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Deliverable 7.4
Application of Governance and Capacity Assessment Models

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Abstract:
This is a consolidated report on the initial proposal to apply governance and capacity assessment models in the case countries as part of WP7 'Govern and Grow: Sustainable governance and capacity buildings models'

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Executive Summary

Its4land is a European Commission Horizon 2020 project funded under its Industrial Leadership program, under an ICT call (H2020-ICT-2015) with the topic of 'International partnership building in low and middle-income countries'. Its4land combines an innovation process with emerging geospatial technologies, including smart sketchmaps (Smart SkeMa), unmanned aerial vehicles (UAVs), automated feature extraction (AFE), and geocloud services (GS), to deliver land recording services that are end-user responsive, market-driven, and fit-for-purpose. The transdisciplinary work develops supportive models for governance, capacity development, and business capitalization.

This Deliverable 7.4 is directly linked to 'Work Package 7 (WP7) – 'Govern and Grow: Sustainable governance and capacity building' of the its4land project. WP7 deals specifically with the development of a governance and capacity development model to support the implementation and evaluation of innovative technologies and their use to meet stakeholders' needs so that the innovation process can have sustainable effects.

This report presents the application of 'Initial Governance and Capacity Development Model' (IGCDM) in the selected country cases in the process of the development 'Governance and Capacity Development Model'. The application of the IGCDM allows an understanding of the issues that the adoption of the its4land tools face and the formulation of the implementation strategies according to the contextual framework. The resulted understanding from Deliverable 7.4 will permit the scalability of the Model. This refinement will take place in Deliverable 7.5.

Deliverable 7.4 is divided into four sections. Section 1 introduces the scope of the deliverable and summarizes the previous works that have been done in this work package. Section 2 presents the methodological choices in the case studies and presents the analytical tools developed for the analysis of the governance and capacity development dimensions to implement the its4land tools. Section 3 presents the results from country cases for governance and capacity development dimensions and highlights the most significant challenges for the implementation of the tools. Section 4 reflects on the main conclusions from the cases and shares the roadmap for the next deliverable.

Keywords: fit-for-purpose approach, Fit-4-Purpose governance assessment framework, Fit-4-Purpose capacity assessment framework, its4land scorecard.

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List of acronyms

AFE	Automated Feature Extraction
ASAL	Arid and semi-arid lands
EU	European Union
FCAF	Fit-for-purpose capacity assessment framework
FGAF	Fit-for-purpose governance assessment framework
FFP	Fit-for-purpose
FFPLA	Fit-for-purpose for Land Administration
GS	Geocloud Services
GIS	Geoinformation System
GAT	Governance Assessment Tool
GNSS	Global Navigation Satellite System
H2020	Horizon 2020
ICT	Information and Communications Technology
IGCDM	Initial Governance and Capacity Development Model
IT	Information Technologies
LAIS	Land Administration Information System
LAS	Land Administration System
LIMS	Land Information Management System
LRT	Land Recording Techniques
NLC	National Land Commission
NSDI	National Spatial Data Infrastructure
OECD	Organization for Economic Co-operation and Development
P&S	Publish and share platform
R&D	Research and development
RLMUA	Rwandan Land Management and Use Authority
SmartSkeMa	Smart sketchmaps
UAVs	Unmanned Aerial Vehicles
WP	Work Package

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1 Introduction

Its4land is a European Commission Horizon 2020 project funded under its Industrial Leadership program, specifically the 'Leadership in enabling and industrial technologies – Information and Communication Technologies ICT (H2020-EU.2.1.1.)', under the call H2020-ICT-2015 – and the specific topic – 'International partnership building in low and middle-income countries' ICT-39-2015.

Its4land aims to deliver an innovative suite of land tenure recording tools that respond to Sub-Saharan Africa's immense challenge to rapidly and cheaply map millions of unrecognized land rights in the region. ICT innovation is intended to play here a key role. Many existing ICT-based approaches to land tenure recording in the region have not been successful: disputes abound, investment is impeded, and the poorest in the community loses out. Its4land seeks to reinforce strategic collaboration between the European Union (EU) and East Africa via scalable and transferrable ICT solutions. Established local, national, and international partnerships seek to drive the project results beyond R&D into the commercial realm. Its4land combines an innovation process with emerging geospatial technologies, including smart sketchmaps (SmartSkeMa), unmanned aerial vehicles (UAVs), automated feature extraction (AFE), and geocloud services (GS), to deliver land recording services that are end-user responsive, market-driven, and fit-for-purpose. In this context, fit-for-purpose seeks to be an answer to the deficiencies that conventional land recording methods find in African countries (Enemark, et al., 2014).

The transdisciplinary work in its4land also develops supportive models for governance, capacity development, and business capitalization. Set in the East African development hotbeds of Rwanda, Kenya, and Ethiopia, its4land is divided into three major phases, hosting nine work packages that enable contextualization, design, and eventual land sector transformation. In line with Living Labs thinking, localized pilots and demonstrations are embedded in the design process. The experienced consortium is multi-sectoral, multi-national, and multidisciplinary. It includes Small and Medium Enterprises and researchers from 3 European Union countries (Belgium, Germany, The Netherlands) and 3 East African countries (Rwanda, Kenya, and Ethiopia): the necessary complementary skills and expertise are delivered. Responses to the range of barriers are prepared: strong networks across East Africa are key in mitigation. The tailored project management plan ensures clear milestones and deliverables and supports result dissemination and exploitation: specific work packages and roles focus on the latter.

This document is directly linked to 'Work Package 7 (WP7) – 'Sustainable governance and capacity building' of the its4land project. In Deliverable 7.1 we presented definitions for governance and capacity development. We defined governance as a process of interactively steering the land tenure society to sustain the use of the its4land tools. Besides, capacity development was defined as the development of knowledge, skills, and attitudes in individuals and networks of people that are relevant for the sustained use of the its4land tools. In Deliverable 7.2 we presented a selection of six governance and capacity development models as a

result of extensive literature review of contemporary publications on governance and capacity development models. Derived from this selection, in Deliverable 7.3 we presented the initial version of the governance and capacity development models (IGCDM) to support the adoption of the its4land tools from a governance and capacity development perspective. The IGCDM has been the first step to construct the analytical tools to assess the governance and capacity development frameworks in the selected case countries and later to develop the governance and capacity development models for the sustainable implementation of its4land technologies in the East African land administration systems.

The Deliverable 7.4 presents the refined analytical tools to assess the governance and capacity development frameworks in Rwanda and Kenya[1]. By adopting the Fit-for-purpose (FFP) approach, two novel assessment frameworks, Fit-for-Purpose Governance Assessment Framework (FGAF) and Fit-for-Purpose Capacity Assessment Framework (FCAF), have been developed to assess the compatibility of the contextual framework with the implementation of the its4land toolbox.

To present the application of these assessment frameworks, the report is divided into four sections, including the introduction section. The second section presents the methodological choices and the analytical tools of the research. This section is divided into five subsections. The first subsection summarizes the conceptualization of the seven elements of the Fit-for-Purpose Land Administration (FFPLA) in our analysis. The second and third subsections present two novel governance and capacity assessment frameworks, FGAF and FCAF, developed based on the IGCDM. The fourth introduces the scorecard for the evaluation of the land administration system's compatibility, and the last section elaborates the research design and gives the overview of the fieldwork conducted in the case countries.

The third section is about the application of the analytical tools in the case countries of Rwanda and Kenya. The findings on the governance and capacity dimensions are presented by highlighting the most salient governance and capacity challenges for the implementation of the its4land toolbox. The toolbox contains four tools to implement in the land administration system. These are unmanned aerial vehicles (UAV), smart sketch maps (SmartSkeMa), automated feature extraction software (AFE), and publish and share platform (P&S). The assessment matrices of each its4land tool for Rwanda and Kenya are provided in the Appendix.

The Conclusion section highlights the main outputs of this deliverable and reflects on the coming deliverable. Deliverable 7.5 will share the policy recommendations for Rwanda and Kenya on how to implement the its4land toolbox sustainably. The models will then be used to study potential governance scenarios, concerning policy, in the case countries. The applicability of the models in East Africa and Sub-Saharan Africa will also be explored more generally.

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[1] By taking into account the limitations with the field data, Ethiopia is removed as a case study from WP7.

2 Methodology

The Methodology section introduces the analytical tools developed for the operationalization of the IGCDM and elaborates the research design. The first subsection recaps the elements of Fit-for-purpose land administration and explains their operationalization for the analysis. The second subsection introduces the Fit-for-purpose Governance Assessment Framework (FGAF), the analytical tool developed to assess the governance-related challenges. The third subsection explains the Fit-for-purpose Capacity Assessment Framework (FCAF), the analytical tool developed to assess the capacity development-related challenges. The fourth subsection explains the its4land scorecard to assess the compatibility of the land administration system for the sustainable implementation of the its4land tools. The fifth subsection gives the research design and the overview of the fieldwork in Rwanda and Kenya.

2.1 Fit-for-purpose land administration and its seven elements

Around the 2000s, given the failures of several projects to deliver appropriate and adequate land tenure recording data in developing countries, the FFP approach was introduced (Enemark et al., 2014). This approach provides an answer to the inability of conventional methods to fully accommodate existing conditions (e.g. the diversity of formal, informal, social or customary land tenure types), and to be sensitive to the limited resources in developing countries. According to the FFP literature, there are seven elements that a land administration system should consider (Enemark et al., 2014):

1. **Flexible** in the spatial data capture process to provide information about the different uses and occupations of the land.
2. **Inclusive** in the extension to cover all types of tenure and all types of land.
3. **Participatory** in the manner to capture and use data, ensuring community support.
4. **Affordable** operation for the government and society to use it.
5. **Reliable** regarding the information, it should be authoritative and updated.
6. **Attainable** to create a system within a short timeframe and with the available resources.
7. **Upgradable** regarding improvement over time to respond to social and legal needs as well as economic opportunities.

These seven elements are selected as evaluative qualities in modeling the governance and capacity assessment frameworks of the land administration systems and to provide insights about the contextual framework conditions to implement the its4land tools.

Long term vision and system maintenance are considered to be included in FFP elements "Affordable (operation)" and "Upgradeable". These elements are especially important for the sustainability of a land administration system, because the operational costs of running such a system– unlike capital expenditures for the implementation – will not be co-financed by donors anymore, but are to be

shouldered exclusively by the government owning the system. The financial aspects of maintaining a land administration system are further elaborated in the its4land deliverable Deliverable 8.1, "Design of a Business Model and Set-up of Business Plan"

2.2 Fit-for-purpose Governance Assessment Framework (FGAF)

The FGAF provides an assessment of the current governance context to identify the degree of supportiveness of the governance factors when implementing and using the its4land tools under the FFP approach. Governance assessment frameworks are important because they allow the identification of implementation bottlenecks and they can propose pragmatic answers to the identified challenges (Casiano Flores et al., 2017). Among the most well-known frameworks are the OECD multi-level governance framework (Akhmouch and Correia, 2016), the Management Transition Framework (Pahl-Wostl et al., 2010), the Land Assessment Framework (World Bank, 2015) and the Governance Assessment Tool (GAT) (Bressers et al., 2016).

The FGAF is the result of aligning the seven FFP land administration elements with five governance dimensions of the Governance Assessment Tool (GAT) (Bressers et al., 2016). The GAT sees governance as 'a context for decision-making and implementation'. The governance context here assumes the existence of various actors, levels, goals, instruments and different means that can be applied (Bressers et al., 2016).

The five governance dimensions of GAT are: multilevel, multi-actor, multifaceted nature of the problems, multi-instrumental, and multi-resources-based. These dimensions are derived from questions that respond to the characteristics that feature modern governance systems: Where?, Who?, What?, How and With what? (Kuks, 2004). These five dimensions of governance are conceptualized in this report as follows:

1. **Levels & Scales:** governance assumes a multi-level character of the land administration system when implementing it with the its4land toolbox.
2. **Actors & Networks:** governance assumes the involvement of multiple actors in the land administration system when implementing it with the its4land toolbox.
3. **Problem perspective & Goal ambitions:** governance assumes a multi-faceted character of the problems and goals in the land administration system when implementing it with the its4land toolbox.
4. **Strategies & Instruments:** governance assumes the nature of multiple strategies and instruments that affect the land administration system when implementing it with the its4land toolbox.
5. **Resources:** governance assumes the existence of multiple resources to support the land administration system when implementing it with the its4land toolbox.

By aligning the governance dimensions of GAT with the FFP elements, the assessment matrix of Table 1 was created. Through specific questions and sub-questions in each cell, the matrix assesses the governance context for the

implementation of the its4land tools under the FFP perspective[2]. However, the manner to assess these qualities is based on the GAT approach. This means that the seven evaluative qualities will be considered as semi-normative. Therefore, the normative content will be derived and dependent on the importance and urgency of the implementation process that is being assessed (Casiano Flores et al., 2018).

