a patchwork of different approaches depending on local circumstances. At its most basic level there could be one approach for urban and peri-urban areas, and another approach for all rural areas. However, this simplistic divide between urban and rural will never meet the variety of local requirements, as there are a wide range of factors influencing the choice of approaches and associated technologies. These legal, social and geographical factors influencing the design of the spatial framework are discussed below to help guide the decision support. It is recommended that a digital National Atlas with a number of themes, e.g. tenure types and land use patterns, be created to guide the design of the country specific spatial framework.

Range of Tenure Types

The objective of the FFP approach is to ensure security of tenure for all. Therefore, types of rights that are legally recognized within a country need to be increased to ensure comprehensive coverage of the country. This process of including legitimate tenure types in the formal system through the revision of legislation is called national 'recognition'. The end result of this recognition process is a set of categories of legitimate rights officially agreed to within the country, which are legitimate under current legislation or proposed revised legislation. This will ensure a truly national land administration solution.

It is recommended that a tenure theme for the National Atlas be developed to provide an overview of the spatial distribution of legally recognized and legitimate tenure types across a country, e.g. areas of customary tenure, areas of informal tenure, areas of private ownership, state land, etc. This will help to identify where land rights documentation needs to be undertaken and enable administration and coordination between state and customary authorities through co-management. Figure **27** is an example of such a National Atlas of tenure from Namibia. More details are explained in the legend below.

Resettlement Registry is an administration of farms acquired by the government for the purpose of resettling citizens that qualify. .

AALS farms are farms acquired by a Namibian citizen with financial support of the Agribank under the Affirmative Action Loan Scheme (AALS)
FLTS areas are peri-urban informal settlements targeted by the government of Namibia using the new Flexible Land Tenure System (FLTS).

Surveyed Land in Communal Areas contains around 250.000 communal land parcels.

MAWF Farms are farms that are being operated under control of the Ministry of Water and Forests (MAWF).

Conservancies are farms operated under the Conservancies Scheme, with special extra attention to the purpose of nature conservation.

Restricted areas relate to diamond mining areas and thus closed to the general public.