Table 1. FFP Governance Assessment Framework

Governance Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	*How flexible is the land administration system concerning the multi-level governance setting to implement the tool?*	*How inclusive is the land administration system concerning the multi-level governance setting to implement the tool?*	*How participatory is the land administration system concerning the multi-level governance setting to implement the tool?*	*How affordable is the land administration system concerning the multi-level governance setting to implement and maintain the tool?*	*How reliable is the land administration system concerning the multi-level governance setting to implement the tool?*	*How attainable is to implement the tool in the land administration system concerning the multi-level governance setting?*	*How upgradable is the tool concerning the multi-level governance setting in the land administration system?*
Actors & Networks	*How flexible is the land administration system to implement the tool concerning the actors and networks?*	*How inclusive is the land administration system to implement the tool concerning the actors and networks?*	*How participatory is the land administration system to implement the tool concerning the actors and networks?*	*How affordable is the land administration system to implement and maintain the tool concerning the actors and networks in governance?*	*How reliable is the land administration system to implement the tool concerning the actors and networks in governance?*	*How attainable is to implement the tool in the land administration system concerning the actors and networks in governance?*	*How upgradable is the tool in the land administration system concerning the actors and networks?*
Problem perspective & Goal ambition	*How flexible is the land administration system concerning the problems that may emerge during the implementation of the tool?*	*How inclusive is the land administration system concerning the problems that may emerge during the implementation of the tool?*	*How participatory is the land administration system concerning the problems that may emerge during the implementation of the tool?*	*How affordable is the land administration system concerning the problems that may emerge during the implementation and maintenance of the tool?*	*How reliable is the land administration system concerning the problems that may emerge during the implementation of the tool?*	*How attainable is to implement the tool in the land administration system concerning the problems that may emerge?*	*How upgradable is the tool in the land administration system concerning the problems that may emerge during the implementation and/or changing goal ambitions?*
Strategies & Approaches	*How flexible is the land administration system concerning the available strategies and approaches to implement the tool?*	*How inclusive is the land administration system concerning the available strategies and approaches to implement the tool?*	*How participatory is the land administration system concerning the available strategies and approaches to implement the tool?*	*How affordable is the land administration system concerning the available strategies and approaches to implement and maintain the tool?*	*How reliable is the land administration system concerning the available strategies and approaches to implement the tool?*	*How attainable is to implement the tool in the land administration system concerning the available strategies and approaches?*	*How upgradable is the tool in the land administration system concerning the available strategies and approaches?*
Resources	*How flexible are the available financial resources in the land administration system to implement the tool?*	*How inclusive is the land administration system concerning the available financial resources to implement the tool?*	*How participatory is the land administration system concerning the available financial resources to implement the tool?*	*How affordable is the land administration system concerning the available financial resources to implement and maintain the tool?*	*How reliable is the land administration system concerning the available financial resources to implement the tool?*	*How attainable is to implement the tool in the land administration system concerning the available financial resources?*	*How upgradable is the tool in the land administration system concerning the available financial resources?*

2.3　Fit-for-purpose Capacity Assessment Framework (FCAF)

The FCAF is based on the "Framework for understanding policy competences and capabilities" (Wu et al., 2015). Among the six models introduced in Deliverable 7.2, this model is the most explicit in capacity development aspects. It considers that public managers and policy analysts have a determinant role in the activities they carry out (Wu et al., 2018). This model considers that there are three levels of resources and capabilities (individual, organizational and systemic) that

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[2] The sub-questions are provided in the Appendix.

correspond to the three types of skills and competencies (analytical, operational and political).

This multi-layered and holistic approach to capacity assessment has been adjusted to the key competence areas for the implementation of the its4land toolbox (regulations, political systems, operational unit, social norms, land recording techniques, and software[3]) that are identified by the stakeholders through an online survey. This survey was presented in Deliverable 7.1. In FCAF, we have aligned these competence areas with the seven elements of FFPLA to create the assessment matrix for the land administration system's capacity to implement the its4land toolbox.

Table 2 presents how these competencies and capabilities are operationalized in the FCAF. Through specific questions in each cell, the matrix assesses the capacity development of the land administration system for the implementation of the its4land tools under the FFP perspective.

Table 2. FFP Capacity Assessment Framework

Capacity Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	*How flexible is the LAS concerning the regulations?*	*How inclusive is the LAS concerning the regulations?*	*How participatory is the LAS concerning the regulations?*	*How affordable is the LAS concerning the regulations?*	*How reliable is the LAS concerning the regulations?*	*How attainable is the LAS concerning the regulations?*	*How upgradable is the LAS concerning the regulations?*
Political System	*How flexible is the LAS concerning the political system?*	*How inclusive is the LAS concerning the political system?*	*How participatory is the LAS concerning the political system?*	*How affordable is the LAS concerning the political system?*	*How reliable is the LAS concerning the political system?*	*How attainable is the LAS concerning the political system?*	*How upgradable is the LAS concerning the political system?*
Operational Unit	*How flexible is the LAS concerning the operational unit?*	*How inclusive is the LAS concerning the operational unit?*	*How participatory is the LAS concerning the operational unit?*	*How affordable is the LAS concerning the operational unit?*	*How reliable is the LAS concerning the operational unit?*	*How attainable is the LAS concerning the operational unit?*	*How upgradable is the LAS concerning the operational unit?*
Social Norms	*How flexible is the LAS concerning the social norms?*	*How inclusive is the LAS concerning the social norms?*	*How participatory is the LAS concerning the social norms?*	*How affordable is the LAS concerning the social norms?*	*How reliable is the LAS concerning the social norms?*	*How attainable is the LAS concerning the social norms?*	*How upgradable is the LAS concerning the social norms?*
Land Recording Techniques (LRT)	*How flexible is the LAS concerning the LRT?*	*How inclusive is the LAS concerning the LRT?*	*How participatory is the LAS concerning the LRT?*	*How affordable is the LAS concerning the LRT?*	*How reliable is the LAS concerning the LRT?*	*How attainable is the LAS concerning the LRT?*	*How upgradable is the LAS concerning the LRT?*
Software	*How flexible is the LAS concerning the software?*	*How inclusive is the LAS concerning the software?*	*How participatory is the LAS concerning the software?*	*How affordable is the LAS concerning the software?*	*How reliable is the LAS concerning the software?*	*How attainable is the LAS concerning the software?*	*How upgradable is the LAS concerning the software?*

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[3] In the Deliverable 7.3, 'usage of the tool' was identified as a separate competence, but in the refined version of the model, this competence has been removed and treated as an integral part of the other competences.

2.4 Its4land Scorecard

The final analytical tool developed as part of the Deliverable 7.4 is the its4land scorecard. The its4land scorecard shows the land administration system's compatibility according to the FGAF and FCAF through a ranking of low, moderate and high compatibility. **Low compatibility** (red colored cells) infers there are significant challenges concerning the FFP element and the land administration system needs structural changes for the sustainable implementation of the tool. **Moderate compatibility** (yellow colored cells) infers that there are both hindering and supportive factors concerning the FFP element. In moderate compatibility, even though some elements are already in place in the land administration system, some processual changes are considered necessary for sustainable implementation. **High compatibility** (green colored cells) infers that the context is largely supportive concerning the FFP element and there is no need for changes in the land administration system or only a need for simple adjustments for the implementation of the tool.

2.5 Research Design

The case study in Rwanda and Kenya adopted an exploratory research design and a qualitative approach in its analysis based on the semi-structured and in-depth interviews. A guiding topic list questionnaire was used to focus on the governance and capacity challenges associated with the its4land tools. The questionnaire was a combination of both the alignment of the FFP elements with the governance and capacity development dimensions and a compilation from an extensive literature review on governance and capacity development (Alemie et al., 2015; Bevir, 2009; Deininger et al., 2010; Edelenbos and Van Meerkerk, 2016; Goodwin and Painter, 1996; Hirst, 2000; Jessop, 1997; Klijn, 2008; Kooiman, 1993; Osborne, 2010; Rhodes, 1996; Saito, 2008; Van Kersbergen and Van Waarden, 2004). The interview questions were open enough to allow clarifications or new insights.

The fieldwork in Rwanda took place in June-July 2018 with a total of 38 interviews conducted in Musanze and Kigali. The participants were selected through purposive sampling in close collaboration with the country specialist project partners. In Rwanda, among the 38 stakeholders related to land tenure, 23 refer to the government, 9 to the private sector, 9 to non-governmental organizations and 5 to the academic sector. An overview of the conducted interviews is presented in Table 3.

Table 3. Overview of the conducted interviews in Rwanda (June-July 2018)

Participants	Name of the organization or institution	Number of interviews
National level	Rwanda Land Management and Use Authority Water for growth	11
Province	Northern province	3
District	Musanze	1
Sector	Busogo, Muhoza, Kinigi, Cyuve	5
Cell	Gisesero, Cyabararika and Rwambogo	3

Private companies	Esri Rwanda Ltd., GISTech Consultants, CHARIS UAS and Geospatial solutions Ltd	9
NGO	Rwanda Initiative for Sustainable Development	1
University	University of Rwanda INES-Ruhengeri, Institute of Applied Science	5

The fieldwork in Kenya took place in September-October 2018 in Kaijado and Nairobi with a total of 16 individual interviews and three one-day workshops with local stakeholders. Table 4 presents an overview of the conducted interviews.

Table 4. Overview of the conducted interviews in Kenya (September –October 2018)

Participants	Name of the organization or institution	Number of interviews
National Level	The Ministry of Land, The National Land Commission	3
County Level	Field agencies of the Ministry of Land in Kaijado, County government in Kaijado, Land Registrar's Office in Kaijado	8
Private companies	GEOID Services	3
NGO	The Global Land Tool Network	1
University	Technical University of Kenya	1

The workshops titled 'innovative geospatial technologies to enhance land tenure security in Kenya' were organized for three days for three different target groups with a total of 51 participants. The first workshop took place at Enchula Resort, Kajiado for local government officers on 28 September 2018. The second and third workshop took place at the Regional Centre for Mapping Resources for Development (RCMRD) in Nairobi on 01 and 02 October 2018. The first day with participants from the private sector and NGOs and the second day with participants from the National Government. The details of these workshops can be found in a separate its4land report published in March 2019 (Stöcker et al., 2019a),

In order to carry out the assessment, the findings from the fieldwork were synthesized with the results of the pilot tests and prior work conducted in the other its4land work packages and complemented with the secondary sources inter alia official records, national strategy documents, international reports (e.g. the World Bank's Land Government Assessment country reports), its4land publications (Ho et al., 2017b, 2018,; Stöcker et al., 2018, 2019b,), news reports and other academic and media outlets. The conclusions are drawn inductively followed by an analytical discussion among the authors, based on a previous agreement on the key elements to highlight in each cell of the matrices. The quality assurance of the conclusions is provided by the technology and country specialists of the its4land consortium.

3 Application to the Case Countries

This section presents the summary of our assessment on the compatibility of the its4land toolbox with the land administration systems in the case countries. The assessment is based on the analysis of each tool separately according to the analytical tools mentioned above. It is important to note that, unlike UAVs and SmartSkeMa, AFE and P&S are at an early prototype stage at the moment and the entire technology first needs to be developed in its4land before being a real-world scalable mapping solution. Therefore, our assessment concerning the technical dimensions of AFE and P&S is not based on the pilot studies in the case countries but rather on the technical reports published about the current prototypes.

Due to space limitations, in this section, we have highlighted the aspects, on which the analysis suggests the most significant challenges (i.e. red marked cells) for the implementation of the its4land tools. However, the assessment matrices, which are provided as an appendix to this report, contain a detailed analysis of each dimension and the source of information. The scorecards at the end of each subsection present the overview of the challenges concerning the implementation of the its4land toolbox.

3.1 Rwanda

This subsection presents the key findings on the governance and capacity compatibility of the Rwandan land administration system to implement the its4land tools. The analysis is based on the challenges identified for UAV, AFE, and P&S. We excluded SmartSkeMa from the analysis as the needs assessment study in Rwanda suggested (Ho et al., 2015).

3.1.1 Governance Framework

Levels & Scales: The land administration system in Rwanda assigns clear responsibilities to each level of government and administration (i.e. central, district, sector and cell) in land recording, registration, and development of land management policies. Here the role of the institutions at the national government is to coordinate and manage the system, and except some special cases (e.g. big investments), cadastral data is updated and new data are collected at the district level. At the district level, the District Land Bureaus (DLBs) are charged with monitoring, land surveying, valuation, and land use. Our analysis suggests that both the national government and the district land bureaus can operate UAVs and AFEs with their resources, but the sector and cell levels of administration mostly lack the resources to maintain the operations. By analyzing the role and characteristics of each level, we recommend the governance of the UAV and AFE operations to be carried out at the district level and the central government to support the implementation by monitoring and facilitating the operations. For the governance of the P&S, we expect the Rwandan Land Management and Use Authority (RLMUA) to be the responsible land administration entity. RLMUA is in charge of organizing,

coordinating and monitoring collection, use, and dissemination of geo-information in the country under the National Spatial Data Infrastructure Framework and already manages the Rwanda Geoportal and Land Administration Information System (LAIS).

The multi-level governance of the land administration system is mostly compatible with the implementation of the its4land tools. However, our analysis identified two significant challenges regarding the multi-level governance structure that can affect the implementation. The first challenge is the lack of flexibility on the governance framework of the UAV. Any private and commercial operator should go through the licensing procedures of the Rwandan Civil Aviation Authority (RCAA), which is the agency in charge of the UAV flight authorizations. The findings suggest that this procedure is time-consuming, expensive and lengthy, and can create bottlenecks for the growth of the UAV market in Rwanda. Therefore, we recommend that either the rules on the licensing procedures are to be eased and/or the efficiency of the authorization procedures to be improved. The second challenge is the attainability of the P&S regarding the existing multi-level governance structure. Our fieldwork suggests that the governance of P&S at the national level is attainable since the IT unit at the RLMUA is already in charge of the current information-sharing operations and they have the capacities on human resources and server equipment. However, lower levels of government will need appropriate ICT infrastructure and Internet connectivity to access geocloud services. Furthermore, the reorganization of organizational processes and migration of data may delay the adoption efforts.

Actors & Networks: The most significant challenges in this governance dimension are identified for the UAVs. The strict aviation regulations on UAV operations, weak market conditions for private operators, and the lacking technical and financial capacities are likely to impede the integration of non-governmental and private actors in the governance of the UAV operations. Only a few commercial operators have the licenses and the necessary managerial and financial capacities to conduct UAV operations. Monopolistic or oligopolistic market conditions may emerge in the short run unless the government enables supportive mechanisms for private and non-governmental actors' participation. As an interviewee stated during our fieldwork; '*what you always see when companies have a monopoly, little inspiration for innovation*'. Therefore, for the sustainability of the UAV operations in the land administration sector, it is important for the government to encourage private and community initiatives. By taking into account its pivotal position in the land administration sector, we recommend that the national government needs to facilitate the integration of non-governmental actors in the UAV operations at least until certain capacities are developed in the governance network. In this transition stage, the national government can lease UAVs to private operators and provide training. Co-production can be a viable alternative to outsourcing the operation. Government funds and support programs by the international donor organizations can also help to incentivize local initiatives for the cost-effective production of UAV equipment and enhance the innovation potential of local stakeholders, thus support the sustainability of the land administration system.

Problem Perspectives & Goal ambitions: Each its4land tool has certain governance challenges in this dimension that can affect adoption and implementation. The

current governance system does not identify any participatory mechanisms for the local stakeholders to engage in the UAV-based land surveying. Especially, in case there are conflicts with the land rights or delineation of the boundaries as in urban and peri-urban areas, the adoption of the UAVs in the land administration sector can be affected. The inclusion of local stakeholders on the identification, delineation, and adjudication of the parcel boundaries on the orthophoto imagery can support the adoption of the UAVs in the urban planning and development processes. Furthermore, various parameters are interconnected and influence the final data quality of UAV-derived orthomosaics. That also affects the reliability of the boundary delineation with AFE. The AFE tool requires more development and adaptation before being reliably included in real-world cadastral mapping procedures. Concerning the P&S, the attainability and upgradability aspects suggest the most significant challenges for the adoption of this tool. There is hardly any local support for open source technologies, and the GIS skills, particularly at local government levels, tend to be low. Path dependency around existing land information management systems may also be too great to overcome for the implementation of open-source technologies. Therefore, it is important to control the interoperability and user-friendliness of the P&S with existing data-sharing platforms. The implementation and substantiation of the approved 'Data Revolution Policy' and its application to the technology is also recommended for the upgradability of the system.

Strategies & Approaches: The strategies and approaches for the adoption and usage of the its4land tools are to a large extent compatible with the Rwandan land administration system and indicate an easier adaptation process. Two challenges, however, stand out concerning this governance dimension. First, participatory mechanisms can improve the effectiveness of the UAV missions and build trust among the community actors especially in case of dispute or lower trust to the government institutions. The workflow of the UAV-based surveying does not infer strategies to include stakeholders in the land administration sector. The existing surveying mechanisms allow the participatory approach to the fixed boundary system, but there are limitations to it due to the illiteracy rate. Therefore, local stakeholders can only participate during demarcation and adjudication. We recommend clear participatory mechanisms for the stakeholders, by taking into account existing limitations, to be identified before using UAVs in the land administration sector. The second significant challenge concerns the attainability of the P&S. The P&S foresees interoperability with existing land information systems. Yet, the extent of the system is dependent on the ICT infrastructure and the capacity of local and private surveyors. Especially, the geocloud function is contingent on the Internet coverage of the area. Therefore, we cannot assess at the moment to what extent the features of P&S can be fully operational in Rwanda. Furthermore, the P&S is designed foremost to be compatible with open-source-based systems, but our fieldwork suggests that the migration of data and adaptation to open-source software solutions can create an administrative burden for the operators. Therefore, we expect the attainability of the platform to be low until these limitations are addressed.

Resources: The overview of the revenue sources and the governance of the financial resources in the Rwandan land administration system suggests that the land administration units that are estimated to take the lead in the adoption of the tools

can cover the financial cost of using the tools. However, Rwanda's experience on land administration projects suggests that many innovations are project-based where long-term visions and maintenance cost for the government are not adequately considered. Therefore, the financial plans should include the costs for maintenance and upgradability from the beginning of the adoption process. To support the adoption of the its4land toolbox at the national level as well as in lower tiers of government (e.g. sectoral and cell levels), we recommend structural reforms to directly support financial capacities at these levels. The Rwanda Revenue Authority (RRA) could support this task; however, this requires legal amendments to modify the RRA's mandate (Ngoga et al., 2017). RRA collects the land lease taxes/fees and the transaction fees, which are then transferred to the Ministry of Local Government, who employs the District Land Professionals. They are to work amongst other things on the cadastre for RLMUA, which is in a different Ministry, to whom they do not report. Strengthening the financial decentralization at the district level, especially in areas with higher tax/fees bases, is also recommended to collect taxes directly to their own-source revenues. This could facilitate the adoption of the its4land toolbox at the district level. For the usage of the P&S, we cannot estimate at the moment the exact cost of operations but the cost of adopting the solution locally, e.g. the inclusion of qualitative data, might be unaffordable for certain local and private operators. This can limit the inclusiveness of the system in areas with weak communication network connections and financial capacities. For the financial sustainability of the its4land toolbox, establishing a fair and affordable land administration fee structure is important. The financial support from government or donor may be required until the system is fully established, accepted and fully support itself (Ngoga, 2018).

Table 5 Governance Scorecard- Rwanda

	Flexible		Inclusive		Participatory		Affordable		Reliable[4]		Attainable		Upgradable	
Levels & Scales	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Actors & Networks	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Problem Perspectives & Goal ambitions	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Strategies & Approaches	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Resources	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S

* Red- Low compatibility, Yellow- Moderate compatibility, Green- High compatibility

3.1.2 **Capacity Framework**

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[4] We did not have a pilot study to test the reliability of the strategies for the P&S system. Therefore, we left the corresponding cell on 'Strategies and approaches' blank.

Regulations: The legislative framework of the UAVs presents the most salient capacity-related challenges for the adoption of the its4land toolbox in Rwanda. The capacity dimensions related to flexibility, inclusiveness, and affordability are most affected by the present regulations. In Rwanda, UAVs' licensing and rules of operation complies with the 2016 Ministerial regulation N°01/MOS/Trans/016 and 2018 law on governing civil aviation. The legislative framework requires high quality and compliance standards from private/commercial operators and the same rules apply for both commercial and private flights. The rules oblige commercial operators to have an internationally recognized pilot license that can be only obtained outside of the country – which is what two members of the its4land consortium from Rwanda did. The Rwandan officials justify high-quality standards in UAV operators to ensure public safety, but only a few operators have the financial and technical means to go through the rigid licensing procedure. As of the time of writing this report, there is only one commercial UAV operator in Rwanda, which has completed the licensing procedure. Furthermore, our pilot study in Rwanda showed that this procedure is lengthy, time-consuming and expensive. Although the cost of the UAV registration is about $150 (110.000 RWF), Reg. 26 of N°01/MOS/Trans/016 obliges any person conducting UAV operations to subscribe to liability insurance which is no less than US$ 1 million. Additionally, Rwanda does not produce UAVs and thus the administrative cost of UAV import and certification process can add up to 20% of the initial purchase price. Overall, these regulations restrict the affordability and flexibility of UAV operations. The flight restrictions as part of the civil aviation safety rules are also restrictive for the use of UAVs in some urban and peri-urban areas.

Political System: Rwanda has a strong presidential system and hierarchical political traditions, which situates the central government at the core of the land administration sector. The current government has a progressive agenda toward sustainable development goals and supports fiscal and administrative decentralization in land administration toward district level without relinquishing its political control. The political system is also inclusive in recognizing different tenure rights as long as there is evidence to support the ownership claim. The political system has high legitimacy and the stakeholders trust the capacity of the national government to implement the its4land tools. Therefore, we do not expect any significant challenge with the political capacity of the land administration system.

Operational Unit: The operational capacity of the land administration units shows overall moderate compatibility for the adoption of the its4land toolbox. Here the most significant challenges are related to the attainability of the UAVs and P&S. For the UAV, the private surveyors and the government operators require additional training and resources to operate UAVs in land surveying. Furthermore, at the moment a limited number of pilots have UAV flight licenses. For P&S, we expect the national government, possibly with the assistance of donor organizations to provide the necessary financial and human resources as well as the training to the operational units for the adoption of the P&S. The reorganization of organizational processes and the migration of data to the P&S could, however, delay the adoption process. The operational units at lower levels of government would need appropriate ICT infrastructure and Internet connectivity to access cloud services that suggest the scaling of the platform could be limited until sufficient bandwidth

is available. All in all, the current operational capacities in the land administration units restrain the adoption of the UAV and P&S in a short period. Therefore, we recommend a targeted capacity development program to accompany the scaling-up efforts of the its4land toolbox.

Social Norms: Our analysis does not point out particular social norms, which can challenge the compatibility of the its4land tools with the land administration system. Quite the contrary, the Rwandese government embraces a strategy called 'Home Grown Solutions' to combine traditional practices with sustainable development goals. One of them is the *Imihigo*, where government officials and/or individuals commit to deliver certain act within a specific period. It is possible to use these social practices to facilitate the adoption process.

Land Recording Techniques: The analysis suggests that the compatibility of the its4land tools vary from a moderate to high compatibility according to each principle. It is possible to improve the capacities concerning the land recording techniques for a better transition, but we do not expect a significant challenge to affect the implementation process.

Software: The technical framework of the P&S operates smoothly without any adaptions if the image processing tools, i.e. UAV and AFE, use open source solutions. The fieldwork suggests that it is common to use pirated or cracked GIS licenses at the sector level, sometimes without even being aware of the licenses are expired or illegal. These practices affect the reliability of the current practices with commercial software, as they cannot be upgraded and they risk a security breach. In terms of attainability, there are limitations in implementing open-source solutions in the land administration sector due to established practices with using commercial software in UAVs and GIS systems such as ArcGIS is common instead of QGIS. Therefore, institutional change to open source systems would require first of all a solid business case, then time, technical and policy support as well as further training with open-source software.

Table 6 Capacity Scorecard-Rwanda

	Flexible		Inclusive		Participatory		Affordable		Reliable		Attainable		Upgradable	
Regulations	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Political System	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Operational Unit	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Social Norms	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Land Recording Techniques	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Software	UAV		UAV		UAV		UAV		UAV		UAV		UAV	
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S

* Red- Low compatibility, Yellow- Moderate compatibility, Green- High compatibility

3.2 Kenya

This subsection presents the key findings on the governance and capacity compatibility of the Kenyan land administration sector to adopt and use all four its4land tools (UAV, SSM, AFE, P&S).

3.2.1 Governance Framework

Levels & Scales: The multi-level governance of land administration in Kenya is fragmented over different types of tenures and land organizations. In terms of tenure types, the Constitution of Kenya recognizes four forms of land tenure, namely: public land, community land, private land, and wakf land. However, six land tenure types are discernible in Kenya: Public Tenure, Private Tenure, Customary Tenure, Wakf Tenure and two special types of tenure; Informal Tenure and Ten-Mile Coastal Strip Tenure. The latter two fall under the broad category of 'social' tenure. In arid and semi-arid land (ASAL) areas, two models of regulated tenure dominate over customary land – trust lands (pastoralists) and group ranches. While customary tenure dominates most of the rural lands in Kenya, private and public tenure systems control land in the urban areas. Rapid urbanization though means that increasingly, customary tenure needs to be reconsidered concerning the urban and peri-urban areas. Communal group ranches were mainly imposed in the ASAL areas of Kenya (e.g. in the project's case study site, Kajiado). Informal tenure is dominant in urban areas as well as in several large-scale farms in the country in the form of squatters. The Ten Mile Coastal Strip is found only in the Coast Province of the country and has the longest history of all the tenure systems in Kenya.

There are three key actors in the country, the Ministry of Land and Physical Planning, county government, and the National Land Commission (NLC) in the governance of the land administration system in Kenya. Overall, each organization represents entry points to different tenure types: NLC – public tenure; the ministry – private tenure; and county governments – private and customary tenure.

Both the county government and the national government collect and store the data about the respective tenure types. However, the public land tenure, that corresponds to 10% of the land in Kenya, is delineated in two broad areas, in which both the national government and the county government have responsibilities in recording the land data. Although the responsibilities in the land administration have been decentralized to county-level after the 2012 reforms, in reality, there are numerous cases of overlapping boundaries (mostly concerning public lands), and double registrations in Kenya's land information management, clearly indicating that cross-checks are not sufficient. UAV and AFE can improve the reliability of the data in the land administration system but for that, first the digitization of the land records is required and without the digitization of the land records the successful adoption of AFE is not attainable at the national scale. However, depending on the availability of digitized records and infrastructure, it might be possible to pilot AFE in certain land administrations.

Concerning the governance of the land records, most of the land data are stored in paper format and the data are often not up-to-date. There are currently 52 different land registries in Kenya, which the Ministry of Lands has been trying to integrate through the large-scale digitization of land records. The digital land registry was launched in 2018 and has become operational for Nairobi, and for the rest of the country, it is expected to be operational by 2019. Collection and management of data remain a challenge and it is an area that the P&S can contribute in terms of access. However, longstanding distrust between land institutions, limited data-sharing between county government and national government, and differences in terms of digitization of records are salient challenges for the implementation of the P&S. Besides, NLC works on another unified system to merge separate databases but this system is still under development. This suggests that not only digitization of paper-based records but also a more streamlined governance structure in land information management system (LIMS) is needed for the reliability of the land administration system. After the 2016 amendments of the Land Act, the Cabinet Secretary was appointed to be in charge of the coordination of the National Spatial Data Infrastructure (NSDI) and to coordinate the development and implementation of the NSDI in collaboration with the National Land Commission (NLC). However, the establishment of the Kenyan NSDI has been going on since 2001. To date, no tangible progress is visible.

Affordability is also affected by the challenges of the multi-level governance structure. It is estimated that to re-launch the NSDI, Kenya will need about 7 billion Kenyan shillings (about US$ 70 million or 0.1% of GDP in 2016) over a five-year period (Mwange et al., 2017). County governments have different financial capacities depending on their natural resources, commercial activities and revenue collection efficiencies. The fieldwork suggests that there are big discrepancies in terms of ICT infrastructure and equipment at the county level. The spatial definition of counties in new planning regulations has often meant that county governments are hugely under-resourced to take on urban management activities, including land administration. Therefore, we don't think it is affordable for the county governments to adopt the P&S with their resources. Yet the need to establish a GIS system at the county level may provide an opportunity to implement the platform through the means of the national budget. It might be possible to introduce the system at the county level through the field offices of the ministry as their financial resources are allocated from the central budget. However, we do not know at the moment how affordable this option would be to the Ministry of Land.

The affordability of the AFE application is also closely linked with the affordability of acquiring high-resolution ortho-images of the targeted areas. As most cadastral maps are paper-based and there is no country-wide coverage of high-resolution imagery makes us conclude, that the affordability of the AFE is limited only to the authorities at the national level or to certain county governments with adequate resources and digital infrastructure to obtain high-resolution image data.

Actors & Networks: Women's access to land and indigenous land rights remain significant governance challenges concerning the inclusiveness of the land administration system. The land administration system does not recognize the rights of informal communities, and given the dominance of informal tenure (due to a weak land market), there is the propensity for many to be excluded if AFE is

implemented in cadastral surveying. Despite the recent institutional reforms, a legacy of patronage and clientelism indicates difficulties in achieving true transparency and inclusion in the land sector.

The current land administration system has also low compatibility with the attainability of the AFE and P&S by the governance actors. There are several challenges for private surveyors to adopt AFE, such as completion of the regulative framework for UAV, the completion of the digitization of paper-based land records, and implementation of a LIMS, which allows editing and uploading of cadastral maps through an online platform. Although there are on-going initiatives in each one of them, we do not expect the procedures to be completed within a short period. We also expect the attainability of an open-source P&S to be low at the moment, given the presence of multiple projects at the national level for GIS-based information systems, and the lack of resources (financial and HR) available at the county level.