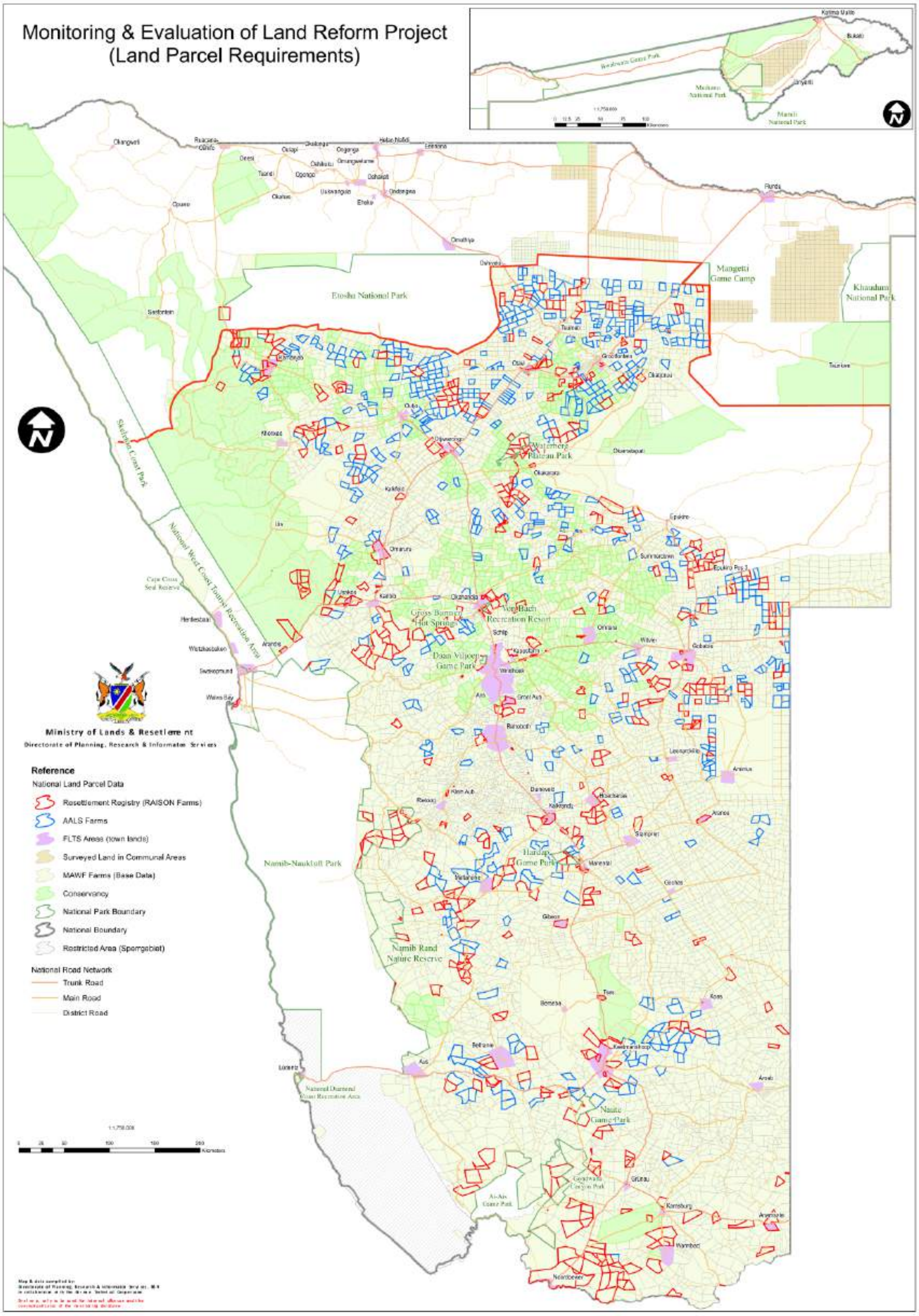


Figure 27: Example of a National Tenure Atlas

[Source: Ministry of Lands and Resettlement, Namibia]

The type of tenure has a significant impact on the approach and technology to be adopted in that region of the country. For example, in an area of forest such as the Congo Basin with indigenous people then an approach used by Mapping For Rights would be appropriate. In other areas where there is complex customary tenure then solutions that use the STDM data model, such as Open Tenure and STDM System, could be adopted. In areas where there are concentrations of smallholder farmers then an approach used by Landmapp could be highly compatible.

Land Use & Visible Boundaries
Topography, soil types, climate, availability of water for irrigation, population density and types of produce grown, for example, influence the patterns of human habitation in rural areas. This leads to a whole variety of land use patterns being established across a country. Some land use patterns involve the use of natural features to delineate boundaries between land parcels. In these areas, the parcel boundaries are normally visible on imagery and these are the ideal areas to apply the FFP approach. A good example of this land use pattern is in Rwanda – see the case study. Some vegetation delineating boundaries will be seasonal. Therefore, imagery should be created during the appropriate seasons.

Where possible, these areas of the country with visible boundaries should be identified, say from freely available satellite imagery, and a national atlas of areas compatible with the FFP visible boundary approach recorded. These areas should be classified by the estimated percentage of parcels that have visible boundaries on imagery. Experience in the field will determine what percentage of parcels with visible boundaries, say 60%, are required to make this approach feasible before considering other approaches. Create a National Atlas with a theme of regions where the percentage of parcels having visible boundaries is high (say >50%). This will allow orthophotomaps to be used in these areas, which is the preferred approach within the FFP spatial framework

Urban Density and Land & Property Values
As urban density of buildings and plots increases then use of visible boundaries on imagery becomes more problematic. Also in areas of high real estate values the parcel boundary accuracy may not meet the requirements for high-value properties. Therefore, more conventional forms of surveying will have to be adopted for these urban areas or the use of high accuracy drones could be used for isolated areas of dense settlements. Create a National Atlas theme of high density and / or high value urban developments where more conventional forms of surveying will have to be adopted.

Informal Settlements
Over 2 billion people live in informal settlements / slums across the world. Each country has different ways of engaging with these 'communities' and potentially providing security of tenure. The type of technology selected to support this process needs to be customized for the countries' approaches to informal settlements. However, the STDM system has been successful at supporting this process. Create a National Atlas theme of informal settlements / slums where specialist, participatory recordation approaches will have to be adopted.

State Land
One of the weakest aspects of land administration globally is the poor recording and registration of state land. This causes uncontrolled encroachment and loss of state land. Wherever possible, countries should delineate state land as a theme on the National Atlas to safeguard these state assets.

Areas of Perception of Insecurity of Tenure
Areas of known conflicts over land issues need to be identified, especially where infractions are taking place. This will help to prioritize the FFP land administration program through quick adjudication in those identified areas or no go areas. These conflict areas may require higher accuracy boundaries and different technology approaches due to the level of conflict over land.

Initiatives such as PRindex are being trialled to provide a greater insight into citizens' / communities' perception of insecurity of tenure. These surveys are valuable to identify priority areas for the FFP land administration program.

Create a National Atlas theme of areas where there is perception of insecurity of tenure. This will help to prioritize areas for adjudication or create exclusion zones.