Problem Perspectives & Goal ambitions: This dimension constitutes the most significant governance challenges for the adoption of the its4land tools. For the UAV, legal uncertainties and lack of hardware and software capacities at the devolved national governments can limit the attainability of the UAV's adoption in the land administration system. These shortcomings could be addressed in a short period, but for that, there is a need for political leadership. The its4land fieldwork suggests that to gain the endorsement of political actors there is a need for success stories. Furthermore, bureaucratic resistance toward digitization can impair the effective uptake and upgradability of the UAV technologies in the land administration sector. As one interviewee stated: "*The legal requirement to submitting work on the operational level is still manual or still old school. This blocks innovation. Why would I as a surveyor bother to do digital things if the government doesn't need it? It makes it easier for me to use the old tools. Another one is the legality. So, for example, the title deed is legally only valid because of the green card, until a digital title is legal. We will not go that way. A survey plan, if I want to reassemble a boundary, I need to use a legal survey plan, which is paper-based at the moment. It will not make sense to have a digital map in the governmental office when it is legally not recognized. Those are some of the challenges.*"

Since a sketch map is based on a person's spatial knowledge, errors are likely to arise, which is common to the qualitative information that SmartSkeMa gathers. Errors can also occur due to the lack of writing and drawing skills of the participants. This reduces the reliability of SmartSkeMa data for cadastral mapping. The information may, however, be conceived reliable from a community perspective. Keeping the LAS up-to-date with SmartSkeMa is also a time-consuming process, which requires a continuous updating of the LAS with fieldwork. Once the domain model is developed, however, we expect that it will become faster to gather the required information. However, in that regard, SSM has clear disadvantages in comparison to UAVs. Bureaucratic resistance towards digitization and significant time needed to apply SmartSkeMa for larger areas are some other challenges against upscaling the SmartSkeMa in the land administration system.

AFE can be applied with visible boundaries, but there are limitations (non-visible boundaries or clear landscapes that form the general boundaries…etc.) for the

reliability of the output. There are also limitations with the quality of the aerial images. The Kenyan government at the moment uses simple tracings from the aerial photos to produce temporary and interim maps called the Preliminary Index Diagrams (PIDs) for the first registration. These PIDs are still being used for registration of land adjudicated areas to the present day. We expect difficulties in automatically extracting the boundaries from these images.

There are three main potential risk factors, which may affect the flexibility of the P&S. First of all, Internet coverage and the ICT infrastructure is an impeding factor. Secondly, the limitations with the digitization of maps suggest that the P&S would have limited functionality until the data is converted into a digital format. Thirdly, the conflicting data on land tenure stored both in county government and in the field offices of the Ministry suggest that there is a need for a quality assurance system for the information to be published in the platform. The P&S can publish multiple types of tenure information, but the platform cannot verify the validity of that information as long as the role of governance actors is not clear.

The reliability of the P&S largely depends on the level of collaboration among the actors in LAS, and who the custodian organization for the implementation will be. Especially, there is a need for clear governance and policy guidelines for the integration of different portals into the system. Another impeding factor for the reliability is most geospatial datasets are not regularly updated and the processing and storage of land data are manual.

Last but not the least, there are several political (e.g. corruption scandals, and low cooperation among state actors), technological (e.g. lack of HR capacities with open-source solutions, prevalence of paper-based maps), infrastructural (i.e. limited material capacities at county level, network infrastructure at counties) and financial (e.g. limited resources at county level) problems that hinder the attainability of the P&S within a short period of time.

Strategies & Approaches: Existing uncertainties on the rules of UAV operations restrain available strategies with UAVs in land administration. Although AFE can be used on any airborne imagery or satellite data, the workflow of the AFE is developed primarily for the UAV-based surveys in cadastral mapping, thus the limitations concerning with UAV operations can affect available strategies for AFE as well.

Resources: There are differences among the relevant authorities (i.e. county governments, field offices of the national government) in terms of financial capacities. Furthermore, some county governments have better access to financial resources from private and international donors. Despite these differences, it is still possible to adopt its4land tools with available resources. Nonetheless, the fieldwork suggests that there are limited resources for innovation activities, and we did not encounter a special budget, which could be used for them.

Table 7 Governance Scorecard- Kenya

	Flexible		Inclusive		Participatory		Affordable		Reliable[5]		Attainable		Upgradable	
Levels & Scales	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Actors & Networks	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Problem Perspectives & Goal ambitions	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Strategies & Approaches	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Resources	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S

* Red- Low compatibility, Yellow- Moderate compatibility, Green- High compatibility

3.2.2 Capacity Development Framework

Regulations: The legislative framework in Kenya shows rather limited compatibility for the adoption of the its4land tools. Our analysis suggests especially severe challenges for the reliability of the land administration system when implementing the UAV with it. The initial law on UAVs has been withdrawn in 2017 following the political pressures on the government due to the former legislative process had been conducted without participatory mechanisms, and the current legislative process is still in progress. In this interim period, informal channels are common for the licensing of UAVs. Although this brings a certain level of flexibility, it does not suggest a reliable regulative framework. Furthermore, the present land regulations are not prescriptive on the capture and use of aerial imagery. There is also a lack of enforcement of laws and regulations and conflicting state records due to the duplication of mandates for the management of the public lands. All these factors suggest low compatibility for the adoption of the UAV and AFE. Not all challenges about reliability are related to the low regulative capacity of the land administration institutions. In the case of the SmartSkeMa, the challenges are also related to the authoritativeness of the sketch maps. Although the current regulative framework recognizes the customary tenure, sketch maps are not necessarily accepted as authoritative data by administrative authorities, since the data is provided by the community and might differ from official sources. At this stage, it is not clear how well data collected using SmartSkeMa will be aligned with official records and how the data collection processes can be aligned with official processes. Nonetheless, SmartSkeMa can serve as an entry point to issue a legal, authoritative document, which would add value to the land administration system. The sketch maps can be used by surveyors to produce an actual legal record of the land, and possibly they can issue a certificate to achieve tenure security. Relative accuracy is acceptable for this purpose; at a later stage, the absolute accuracy can be established.

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[5] We did not have a pilot study to test the reliability of the strategies for the P&S system. Therefore, we left the corresponding cell on 'Strategies and approaches' blank.

Another challenging dimension about regulations is the upgradability of the land administration system when implementing the UAV with it. On that regard, UAV and P&S suggest the most severe limitations. The legislative process of UAVs and surveying techniques are still in progress. Therefore, we do not know to what extent the final act will allow improvements in surveying techniques with UAVs. However, the current draft law on UAV contains restrictive provisions on the upgradability of UAVs. For example, the rules on import and export of unmanned aviation systems (UAS) states: "A person shall not import a UAS or a component thereof without a permit issued by the Authority." Similarly, the rules on manufacture, assembly and testing of UAVs state: "Any person intending to manufacture, assemble, test or sell a UAS or a component thereof shall apply for authorization from the Authority." Both of these clauses suggest rather a restrictive framework for the upgradability of the system. Concerning the P&S, there are no clear regulations about the implementation of cloud systems in the LIMS. The National ICT Masterplan 2017 is the only policy document mentioning cloud computing. Accordingly, the Government Data Center (GDC) infrastructure, which is being developed to ensure security for government data and applications will also provide an environment for cloud computing for the services delivered by the county governments. The absence of regulative criteria on cloud computing standards may hinder adoption of the geocloud solutions at a nation-wide level.

Political System: The political capacity of the land administration system in Kenya is somewhat limited particularly concerning the boundary disputes and securing the rights of specific groups and actors despite the participatory clauses in the Land Law. The provisions of the Land Law on guiding principles state that public officials should encourage communities to settle land disputes through recognized local community initiatives. However, actual practices suggest that the system has been less participatory than the regulative framework is indicating. For example, existing processes around the subdivision of group ranches have been by no means participatory or transparent, and have led to members within a group, particularly women, being dispossessed of their land. The Ministry has also recently been in the news about lacking in participatory processes. Devolution has increased a sense of ethnic-based land ownership but the land is currently already in the hands of external owners, therefore, local ethnic communities are not easily included. For example, in Kajiado, which is a Maasai majority county, much land is owned by non-Maasai, leading to tensions between the communities. Furthermore, 'winner takes all' policies at county level lead ethnic majorities in power to excluding minorities from accessing the state resources. We assess that these limitations suggest low compatibility for the adoption of the AFE and P&S, particularly at the county level.

Making spatial data freely available can threaten the relative power, which governments and other entities (e.g. Survey of Kenya) maintain by keeping data private or available only at a high cost. This suggests that –despite Kenya having an open data policy - certain political elites might find it politically costly to adopt a free and open data-sharing platform as advocated by the its4land project. The political system has also challenges due to the lack of trust vested in the land administration institutions. A 2002 report of the Njonjo Land Commission suggests that citizens have low trust in the land dispute settlement mechanisms and institutions due to delays, incompetence, corruption, nepotism, and political interference. Furthermore, an overlap of roles and functions lead to conflict, confusion and

unnecessary bureaucracy especially when there is low participation of the local people in land dispute resolution mechanisms. The current situation has improved after the enactment of the National Land Policy and recognition of the alternative dispute mechanisms. Yet, cases of corruption concerning the land administration institutions suggest that the lack of trust is still an issue of concern. For instance, recent findings of corruption regarding NLC commissioners have threatened the legitimacy of the organization in the management of spatial data concerning the public lands.

Operational Unit: The analysis of the participatory dimension infers low compatibility between the land administration system and the operational capacities needed for the usage of the UAV and AFE. To begin with, the field offices of the ministry and county governments do not share their land data, which is an important problem in the land administration system. Moreover, collaboration with non-governmental actors takes place on an ad-hoc basis, and there are no well-established participatory mechanisms at the local level. Especially for the AFE, we expect a need for collaboration with non-governmental actors (e.g. universities or private sector organizations) for training purposes or to acquire high-quality UAV-ortho-images. One interviewee from the National Land Commission during the fieldwork suggested that there is a need for capacity building and additional resources to support participatory processes. He stated that; "*If I may tell you the truth and the bitter truth, there is no capacity building [at least from the commission's point of view] so that the field has completely been overlooked or has been neglected by one reason or another. Because for example, we need to train the group ranch officials on how to manage land. We need to talk to women, whose rights are been violated by men. Their disputes come to us. OK, we have issues of capacity building where you have to enlighten people on their rights about their land, land information. It is not there. So all this is a result of lack of resources. Even despite we like to propose, who is going to fund? There is a clear gap in the capacity; both for the staff as the capacity for people and other stakeholders too.*" There are certain limitations concerning the upgradability of the UAVs in the system as well. Findings suggest that the operational units lack the specialized knowledge and technical expertise to improve the operation of UAVs. There is a need for specialized training and capacity building programs for the sustainable deployment of UAV operations.

There are also certain capacity limitations at the operational units that might affect the adoption of the P&S. At the county level, many government organizations have outdated paper-based maps, which do not present the reality on the ground. Therefore, for the reliability of the system of the land administration system, there is a need for resurveying activities to provide up-to-date digital records, a process which can swiftly be undertaken if the regulatory framework for the usage of UAVs and AFE are in place. Furthermore, not all county governments have GIS installations to support such updating activities.

Social Norms: The analysis of social norms does not suggest major limitations for the adoption of the its4land tools. Nevertheless, following the devolution of the land administration system, the ethnic diversities at the county level have become a source of violence and exclusion toward ethnic minorities. There have been reports on the displacement of certain ethnic and social groups (e.g. pastoralist or farmers),

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in rural and community-owned areas. In the absence of mitigating political and judicial actions, these exclusionary practices toward non-ethnic communities may affect the sustainability of the its4land technologies related to the effectiveness of the UAVs and P&S.

Land Recording Techniques: The capacity conditions concerning LRT suggest a variety of challenges for the adoption of the its4land tools. Especially, the attainability of the tools stands out as the most challenging issue. To begin with, it is difficult to use UAVs and AFEs in most places with existing financial and HR capacities as tools in the land recording system. Even if the field offices of the Land Ministry and certain county governments might have the necessary financial and HR capacities to adopt the AFE, AFE's effectiveness in the land administration system relies on the availability of high-quality aerial images as well as ideal case access to digital cadastral maps. Both of these conditions are not common in Kenya. Similarly, for the effective adoption of the P&S, there is a need for the digitization of records. Also, there is a need for the adoption of the UAVs and preferably either or both of SSM and AFE in land recording processes to generate digital data for dissemination in P&S. By taking into account all these elements, we think that there are at the moment significant challenges for the adoption of the its4land toolbox in the land administration processes. The lack of technological capacities in land recording processes is also an impeding factor for the upgradability of the UAVs. It is possible, to improve the performance of the UAVs due to their modular design. However, at the moment it is difficult to automate the data collection with UAVs given the lack of technological skills and infrastructure in most of the local offices.

There are also challenges with the reliability of data created with AFE and SmartSkeMa. On the one hand, AFE allows expediting the cadastral mapping and this way keeps them up-to-date. However, the reliability of the AFE depends on the availability of visual boundaries and high-quality aerial images to be available. This is not the case in Kenya. On the other hand, the inclusion of SmartSkeMa in the data collection processes about parcel boundaries is considered as time-consuming, and it is possible that gathered qualitative data becomes quickly outdated and therefore unreliable. Furthermore, we expect some difficulties in adopting cloud computing into data maintenance processes, mainly because of the low availability of the Internet connection in many rural areas. Yet, one can make use of the cloud servers and still store data locally. Updates can be processed when there is an Internet connection available. The downside of this option is it might pose a challenge concerning data integrity since data cannot always be up-to-date. The choice of spatial representation has a severe impact on the outcome of map alignment between a sketch map and a metric map. Especially, in communal lands, there are several possible impeding factors (e.g. lack of writing skills of the participants; availability of the metric map...etc.), which may affect the reliability of the final data.

Software: The capacity conditions are mostly compatible with the local framework in Kenya though, about attainability, the analysis suggests compatibility issues with SmartSkeMa and P&S. Many county governments lack digital infrastructures and adequate HR capacities in terms of computer literacy. Therefore, for many county governments that are expected to adopt SmartSkeMa, it could be difficult to install and use the software with available capacities. Furthermore, open-source solutions

are not prevalent in Kenya, and this may exacerbate the skill gap in HR capacities. Similarly, there are limitations in implementing open-source solutions in the land administration system due to existing GIS systems, which operate on ArcGIS instead of QGIS (e.g. the GIS platform of the NCL). Therefore, institutional change to open source systems would require first of all a solid business case, then time, technical and policy support as well as further training with open-source software.

Table 8 Capacity Scorecard- Kenya

	Flexible		Inclusive		Participatory		Affordable		Reliable		Attainable		Upgradable	
Regulations	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Political System	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Operational Unit	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Social Norms	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Land Recording Techniques	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S
Software	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM	UAV	SSM
	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S	AFE	P&S

* Red- Low compatibility, Yellow- Moderate compatibility, Green- High compatibility

4 Conclusion

In Deliverable 7.4, we have further developed the initial models through analytical tools and analyzed the governance and capacity development framework conditions in the case countries of Rwanda and Kenya. The analysis of the governance and capacity dimensions has focused on the compatibility of the its4land tools with the land administration systems of these countries. Each its4land tool has been analyzed separately from governance and capacity assessment perspectives. The evaluation scorecards and assessment matrices display the challenges that may alter the tools adoption process. Although the report only highlighted the most challenging dimensions for the adoption, the attached assessment matrices provide further insight into the compatibility conditions for each tool according to the Fit-for-purpose principles.

In general, the analysis suggests different framework conditions for Rwanda and Kenya. In Rwanda, the governance and capacity framework conditions are more supportive for easier adoption of the its4land tools in the land administration process. Nonetheless, weak market conditions regarding the availability of the UAVs and strict regulations in their operations suggest certain concerns for the sustainability of the land administration system when implementing the its4land toolbox unless certain regulative and institutional adjustments take place.

Kenya, on the other hand, portrays a more complicated picture for the adoption. Existing institutional and political challenges in the land administration system raise concerns about the reliability and attainability of the its4land tools under current framework conditions. Despite that, unlike in Rwanda, there are supportive market conditions and capable non-governmental and private actors that can bolster the adoption processes into a more sustainable and scalable land administration system.

The next and final deliverable of the 'Govern and Grow' work package 7 will focus on the strategies and scenarios for the successful implementation of the its4land toolbox in Rwanda and Kenya. The findings of Deliverable 7.4 will provide the pathway to develop the strategies and policy recommendations for the adoption. The aim of the Deliverable 7.5 is to set up a model for the case countries by taking into account the challenges identified in this deliverable, to implement the tools at a national scale in a sustainable manner. The model will contain governance and capacity development strategies according to the framework conditions as well as policy recommendations for an innovative and robust land administration system when implementing the its4land toolbox. The recommendations will not only be limited to the case countries but also adopt a wider regional scope toward East and Sub-Saharan African countries.

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Appendix

Governance Assessment Matrix

	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	How flexible is the land administration system concerning the multi-level governance setting to implement the tool? (Are the responsibilities concerning the tool inside the government centralized or decentralized? To what extent the system allows flexibility among levels of government in the governance of the tool?)	How inclusive is the land administration system concerning the multi-level governance setting to implement the tool? (Are all tenures recorded in the state (central, regional, local) ledgers?)	How participatory is the land administration system concerning the multi-level governance setting to implement the tool? (Do the different - levels of government implement participatory practices in acquisition and recording of land data?)	How affordable is the land administration system concerning the multi-level governance setting to implement and maintain the tool? (Is it affordable for different levels of government to operate the system with its resources?)	How reliable is the land administration system concerning the multi-level governance setting to implement the tool? (Do stakeholders and citizen trust the data provided by different levels of government? Are the data provided by the government up-to-date?)	How attainable is to implement the tool in the land administration system concerning the multi-level governance setting? (Is it possible for the government to establish the system with its resources within a year?)	How upgradable is the tool concerning the multi-level governance setting in the land administration system? (Is there a special unit in government for innovation concerning the tool?)

Actors & Networks	How flexible is the land administration system to implement the tool concerning the actors and networks? (Is it possible that new actors are included in the operation of the system or shift of the roles from one actor to another when there are pragmatic reasons for this?)	How inclusive is the land administration system to implement the tool concerning the actors and networks? (Are some groups of actors excluded during data acquisition and recording concerning a certain type of land and tenures?)	How participatory is the land administration system to implement the tool concerning the actors and networks? (Are community and non-government actors partake in data acquisition and recording? If yes, what is their specific role?)	How affordable is the land administration system to implement and maintain the tool concerning the actors and networks in governance? (Is it affordable for the stakeholders to participate in the system? Is outsourcing to non-governmental actors or co-production a viable alternative?)	How reliable is the land administration system to implement the tool concerning the actors and networks in governance? (Do the stakeholders and users trust the actors in the governance network? Which actors are most trusted for the implementation of the tool?)	How attainable is to implement the tool in the land administration system concerning the actors and networks in governance? (Is it possible for the government to establish the system with the resources of stakeholders within a year?)	How upgradable is the tool in the land administration system concerning the actors and networks? (Does the governance network include external actors specialized in new technologies and business models to upgrade the system?)
Problem perspectives & Goal ambitions	How flexible is the land administration system concerning the problems that may emerge during the implementation of the tool? (Are there any potential external risks (e.g. environmental risks, political risks...etc) which may affect the operation of the tool? Are there alternative means to overcome the problem?)	How inclusive is the land administration system concerning the problems that may emerge during the implementation of the tool? (Is there any specific risk concerning a certain type of land/ tenure data?)	How participatory is the land administration system concerning the problems that may emerge during the implementation of the tool? (Are there participatory mechanisms for stakeholders to mitigate emergent problems?)	How affordable is the land administration system concerning the problems that may emerge during the implementation and maintenance of the tool? (If there is a problem during the implementation, is it possible to cover the cost with available financial resources?)	How reliable is the land administration system concerning the problems that may emerge during the implementation of the tool? (Is the system robust enough in providing the right and up-to-date information in case of emergent problems?)	How attainable is to implement the tool in the land administration system concerning the problems that may emerge? (Is it possible to solve the problem within an acceptable timeframe with available resources?)	How upgradable is the tool in the land administration system concerning the problems that may emerge during the implementation and/or changing goal ambitions? (Does the system allow improvements in its operation in case of emergent problems and/or changing goal ambitions?)

Strategies & Approaches	How flexible is the land administration system concerning the available strategies and approaches to implement the tool? (Does the system allow selecting or combining different strategies/ approaches in data acquisition and recording?)	How inclusive is the land administration system concerning the available strategies and approaches to implement the tool? (Do the selected strategies allow the inclusion of different types of land and tenures in data acquisition and recording?)	How participatory is the land administration system concerning the available strategies and approaches to implement the tool? (Do the selected strategies include non-governmental/community actors in data acquisition and recording?)	How affordable is the land administration system concerning the available strategies and approaches to implement and maintain the tool? (Is it possible to realize the selected strategies with available resources?)	How reliable is the land administration system concerning the available strategies and approaches to implement the tool? (Do the selected strategies/approaches provide authoritative and up-to-date information about land tenures?)	How attainable is to implement the tool in the land administration system concerning the available strategies and approaches? (Is it possible to implement the strategies within an acceptable timeframe with available resources?)	How upgradable is the tool in the land administration system concerning the available strategies and approaches? (Do the strategies allow improvements over time in response to social and legal needs and emerging economic opportunities?)
Resources	How flexible are the available financial resources in the land administration system to implement the tool? (Does the system allow the operational unit to use its financial resources flexibly? Are the resources earmarked or does the unit have the autonomy to decide where to allocate the resources?)	How inclusive is the land administration system concerning the available financial resources to implement the tool? (Do the available financial resources allow the data acquisition and recording of different land and tenures types?)	How participatory is the land administration system concerning the available financial resources to implement the tool? (Does the system allow using different resources to finance the operation?)	How affordable is the land administration system concerning the available financial resources to implement and maintain the tool? (Do the revenues from land registry system (i.e taxes, fees..etc) match the cost of operations in data acquisition and recording? Is the system financially sustainable?)	How reliable is the land administration system concerning the available financial resources to implement the tool? (Are the financial sources (e.g. gov., non-gov.) reliable in maintaining the costs of operations in data acquisition and recording?)	How attainable is to implement the tool in the land administration system concerning the available financial resources? (Does the system currently have the necessary financial resources to integrate the tool into the system?)	How upgradable is the tool in the land administration system concerning the available financial resources? (Is there a specific budget for innovation of the system?)

Capacity Assessment Matrix

	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	How flexible is the LAS concerning the regulations? (How strict are the regulations on the capacity of the operators?)	How inclusive is the LAS concerning the regulations? (Are there any regulative obstacles on recording particular land tenure types with the tool?)	How participatory is the LAS concerning the regulations? (Are there any regulative obstacles against certain stakeholders/groups to participating in the land administration system if the tool is implemented?)	How affordable is the LAS concerning the regulations? (Are there any administrative costs and/or user fees anticipated for the implementation of the tool?)	How reliable is the LAS concerning the regulations? (Is the regulative framework reliable and consistent for the implementation of the tool?)	How attainable is the LAS concerning the regulations? (Is there a need for further regulations to implement the tool?)	How upgradable is the LAS concerning the regulations? (Does the regulative framework allow improvements in the operational and technical standards of the tool without a need for further legislation?)
Political System	How flexible is the LAS concerning the political system? (Are there particular political constraints/risks, which can affect the implementation of the tool?)	How inclusive is the LAS concerning the political system? (Are there particular tenure types that are excluded by the land administration system if the tool is implemented?)	How participatory is the LAS concerning the political system?(Are there particular groups (e.g. minorities, pastoral groups…etc.) that are excluded by the political system, that can affect the implementation of the tool?)	How affordable is the LAS concerning the political system? (Is there any political cost for the stakeholders to implement the tool?)	How reliable is the LAS concerning the political system? (Do the stakeholders and the users trust the role of political actors in the implementation of the tool?)	How attainable is the LAS concerning the political system? (Is the political system capable to implement the tool at a national scale in the land administration system?)	How upgradable is the LAS concerning the political system? (Is the political system supportive (e.g strong political authority, alignment of policy priorities) to implement changes/improvements in the operation of the tool?)
Operational Unit	How flexible is the LAS concerning the operational unit? (Do the operational units have multiple strategies to operate with the tool?)	How inclusive is the LAS concerning the operational unit? (Do the operational units have the capacities to operate the tool to collect data on different land tenure types?)	How participatory is the LAS concerning the operational unit? (Do the operational units have the capacities to collaborate with the stakeholders in the operation of the tool?)	How affordable is the LAS concerning the operational unit? (Do the operational units have adequate resources to implement the tool in the land administration system?)	How reliable is the LAS concerning the operational unit? (Do the operational units have the capacities (e.g. technical knowledge, managerial protocols) to provide authoritative and up-to-date data with the tool?)	How attainable is the LAS concerning the operational unit? (Can the operational unit implement the tool without the need for additional resources and training?)	How upgradable is the LAS concerning the operational unit? (Do the operational units have the capacities (e.g. specialized training, technical expertise) to update/upgrade the tool?)

Social Norms	How flexible is the LAS concerning the social norms? (Do the social norms allow different strategies in the implementation of the tool?)	How inclusive is the LAS concerning the social norms? (Do the social norms comply with the inclusion of all existing land tenure types?)	How participatory is the LAS concerning the social norms? (Do the social norms encourage/discourage collaboration of non-governmental and community actors with government actors?)	How affordable is the LAS concerning the social norms? (Can the social capital facilitate the implementation of the system?)	How reliable is the LAS concerning the social norms? (Are there particular social norms, which can undermine the authoritativeness of the tool?)	How attainable is the LAS concerning the social norms? (Are there particular social norms, which can postpone the implementation of the tool?)	How upgradable is the LAS concerning the social norms? (Is the society open for innovation concerning the improvements with the tool?)
Land Recording Techniques (LRT)	How flexible is the LAS concerning the LRT? (Do the LRT allow the use of data in multiple purposes?)	How inclusive is the LAS concerning the LRT? (Do the available LRT allow processing all land tenure information?)	How participatory is the LAS concerning the LRT? (Do the LRT use input from non-governmental and community actors?)	How affordable is the LAS concerning the LRT? (Do the operators have the necessary resources to carry out available LRT?)	How reliable is the LAS concerning the LRT? (Do the available LRTs provide authoritative and up-to-date information?)	How attainable is the LAS concerning the LRT? (Is it possible to implement the LRT with available resources and personnel capacities?)	How upgradable is the LAS concerning the LRT? (Do the LRTs allow improvement in data recording in case there are social and legal needs or problems with data quality?)
Software	How flexible is the LAS concerning the software? (Is it possible to calibrate the software for the country-specific conditions? Are there alternative software programs (e.g. open-source) available to collect and record the spatial data?)	How inclusive is the LAS concerning the software? (Do the available software allow processing of all types of land tenure information?)	How participatory is the LAS concerning the software? (Do the software allow input and/or editing by different stakeholders?)	How affordable is the LAS concerning the software? (Is it affordable for the operator to purchase and use the software with available resources?)	How reliable is the LAS concerning the software? (Are software secure and robust enough to provide authoritative and up-to-date information?)	How attainable is the software? (Is it possible to install and use the software with available resources and personnel capacities?)	How upgradable is the LAS concerning the software? (Do the operational unit have the required skills and authorization to upgrade the software if needed? Are the software programs protected by intellectual property rights or are they open-source?)