Other Issues Influencing the Spatial Framework
There are another set of local characteristics that will influence the design of the spatial framework and the choice of associated solutions and technology. This includes:

- Topography;
- Accessibility through road networks;
- CORS availability and coverage;
- Internet / mobile phone coverage and level of penetration;
- Climate - areas and seasons of cloud free cover;
- Availability of land surveyors / lawyers, for example Uganda has about 30 licensed land surveyors.

Comprehensive, quality information on the local land characteristics highlighted above will improve the accuracy and value of the national spatial framework design and ensure that the most appropriate solutions and technology are applied in each region of a country.

References

Enemark, S., McLaren, R. and Lemmen C., 2016. "Fit For Purpose Land Administration: Guiding Principles for Country Implementation." UN-HABITAT, GLTN, June 2016.

B.11 Legal & Regulatory Framework Considerations

To allow a country specific strategy for FFP land administration to be implemented, changes will have to be made to the Legal & Regulatory Framework to accommodate full recognition of all tenure types in a country and to allow new approaches and technologies in the capture and recording of land rights to be adopted.

National Recognition of Tenure Types and Revision of Legislation to support Legitimate Rights

Tenure rights are the means by which people are able to use and enjoy land, fisheries, forests and other natural resources. Societies have developed rules of tenure that regulate these rights, such as to which resources, and on how the rights are allocated, to whom and under what conditions.

Some types of rights are defined in formal law, with examples being public tenure rights (which are held by the state) and private tenure rights (which are held by private individuals and others). However, many legitimate rights have no legal status under a country's law. For example, customary tenure rights, where the collective and occasionally individual rights are created by custom, are usually not recognized in formal law, but legal recognition is becoming more common. Informal tenure rights are often created spontaneously in informal settlements and are not recognized by formal law. However, the informal rights can be used as the basis for the creation of legally recognized rights where the law allows.

The objective of the FFP approach is to ensure security of tenure for all. Therefore, types of rights that are legally recognized within a country need to be increased to ensure comprehensive coverage of the country. This process of including legitimate tenure types in the formal system through the revision of legislation is called national 'recognition'. For example, where communities with customary tenure are recognized as the legal owners of the land and other natural resources on behalf of their members, the spatial areas owned collectively by such a community can be identified as a spatial unit(s). The identification of the spatial units under the ownership of the communities can help them to protect their rights against encroachment or by others. Also new forms of evidence on who holds the rights need to be recognized where the focus is on the necessary proofs of individuals, families or groups, rather than complete evidence.

Countries need to establish a consultative and participatory process for identifying which rights are legitimate. The VGGTs (paragraph 4.4) provide guidance on this process:

> *Based on an examination of tenure rights in line with national law, states should provide legal recognition for legitimate tenure rights not currently protected by law. Policies and laws that ensure tenure rights should be non-discriminatory and gender sensitive. Consistent with the principles of consultation and participation of these guidelines, states should define through widely publicized rules the categories of rights that are considered legitimate. All forms of tenure should provide all persons with a degree of tenure security which guarantees legal protection against forced evictions that are inconsistent with states' existing obligations under national and international law, and against harassment and other threats.*

The end result of this recognition process is a set of categories of legitimate rights officially agreed to within the country, which are legitimate under current legislation or proposed revised legislation. This will ensure that the FFP approach can record and register all rights across a country and create a truly national land administration solution.

Once the recognition process has been successfully completed through a consultative and participatory approach, the government agreed categories of legitimate rights will need to be protected by law. This will require changes to be made to the corresponding laws and regulations, and possibly the constitution, of the country.

Revision of Legislation to Support New FFP Data Capture Approaches

The innovative and flexible techniques for recording and registering land rights being introduced by the FFP approach will best be feasible if they are supported by an equally sympathetic legal and regulatory framework. Most developing countries have legacy land laws from the colonial era. These are highly restrictive, biased towards formal land rights and types of evidence, and conventional field surveying and land registry recording methods and involve legal rather than administrative processes. This limits the opportunity to introduce radical improvements necessary to provide secure land rights for all.

The introduction of new FFP approaches for capture and recording of the boundaries of spatial units and new forms of evidence rather than complete proof about persons may well require that modifications be made to the corresponding laws and regulations. For example, in some countries the regulations mandate the use of specific surveying equipment, data quality specifications and complete evidence on persons such as citizenship, marriage, death and divorce certificates. These unnecessary constraints will have to be removed to accommodate flexibility under the FFP approach.

The types of land tenure within a country will also have an impact on the choice of technology. Only solutions that support the STDM will be able to be used for recording customary / social tenures.