GOVERNANCE- UAV RWANDA

Governance Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	• The Rwandan Civil Aviation Authority (RCAA) is the responsible institution that handles UAV flight authorizations. Any private and commercial operator should go through the licensing procedures of RCAA[i]. This procedure is time-consuming, expensive and lengthy. • Except for some special cases (e.g. big investments), the district level has full autonomy in data acquisition and recording. The provincial level does the post-check and updates the national ledger. ***Low compatibility***	• Over 90% of the individual lands in rural and urban areas are mapped, and 70-90% of individual lands in urban and rural areas are recorded[ii]. The collected data are digitalized and a hardcopy is saved in state ledgers. In that sense, the system is inclusive in covering different land and tenure types. • UAV flights can be used by different levels of administration in urban, rural and peri-urban areas. ***High compatibility***	• The governance of land management and mapping is steered by the national government. • There are some participatory mechanisms between different levels of administration (e.g. import of UAV equipment, flight permit, the permission of the local government,) in the governance of UAV missions. ***Moderate compatibility***	• At a small to medium scale, the cost of the UAV missions is cheaper in comparison to classical aerial imageries. At larger scales, satellite images could be another solution in case 30 cm resolution is sufficient. • There is a need for ongoing labor costs to cover expenses of the UAV pilot, observer, and surveyors but an only one-off investment for the equipment[iii]. • Both national and district level governments can operate UAVs with their resources, but the sector and cell level of government mostly lack the resources to maintain the operations. ***Moderate compatibility***	• UAVs can provide most up-to-date and reliable data in comparison to other available aerial imageries, because of their high geometric accuracy and high spatial resolution in different terrains and land uses. • The fieldwork suggests that the national government is expected to lead the adaptation of UAV data collection and provides training to private/commercial operators. This suggests that there is not a significant trust[iv] problem within the multi-level governance structure. ***High compatibility***	• It is attainable for the government to adopt UAV systems in a relatively short time because Rwanda has enacted the law on unmanned and civil aircraft systems in 2016 and Rwandan stakeholders, albeit limited in numbers, are already experienced with the authorization process of the UAV missions. • The national administration needs to provide training to local authorities and operators on how to use UAVs for mapping. • It is attainable for the government to cover the cost of UAV equipment and training. ***High compatibility***	• The SMART Rwanda Master Plan (p.9) states that all public institutions should abide by the Government Enterprise Architecture for the integration and interoperability of different government services and data resources. Accordingly, government ICT investments in new services will have to be validated by the Enterprise Architecture Board (EAB). This suggests that future initiatives to improve UAV technologies in the land administration system should cooperate with EAB. ***Moderate compatibility***

Actors & Networks	• Non-governmental actors can operate the UAVs, but the financial, administrative and technical/capacity requirements make it difficult to include new actors in the governance of the land administration system. • The aviation safety regulations and weak market conditions suggest there is a need of centralized governance structure, which may impede inclusion of new actors in the land administration system without new technologies (e.g. blockchain) and/or improved ICT infrastructure. These factors can limit the flexibility of the governance network. *Low compatibility*	• Evidence-based customary rights and land rights of vulnerable groups (e.g. Batwa community; women's land ownership) are largely recognized and recorded by the land registration system. Therefore, the system is mostly inclusive to the specific groups and actors.[v] • UAV missions can be utilized to gather base data to support the recognition of customary rights. *High compatibility*	• The UAV flights allow bottom-up initiatives in data acquisition[vi]. • There are at the moment a limited number of non-governmental initiatives partly due to strict regulative standards and administrative shortcomings with UAV flight permissions (e.g. vague statements by the authorities, non-adherence to deadlines and missing capacities for pilot licensing procedures). • There is only one licensed UAV company (i.e. CharisUAS). The reason for the lack of commercial operators is also due to lack of market demand. These findings suggest that there are impediments to participation. *Low compatibility*	• The fieldwork suggests that private surveyors find the cost of importing UAV equipment high to afford without the government's financial support. However, if the government provides financial support (i.e. distributing the UAVs, or providing funding) private surveyors can cover the cost of the operations with small service fees. • Outsourcing is possible, but administrative burdens, costs of the new equipment and lacking capacities may create bottlenecks for commercial operators. Furthermore, strict regulations with UAV flights limit the affordability of UAVs for private operators by restricting their use for other commercial activities (e.g. touristic purposes, entertainment, agriculture…etc.)	• Governmental actors (i.e central, provincial, district levels) and non-governmental actors are used to working with each other in land registration. In that sense, the fieldwork does not suggest a particular problem for the reliability of data provided by non-governmental actors. • The fieldwork suggests that the national government is the most trusted actor to lead the other actors in the governance of UAV-based land administration systems. However, the inclusion of the commercial operators in the UAV-based surveying is limited for the effectiveness and sustainability of the system. *Moderate compatibility*	• If the national government purchases the UAVs on behalf of commercial operators and provides training, it is possible for the commercial operators to adopt UAVs as part of their operations. • The biggest challenge for commercial operators is the time and money needed to purchase and to get licenses for UAV flights. • Our findings suggest that if the national government facilitates the licensing and purchasing steps, it is attainable for the governance network to implement UAV technology. *Moderate compatibility*	• There are some local UAV initiatives (e.g. CharisUAS), which suggests that there is an innovation potential among local stakeholders. Collaborations with these local initiatives can support the efficiency of current workflows or even upgradability of the UAV technology (even though, there is little capacity in Rwanda that could engineer something new) in the land administration system. • Specialized managerial and technical training programs funded by international donor organizations and collaborations with international institutions can enhance the innovation potential of the local stakeholders. *High compatibility*

				Moderate compatibility			
Problem perspective & Goal ambition	• There is a relatively little political risk that can affect the operation of the UAVs because the country is mostly politically stable. • Combination of different UAV equipment and adjustment of flight planning parameter allow flexibility in coping with environmental and geographical factors during the flight. • During the rainy seasons (February-June and September-December), UAV missions can be interrupted due to tropical rains (especially during the peak season March-May). This may limit the flexibility of the UAV operations into specific periods. • The wind speed can reduce the flight performance of the UAV. Constant wind increases the power consumption of the engine and can reduce the flight time	• There are certain operational challenges (e.g. the need of additional Ground Control Points (GCP) if RTK and PPK are not available; meteorological conditions) and regulative limitations (e.g. prohibition to fly over certain areas) of UAVs about the inclusiveness of the land administration system. These limitations can affect the extent and effectiveness of UAV missions to specific geographical areas in specific periods. • A particularly controversial issue is tenure rights over marshlands. The law recognizes marshlands as state property, but some occupants claim custom tenure[vii]. UAV data can be used to solve these	• We did not find any participatory mechanisms for stakeholders to mitigate emergent problems during the implementation of UAV missions. *Low compatibility*	• Rwanda does not produce UAVs and there is limited capacity inside the country to maintain the UAVs if there are problems with the equipment. Therefore, any problems with the equipment (i.e. damage, lost…etc.) can challenge the affordability as the equipment is subject to custom and registration fees. *Moderate compatibility*	• In the current system, the aerial images are either old (i.e. from 2008) or rely on Google Earth visual data. Therefore, the UAV missions can improve the existing aerial data and bring up-to-date base data for further land registration. • Experiences from various UAV operators infer that many UAV flights occur in non-perfect environments (e.g. temporarily restricted flight permissions, staff availability, product delivery deadlines, weather). Here, various parameters are interconnected and influence the final data quality of UAV-derived orthomosaics. *Moderate compatibility*	• Although the 2016 regulation is prescriptive in establishing the rules of UAV operations to minimize the risks during the flight, the system has still limitations if there is a technical problem with the UAV. In case there is a need to replace a piece of equipment, the time and money to replace the UAV platform risk the attainability of the UAV missions. *Moderate compatibility*	• Different equipment (e.g. lenses, GNSS sensor, IMU) can be upgraded to improve the effectiveness of UAV operations in case of emergent problems and changing goal ambitions (e.g. better accuracy, lower cost). • CharisUAS is the only local stakeholder who has a small unit to maintain and repair UAVs. They could provide repair service for the government and other private operators to fix minor problems (e.g. the fuselage of the UAV). But in case of bigger problems the UAV needs to be shipped abroad for repair. *Moderate compatibility*

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	enormously. The fixed-wing platforms can reduce the impact of the wind but for the best quality in imaging, 8-10 m/s should be considered as the maximum wind speed to fly a UAV. Furthermore, in terrains covered with trees, ground wind can cause the distortion of the images that can decrease the performance in image matching. ***Moderate compatibility***	conflicts given that the UAV equipment is RTK or PPK capable even there might be challenges to employ GCP measurements in the marshlands. ***Moderate compatibility***					
Strategies & Approaches	• UAVs allow collecting data at a high temporal resolution for various purposes. • Different options with UAV platforms and sensors allow a combination of low-cost and high-resolution strategies in data acquisition. Availability of different UAV platforms and sensors allows high flexibility in operations. • The UAV allows using different strategies (e.g. % of forward overlap and side lap; vertical takeoff and landing...etc.) to cover	• UAVs allow capture of land-related information (e.g. land use specifications and topographical features) in addition to cadastral boundaries. This allows the development of a multi-purpose cadaster such as in support of environmental management purposes (e.g. land preservation)[ix]. • Depending on the UAV equipment at hand, different geometric	• Participatory mechanisms can improve the effectiveness of the UAV missions and building trust among the community actors especially in the case of dispute or lack of trust to the government institutions. However, at the moment the land administration system does not identify any strategies towards participation. ***Low compatibility***	• At small to medium scales, the costs for UAV missions are relatively cheaper than classical aerial imagery, which also allow for data with a high temporal resolution. Therefore, the costs of flying missions are expected to be affordable. • Private operators can issue a small fee for their services to cover the UAV-based surveying and the maintenance costs. ***High compatibility***	• Three strategies are important to acquire up-to-date and authoritative data with UAVs; (1) several flights to cover larger areas[x]; (2) additional GCPs to increase accuracy; (3) high-quality equipment to improve data acquisition performance. ***High compatibility***	• Since Rwanda does not have large unmapped areas to cover[xi], it is attainable to adopt UAVs in the land administration with the existing strategies. ***High compatibility***	• The Rwandese government has several strategic plans for ICT transformation of the land administration (e.g. NICI III (2013-2015), ICT Sector Strategic Plan (SSP) (2013 -2018), and SMART Rwanda Master Plan (2015-2020)[xii]. The plans foresee the digitalization of land data and the adaptation of ICT infrastructures to improve it. • CharisUAS is collaborating with the University of

	difficult land surface areas (e.g. urban areas, forests…etc.). However, the land cover with little texture such as sand, and forest entail challenges to image matching.[viii] ***High compatibility***	accuracies can be achieved (from cm – m). If no PPK or RTK setup is available, additional GCP measurements with high-quality GNSS are needed to achieve cm-level of geometric accuracy. • UAVs can be used to gather evidence to solve disputed ownership in peri-urban and rural lands, where boundaries are visible and if the conflict is about the spatial extent. • However, there is a lack of government strategies and user guidelines on how to support the inclusiveness of the land administration system with UAV technology. ***Moderate compatibility***					Rwanda to adopt UAV missions in agriculture. As part of the collaboration, they are planning to include UAV operation in the curriculum. • Our findings suggest that there are both central and local level strategies to support the upgradability of UAV technology. ***High compatibility***
Resources	• After decentralization reforms, the district governments have been granted the financial autonomy and the discretion for	• For small and medium scale areas, the costs for UAV missions are relatively cheap and the quality of	• The system allows the participation of private investors to cover the cost of operations in data acquisition.	• The revenues generated from the fees (e.g. certificates, registration costs…etc.) can support the	• The government sources are reliable to cover the cost of operations and purchasing new equipment.	• The fieldwork suggests that for the commercial and local operators the only viable funding	• The government has a specialized ICT budget, which provides funding for projects according to the strategic

expenditures. However, not all district governments have the same fiscal capacity, which creates pressure on the flexible use of financial resources. • Local authorities and commercial operators expect the national government to buy or provide funding for them to purchase UAVs. ***Moderate compatibility***	imagery is high. Therefore, replacing classical surveying missions with UAV missions in small and medium scale areas can improve the inclusiveness of the land administration system. • However, in larger areas, the cost of operations will be higher due to the need of several flight missions. ***Moderate compatibility***	However, commercial operators find the cost of acquiring UAVs very expensive. • Permit and registration fees can contribute to cover the cost of the operations for the government[xiii]. However, at the moment, there is a limited number of commercial operators and there are potential bottlenecks (e.g. registration costs, waiting periods, high standard of UAV professionality, absence of private market) that can discourage participation of commercial operators. ***Low compatibility***	affordability of the UAV missions for the government without a significant additional financial burden. • It is possible for the private surveyors to issue a small fee for their services to afford the cost of operations. ***High compatibility***	• The purchasing, licensing and maintenance cost of the UAV equipment are financially challenging for non-governmental organizations and commercial operators, which reduces the reliability of non-governmental sources. ***Moderate compatibility***	option to purchase the UAVs is the national government. Therefore, for the initial purchase of the UAV and in case of a problem with the UAV equipment, the national government needs to provide financial solutions to the local and commercial operators for the attainability. ***Moderate compatibility***	importance (socio-economic impact), priority, and input resources (capacity and capability to execute the project)[xiv]. The government can support innovative projects to scale up UAV technologies through this funding option. ***High compatibility***

CAPACITY UAV RWANDA

Capacity Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	• The UAV's licensing and rules of operation complies with the 2016 Ministerial regulation N°01/MOS/Trans/016 and 2018 law on governing civil aviation[xv]. The legislative framework is not flexible for UAV operations and requires high quality and compliance standards from private/commercial operators. • Our pilot study showed that the licensing procedure is lengthy, expensive and time-consuming. ***Low compatibility***	• Our fieldwork suggests that the flight restrictions as part of the civil aviation safety rules can be restrictive in using UAVs in certain urban and peri-urban areas[xvi]. These safety regulations can limit the inclusiveness of UAVs in the land administration system (LAS). ***Low compatibility***	• The regulations are mostly participatory in providing access for vulnerable people (e.g. women, poor population…etc.) into the system. For example, the land rights of vulnerable people are recognized through the issuance of a land title in their name and those who could not afford and who were registered in the list of poor households were exempted to pay registration fees.[xvii] • Rwanda is one of the few countries that incorporate the prohibition of surveillance activities without people's consent into their UAV regulations.[xviii] ***High compatibility***	• The cost of the UAV registration is about $150 (110.000 RWF)[xix]. However, Rwanda does not produce UAVs and the administrative cost of UAV import and certification process can add up to 20% of the initial purchase price[xx]. • In addition to licensing procedure, Reg. 26 of N°01/MOS/Trans/016 obliges any person conducting UAV operations subscribes liability insurance no less than US$ 1 million. These regulations restrict the affordability of UAV operations. ***Low compatibility***	• The legislative framework is clear in terms of rules of operations, but our fieldwork suggests that some administrative processes are still uncertain concerning the operator permit, pilot certification and activity permit[xxi]. For instance, Art. 37 of N°01/MOS/Trans/016 states that if the Authority (i.e. Rwandan Civil Aviation Authority-RCAA) deems necessary for the safety and security of civil aviation, may modify, suspend or revoke any license or certificate issued for UAVs. ***Moderate compatibility***	• Rwanda has legislated the regulations on UAV operations in 2016 and updated them in 2018 with the law on governing civil aviation. In that sense the rules of operations are clear and UAV operations are attainable with current regulations. ***High compatibility***	• N°01/MOS/Trans/016 identifies modification of UAVs as part of the rules of maintenance[xxii]. In that sense, the rules on maintenance (see Reg.12) allows modifications of UAVs as long as they allow safe operations. • However, regulations on autonomous UAVs are more restrictive and it is strictly limited to government entities and public (governmental) functions such as the delivery of disaster or emergency supplies, search and rescue, and other government operational missions[xxiii]. ***Moderate compatibility***
Political System	• Rwanda has a strong presidential political system (i.e. little independent power for judiciary and parliament) and hierarchical political	• The political system is inclusive in recognizing different tenure rights and also customary tenures as long as there is evidence to support the ownership claim.	• Batwa minorities are historically marginalized indigenous groups but the political system recognizes their land	• Our fieldwork does not suggest a particular political cost for the stakeholders (e.g. colliding political interests; political unrest in a certain part	• Our fieldwork suggests that stakeholders rely on the capacity of the central government and its agencies (i.e. RCAA) to govern UAV	• The political system has high legitimacy and capacity to implement UAV operations in the land administration	• The political system is strong enough (i.e. legitimate government, strong political authority) and progressive to implement

	traditions, which situates the central government at the core of the political system. • The current government has a progressive agenda toward sustainable development goals and supported fiscal, and administrative decentralization towards district level without relinquishing its political control[xxiv]. This suggests the political system is flexible concerning political constraints that can affect the implementation of the UAV in LAS. *High compatibility*	Adopting UAV technologies in land administration system can facilitate the verification process of ownership in that regard. • We do not expect the implementation of UAVs to lead to the exclusion of any tenure type by the political system. *High compatibility*	tenure rights similar to other ethnic groups[xxv]. • There are no particular marginalized groups by the political system, which can affect the implementation of the UAV technology in LAS. *High compatibility*	of the country) that can affect the affordability of the UAV technology in the land administration system. *High compatibility*	operations, but there is lower trust to the capacity of lower tiers of administration for the implementation of the UAV technology. *Moderate compatibility*	system on a national scale. *High compatibility*	technological and operational improvements of the UAV technologies in the land administration system. *High compatibility*
Operational Unit	• The operational units of the UAV flights have the flexibility in combining UAV equipment with varying goals (e.g. cost, accuracy, resolution). • The operational units can also combine different flight strategies according to the size of the land area and the need for geographic accuracy[xxvi]. *High compatibility*	• At the moment, there are only a limited number of UAV operators in Rwanda. Yet, the strict flight permit process suggests that existing operators have the skills of flying different UAVs and operating them on different terrains to capture land data. *Moderate compatibility*	• Although there is only one private UAV operator, our fieldwork suggests that governmental and non-governmental stakeholders have the skills to collaborate on UAV operations and training. *Moderate compatibility*	• The central government and to a certain extent the district level government have the financial resources to implement UAVs in their land administration system. • Only a few private operators appear to have sufficient financial resources to implement UAVs without the support of state resources. *Moderate compatibility*	• Our fieldwork suggests that the licensed operators, albeit limited in number, have the skills to provide reliable data with the UAVs. *High compatibility*	• The private surveyors and government operators require additional training and resources to implement UAVs in the land administration system. • There are at the moment a limited number of pilots with UAV flight licenses. *Low compatibility*	• The operational units have some technical capacities to improve the UAVs if there is a need. But Rwanda has a limited number of specialized experts on UAV technologies. • There are new initiatives taking place between universities and private operators to introduce specialized training and courses. *Moderate compatibility*

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Social Norms	• The Rwandese government embraced a strategy called 'Home Grown Solutions' to combine traditional practices with sustainable development goals. One of them is the *Imihigo*[xxvii], where an individual commit to deliver certain act within a specific period. • These social practices suggest there is high flexibility in developing various strategies for the implementation of the UAV in the land administration system. ***High compatibility***	• The Rwandese government is implementing a pro-active policy in achieving social equality among different ethnic groups and the empowerment of women. In line with it, recently the inheritance law has been revised to allow women to inherit more easily. • However, traditionally sons are preferred over daughters in heritage rights, which may cause discriminatory acts against women in rural areas and land disputes about the ownership. • UAV missions can be employed to verify the ownership in disputed areas but they need to be complemented with the testimonies of the local population. ***Moderate compatibility***	• The Rwandese government has promoted participatory policies in the aftermath of the genocide. However, it is possible that in certain regions, the distrust among ethnic groups may hinder the collaboration of community actors with government officials during UAV missions. • In Rwanda, traditionally the third largest ethnic group (1%) of the society, *Twa* or *Batwa,* has been subject to social discrimination. ***Moderate compatibility***	• The Rwandese government adopts policies to promote social justice and inclusion of people in public governance. This suggests that collaboration with local stakeholders, where social capital is high, can facilitate the affordability of the UAVs in the LAS. • However, in rural areas, where the tribal and family ties are stronger, social capital can act against the collaboration of actors with government officials. ***Moderate compatibility***	• The Rwandese central government has a high legitimacy in society. Therefore, we do not expect social norms to undermine the authoritativeness of the land administration system if the implementation of UAVs is backed by the central government. ***High compatibility***	• There are no particular social norms, which can postpone the implementation of UAVs in the land administration system. ***High compatibility***	• The current government has a clear political agenda to turn Rwanda in the innovation hub of Africa[xxviii]. The rate of young population and the citizen's support to the innovation policies of the government suggest that social norms are supportive of the improvements of UAVs in the LAS. ***High compatibility***
Land recording techniques (LRT)	• UAVs are not land recording tools but they can support the LRTs in the land administration system in multiple ways, such as to create	• There are several external parameters, such as land cover, terrain, and wind, which can affect the completeness of UAV	• The UAV does not need the participation of local stakeholders to capture spatial data, but additional ground control points improve	• The data capture operations with UAVs are affordable at small to medium scale land areas and they need only a low-scale labor	• The reliability of the LRT based on UAV data is mostly affected by the image quality. The image quality can be	• The commercial surveyors and some local government operators require additional training	• A reasonable number of GCPs can compensate the poor performance of the onboard system, such as the use of high-

	spatial reference frameworks, to update the existing database, to create a base map to sketch qualitative land and user rights; to track the progress of land development in urban areasxxix. ***High compatibility***	data and thus the inclusiveness of the systemxxx. • Certain land uses such as forests and bare soils or features such as corrugated iron roofs impose challenges to find corresponding tie points, which lead to unsatisfactory results during the image matching. In these cases, a high image overlap and cross flights can prevent imperfection of the final resultsxxxi. • UAVs can set a reference base to cross-match with qualitative data, which can help to include customary tenures into land administration system. ***Moderate compatibility***	the geometric accuracy of data significantly. Here the presence of local participants can prevent intentional or unintentional removal of Ground Control Points (GCPs) by locals, especially in cases there are few GCPs available for geo-referencing.xxxii • Although the data capture process with UAV does need local input, the UAV orthoimages can be used as base maps to sketch qualitative data. This way they can support the recording of non-cadastral tenure information, which is a central need in Rwanda. ***High compatibility***	cost. Therefore, at that scale, they can support land recording processes for both cadastral and non-cadastral purposes. • The cost of the UAV-equipment for high-end data imaging can be expensive and difficult to afford for commercial operators. ***Moderate compatibility***	determined by the sensor quality, flying mode and spatial resolutionxxxiii. ***High compatibility***	on, how to use UAVs to provide base data for land recording processes. However, for that, there is a need for further guidelines and policy documents on how to integrate UAV-based orthoimages in the recording of cadastral and non-cadastral information. ***Moderate compatibility***	quality units with RTK or PPK capabilities or known locations of the camera projection centersxxxiv. • Different equipment (e.g. lenses, GNSS sensor, IMU) can be upgraded to improve the effectiveness of LRT based on UAV orthoimages. ***High compatibility***
Software	• The UAV workflow includes various software programs for different tasks (e.g. flight planning, densification, georeferencing, 3D modeling, data processing…etc.) and it is possible to use different strategies to improve data quality and processing.	• There is not a software-related restriction for capturing data with UAVs on different landscapes. However, there are different software solutions for image processing (e.g. open-source, Pix4D, Agisoft, Photoscan), and depending on the expertise of the users with the software, the choice of software can	• The software solutions for UAV-based orthoimages do not require input from local stakeholders for the final quality. However, permanent ground markers can be established to assess the accuracy and to involve geo-locations of the GCPs into photogrammetric processing.xxxviii	• The software for flight planning and flight execution is delivered with the UAV equipment and no additional costs are added. However, image-processing software is usually not part of this. There are both, commercially and free software available. The price plans for commercial solutions	• Our experience with open source software suggests that in terms of reliability the best open-source software, Open Drone Map (ODM) can currently not compete with Pix4D, which is the commercial software that is used by the CharisUAS. However, we expect ODM	• New software solutions on digital photogrammetry and structure from motion (SfM) image processing allow high-end data products in orthomosaics, terrain models and 3D models. Knowledge of new software solutions is important for the	• Usually, each UAV requires different software for flight control and flight planning. For the commercial software solutions, the update of the software is automatic and it does not require capacity development at the local level. • For upgradability, ODM allows

• There is a need for calibration of the UAV and selection of appropriate geo-referencing methods according to the data quality requirements of the flight mission. However, the software itself is highly flexible and there is no need of using different software for different circumstances. • It is possible to find open source solutions for some tasks (e.g. open-source Mission Planner, Open Drone Map[xxxv]) ***High compatibility***	affect the final quality of orthoimages. In that sense, if the purpose of the orthoimage is to support cadastral mapping processes with boundary delineation (e.g. through the automated feature extraction), it is important that there is not a compliance problem of the software used in different processes and the software provides the required image quality[xxxvi]. Especially, in case there is a need for 3D models (e.g. capturing vertical data on building walls or fences), the deviation is high among different software solutions[xxxvii]. ***Moderate compatibility***	Marking the permanent ground markers can involve local stakeholders as a means to support collaborative processes on defining boundary lines during the participatory mapping. • Furthermore, former experiences in Rwanda showed that the high-resolution orthoimages facilitate update of cadastral maps during participatory mapping[xxxix]. ***High compatibility***	can be subscription-based or one-time charge[xl]. • The only licensed UAV commercial operator in Rwanda, Charis UAS uses Pix4D software. That suggests the proprietary software is affordable for commercial operators. ***High compatibility***	certainly to improve over time. ***Moderate compatibility***	land recording performance of UAV operations. The local expertise on UAV technologies is limited at the moment, but there are new initiatives (e.g. collaboration of CharisUAS with University of Rwanda) to build up the local capacity through specialized training and programs. • Collaborations with foreign universities and private actors can enhance the knowledge transfer to local stakeholders regarding the advancements with open-source solutions. ***Moderate compatibility***	extendable application and API for UAV image processing, as well as visualization, storage, and data analysis functionality[xli]. For the its4Land project, the adoption of open source solutions is preferred for the upgradability. However, the local capacity on open source solutions are limited and therefore less preferred. In that sense, there is a need for capacity development on using open-source software. ***Moderate compatibility***

GOVERNANCE UAV KENYA

Governance Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	• There are three key actors (i.e. Ministry of Land, county government, and National Land Commission) in the governance of land administration system (LAS), and their responsibilities overlap in certain areas mostly concerning the public land. • The Ministry of Land and its field offices at the county level have the responsibility to give the ownership document (i.e. the title deeds) and they are responsible to collect the information on the private ownership. The national government also deals with boundary disputes. Therefore for the dispute resolution, the national government should be involved. • The county government has the responsibility to collect data on community land. The county governments have gained decentralized autonomies with the	• The Constitution of Kenya recognizes four forms of land tenure, namely: public land, community land, private land, and wakf land. However, six land tenure systems are discernible in Kenya: the Public Tenure, Private Tenure, Customary Tenure, Wakf Tenure and two special types of tenure; the Informal Tenure and the Ten-Mile Coastal Strip.xlii • While the customary tenure dominates most of the rural lands in Kenya, the private and public tenure systems control land in the urban areas. The informal tenure is dominant in the urban areas as well as in several large-scale farms in the country in the form of squatters. The Ten Mile Coastal Strip is found only in the Coast Province of the country and has the longest history of all the tenure systems in Kenya.xliii • Both the county government and the national government collect and store the data	• The system integrates both county governments and national government in data collection and recording, but there is a need for a clear regulative framework outlining the responsibilities in the coordination of the land recording efforts. ***Moderate Compatibility***	• County governments have different financial capacities depending on their natural resources, commercial activities and revenue collection efficiencies. Therefore, it is affordable for some county governments to operate UAVs with their resources. • We expect the national government to be able to operate UAVs with their resources. ***Moderate Compatibility***	• There are numerous cases of overlapping boundaries and double registrations in Kenya's land information management, clearly indicating that crosschecks are not sufficientxlv. Although there are ongoing initiatives by the national government and the NLC to merge separate databases into a single standardized system, at the moment these systems are still under development. • Most of the land data are stored in paper-form and the data are often not up-to-date. UAVs can improve the reliability of the data but there is a need for digitalization of the land registries. ***Low compatibility***	• The UAV draft law is waiting for the approval of the parliament to become official. However, the process is taking longer than expectedxlvi. Until that time the UAV flights take place with the special approval of Kenyan Civil Aviation Authority (KCAA). • The fieldwork suggests that the government has adequate resources to implement the UAVs in the land administration system. However, there is a need of organizing training efforts for the sustainability of operations at devolved field offices, and the bureaucratic burden and lack of interest for training can hinder the adaptability of the operations by the national	• Both the national government and NLC have their bodies to innovate the land data management systems. • The national government has a specialized research unit on how to introduce and regulate UAVs. ***High Compatibility***

	2012 law, but not all county governments have the same capacities to collect and process the land data. • The National Land Commission (NLC) is created in 2012. Initially, NLC was supposed to play a larger role in the management of the public lands and lead the land administration system towards a depoliticized, reliable system. However, following an amendment in 2016, NLC's role is replaced by the Cabinet Secretary and NLC is now in charge of the management of the public land without any field offices. ***Moderate Compatibility***	about their respective tenure types. However, the public land tenure that corresponds to 10% of lands in Kenya is delineated in two broad areas, in which both the national government and local government have responsibilities in recording the land data[xliv]. The fieldwork suggests there is limited data-sharing between the ledgers of county government and national government, and there are differences in terms of digitization of records. This suggests that not only the collection of data but also the management of data can be a challenge for the governance of the UAV system. ***Moderate Compatibility***				government. Here our findings suggest that county governments have a better chance to adopt the UAV systems effectively and faster. ***Moderate Compatibility***	
Actors & Networks	• Both counties and the field offices of the Ministry employ surveyors. Both types of surveyors have similar functions but they are part of the different governance structures. • The distinctions between the roles of the surveyors are unclear and this has caused in the past problems concerning overlapping	• Previous work on country needs assessment showed that the indigenous land rights concerning the environmental degradation[xlviii] and women's access to land is still a significant issue[xlix]. • The implementation of UAVs can help to address these land-related challenges more effectively. However, for socially perceived	• There is not a structured framework or signed memoranda to ensure the non-governmental actors partake in data acquisition and recording. But there are ad-hoc collaborations with private actors and civil society organizations. For example, the Global Land Tool Network (GLTN) supports capacity-	• On transfer of property, the cost of registration depends on the value of the property. On average, this cost is about 4% of the property value, which may be 'prohibitive' for many Kenyans[l]. The total cost of recording a property transfer is high by average Kenyan income levels. The high administrative costs	• The lack of cooperation between the national government and county government and the previous conflicts between NCL and national government suggest that there is a trust problem between different levels of government.	• Even if the draft law on UAV is legislated, there are still legal uncertainties on what types of UAVs are allowed and in which areas they are allowed to fly. These uncertainties can affect the effective uptake of the operations by the public and	• The governance network includes private actors (e.g. GEOIT) and international organizations (e.g. GLTN), which have expertise in land administration systems and new technologies. For example, GLTN works mostly with county

responsibilities and jurisdiction. The fieldwork suggests that the situation is solved through a status quo, where both actors conduct surveys and data recording separately. • Since both county governments and field offices of the Ministry of Land collect data, it is possible to shift the roles from one actor to another. There are however capacity differences between county governments and also between county government and field offices of the Ministry of Land in the same region. Therefore, the governance of the UAVs can be undertaken by different local entities (i.e. either by the national or county) in different regions. • There are multiple private UAV companies in Kenya. For example, during the pilot study, it was possible to rent a drone for surveying from a local company when the initial UAV had a malfunction in operation. Furthermore, a private surveying company, OAKAR [xlvii], conducted	tenures, UAVs have limited functionality. ***Moderate Compatibility***	building projects in land governance toward an inclusive and participatory land governance system. • The fieldwork suggests that the county governments are willing to engage with non-government actors and they are seeking collaboration with them in data collection. • The NLC is the only participatory governance structure in land management, which includes stakeholders from civil society, academia, and private actors. However, NLC has a limited role in terms of data acquisition. Although NLC is an independent body, in the past it had been under political pressure and its effectiveness is dependent on the data provided by national and county governments. ***Moderate Compatibility***	discourage formal recording of land transfers, especially in rural areas[li]. • It is possible to outsource surveying activities to private operators (e.g. GEOIT). ***Moderate Compatibility***	• The fieldwork suggests that the county government is more trusted concerning the national government actors because the county government's financial revenues rely on local sources where land revenues are important. • However, there are distinct capacity differences among county governments, which can reduce their reliability in providing authoritative data. ***Moderate Compatibility***	commercial UAV operators. • The fieldwork suggests that it is likely that the Institute of Surveyors of Kenya will support the implementation of the UAVs[lii]. ***Moderate compatibility***	governments, while GEOIT mostly works with the national government. • There are multiple private UAV companies in Kenya. Although these companies do not produce drones themselves, the system has a relatively higher potential to scale up if it is adopted. ***High compatibility***

	GNSS measurements. This suggests it is possible to include private companies in data collection processes with UAVs. ***High Compatibility***						
Problem perspective & Goal ambition	• The evolution of the land administration laws in Kenya suggests that there are some political risks, which can affect the operation of the UAV. Furthermore, there are overlapping responsibilities at the local level and the data are collected in separate ledgers of the county and devolved national government. During the fieldwork, we found that these local authorities don't share their data. • Initially, NLC was responsible for developing a national land information management system. However, at the same time, the Ministry of Land is developing a parallel land information system. • There are vested interests in the management of the public lands and there are reasons to suspect that the political	• The land disputes are very common both in terms of ownership and the size of land area. Some of these disputes go back to the colonial period and the others result from the rapid urbanization of peri-urban areas. Especially, public lands are disputed because of the concerns on historical injustice. For example, during our fieldwork one interviewee said: "Like in Kajiado we have a lot of issues over land, a lot of acres has been taken away. I saw 10 to 20 acres of land that has been taken away and I saw people manipulating the document to have 50 acres of land. These are disputes that raise". • Adapting the UAV missions in rural areas are challenging in accessing to the suitable landing sites. For example, during the pilot work, all UAV and GNSS equipment had to be carried by foot to the area of interest because the	• NLC has a participatory governance structure and works on creating new platforms such as national spatial data platform, through participatory methods. These participatory governance bodies can be used to mitigate problems in land data recording. However, NLC has a centralized governance structure. The Community Land Bill passed on 31 August 2016, dismantled the county land management boards (CLMB), the county-level agencies of the NLC[liv]. This can limit the effectiveness of NLC for the dispute resolution. ***Moderate Compatibility***	• There are high initial costs such as purchasing UAVs, custom and registration costs, and cost of the training[lv]. However, the cost of the operations is expected to be affordable for the public and private operators. • It is possible to have resistance to automation and open-source codes, which can add additional cost to the integration of the UAVs in the data recording system[lvi]. • The digital infrastructure is not stable[lvii] in every region, which can reduce the effectiveness of UAVs in seamlessly feeding data in the land recording system. We do not expect each county has adequate financial resources to develop the infrastructure. ***Moderate Compatibility***	• UAVs can be used to develop baseline images for land data. However, the lack of cooperation between national and county governments can limit the effectiveness of the aerial images in solving land disputes. This can reduce the reliability of the LAS. ***Moderate Compatibility***	• There are certain legal uncertainties and lack of hardware and software capacities at the devolved national governments. It is possible these shortcomings can be addressed in a short period, but for that, there is a need for political leadership. The fieldwork suggests that to gain the endorsement of political actors there is a need for success stories. ***Low compatibility***	• The bureaucratic resistance towards digitalization and legal uncertainties can impair the effective uptake of new UAV technologies in land administration. As one interviewee stated: "The legal requirement to submitting work on the operational level is still manual or still old school. This blocks innovation. Why would I as a surveyor bother to do digital things if the government doesn't need it? It makes it easier for me to use the old tools. Another one is the legality. So, for example, the title deed is legally only valid because of the green card, until a digital title is legal. We will not go

	interests can cause transactions costs on the operation of the tools. However, at the moment it appears that there is a status quo between the actors about not intervening in their operations, which suggests that it is possible to have alternative ways of governing the UAV operations in case of political risks. ***Moderate Compatibility***	vehicles could not pass the river[liii]. Therefore, the adaptation of UAV missions in certain geographical areas can be more labor-intensive and challenging. ***Moderate Compatibility***					that way. A survey plan, if I want to reassemble a boundary, I need to use a legal survey plan, which is paper-based at the moment. It will not make sense to have a digital map in the governmental office when it is legally not recognized. Those are some of the challenges." • However, land disputes are a very important issue in Kenya, and the government can be eager to implement UAVs to solve land disputes. The endorsement of the national government can support the improvement in the operations of UAVs. *Low compatibility*
Strategies & Approaches	• In Kenya, a majority of public lands are not documented, and there are lots of dispute on ownership. Therefore, the UAV data collection strategies should target both data accuracy but also land coverage. However, covering large	• The pilot study in Kajiado showed that it is possible to use UAVs for covering rather larger areas in rural areas. During four individual overlapping flights, a total area of 330ha was covered with images having a ground resolution of 5 cm.[lviii]	• There are some ad-hoc projects, which suggest that it is possible to include non-governmental and community actors in the data acquisition process. Especially, local stakeholders can bring an added value in the	• We estimate that the county governments can afford to operate UAV missions with available resources. However, in the areas with difficulties in terrain and weather conditions, the cost of operations and	• There are certain challenges associated with the UAVs which can affect the reliability of the data, such as varying data quality due to lack of standardized image capture/processing; input lines do not	• There are still legal uncertainties on the rules of UAV flights and there is a lack of centralized land information system, which impairs an effective approach to adopt UAVs in the LAS.	• UAVs are applicable in further object delineation applications (land use mapping) and implementable in the existing system due to a modular design. However, the resistance to

	unmapped areas is difficult and time-consuming with UAVs. Depending on the regions and goal of the operations, different UAV equipment and combination with other aerial surveying strategies can be necessary for the operations. *Moderate Compatibility*	• However, the absence of ground reference points suggests that there is a need for additional effort to position control points. The effectiveness of this process can be subject to weather conditions. For example, due to unstable weather conditions, it was only possible to establish and measure seven ground reference points instead of 12 as initially planned.[lix] *Moderate Compatibility*	delineation of boundaries in community lands. However, there is not a clear strategy to encourage the participation of local stakeholders in LAS. *Moderate compatibility*	equipment can be difficult to afford for certain county governments. *Moderate Compatibility*	cover all boundaries; lines derived from pixels always inherit simplification (especially for long-duration missions, the angle of sun can affect the accuracy of data). • These shortcomings can be mitigated with the support of more suitable UAV equipment and flight strategies, but the pilot study on a customary tenure in Kaijado showed that undulated terrains and harsh weather conditions with constant wind limited image overlap to 70% and necessitated higher quality sensor equipment for image quality[lx]. These suggest that there are some limitations to the reliability of UAV data concerning certain exogenous factors despite the availability of multiple strategies. *Moderate Compatibility*	*Low compatibility*
						innovative solutions and open source solutions suggest that it might be difficult to innovate the system.[lxi] • Furthermore, political resistance can be another factor, which can impede adaptation of certain strategies. • The fieldwork suggests that the field office of the national government is in a better position to introduce innovation in land strategies at the local level. This suggests it is important to collaborate with field offices to improve strategies with UAVs. *Moderate Compatibility*
Resources	• County governments have fiscal autonomies to collect land/property taxes, and they are	• There are differences among local authorities (i.e. county governments,	• Some county governments have better access to financial	• The WB report[lxiv]states: "The fees collected from registry services are	• There are no on-going funding/support to	• There is a need for high initial cost to set up the digital	• The fieldwork suggests that there are limited

allowed to select a valuation rate up to 4% without a central government approval[lxii]. However, not all county governments have the same fiscal capacities and not all of them have updated valuation roles, which affects their ability of revenue generation. • The field offices of the Ministry do not have flexibility in their financial resources. This suggests that the field offices need to receive the support and authorization of the Ministry to implement UAV operations. *Moderate Compatibility*	field offices of the national government) in terms of financial capacities. Especially, in rural areas where more expensive equipment would be necessary for higher image quality due to unsupportive terrain and weather conditions, some local authorities with limited financial capabilities can have difficulties to implement UAVs effectively in LAS. However, the fieldwork does not suggest a particular problem with available resources, which can impede the inclusiveness of the UAVs in the land administration system. *High Compatibility*	resources from private and international donors. Therefore, it is possible using different financial resources to finance the operations at a local level independent from national government resources. • The county governments have the discretion to increase the nominal tax rate and they can higher their private valuers to assess the value of the land. But the revenue collection capacities of county governments vary case by case[lxiii]. *High Compatibility*	generally sufficient to sustain operations but since this money must first go to the Exchequer, there is no guarantee that it will be available when needed to sustain services." This suggests that it is possible to finance the cost of UAV operations with the revenues from land registration, but weak administrative capacities concerning the transfer of revenues to field offices can hinder the affordability of operations. The county governments, on the other hand, have financial autonomy over their resources, but varying financial capacities among county governments can affect the affordability of operations. *Moderate Compatibility*	implement UAVs in LAS[lxv]. • The county governments financially rely on the local resources, which suggest that the reliability of resources depends on their financial and local capacities (e.g. efficiency in revenue collection, the land value…etc.) • The financial resources of the field offices are dependent on the transfers from the central budgets, but there are uncertainties about the availability of the funds to sustain UAV operations when needed[lxvi]. *Moderate Compatibility*	infrastructure and to train the personnel at local level [lxvii] for the implementation of UAV technologies. • However, the fieldwork suggests that the problem with attainability is not about the financial resources but the policy priorities. Therefore, in counties with a higher level of digitization and a better match between the advantages of UAV technologies with the land challenges, we expect the implementation of the UAVs more attainable. *Moderate Compatibility*	resources for innovation activities and we did not encounter a special budget, which can be used for the innovation activities. The national government has more innovations based on private companies and they receive more aid in comparison to county governments. In that sense, the national government has more advantages in innovation activities." *Moderate Compatibility*

CAPACITY UAV KENYA

Capacity Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	• Our first pilot study showed that unlike in Rwanda it is possible to get a temporary permit from Kenya Civil Aviation Authority (KCAA) and the private use of UAVs are separately regulated[lxviii], which give higher flexibility for the capacity of operators. However, this pilot study took place in 2017, when the draft law on UAVs was still in place. Later, this draft law has been withdrawn and a new legislative process has started. • Our second pilot study took place in 2018 when the draft law was withdrawn. Despite this absence of regulative framework, it was still possible to issue a temporary permit through the channels of local administrations and county government. This shows that the system is flexible with licensing procedures despite the limitations with regulations.	• In Kenya, three main types of maps are used for land registration, namely, deed plans, Registry Index Maps (RIMs) and Sectional Property Maps[lxix]. A large portion of rural lands is registered in the RIMS because it is easy to produce through a chain survey and air survey method[lxx]. If UAV based orthoimages are incorporated in the RIM, it can significantly improve the inclusiveness of the LAS, • The 2016 Community Land Act introduced customary tenure rights into the LAS. County governments are in charge of recording and registering the custom tenure. • The Constitution recognizes traditional dispute resolution (TDR) mechanisms. Currently, many communities are relying on TDR as a means of resolving their disputes at the local level. It is important that a framework for recognizing and operationalizing these mechanisms as	• While the Land Act and Community Land Act recognize the continuum of rights and the rights of communities, but secondary rights and rights of women, undocumented rights are difficult to establish as formal ownership recorded in documents is privileged[lxxiii]. • While the National Land Policy was adopted in a participatory manner the process of implementation rarely follows the requirement for consultation and effective participation. When consultations happen, citizens rarely get feedback on the extent to which their views were adopted and for those not adopted why this was the case. A clear legislative, transparent and policy framework for public consultations and feedback is needed.[lxxiv] • The Community Land Act has participatory provisions[lxxv], which allow participation of community representatives in the	• In the former draft regulation on UAVs, the cost of registration was set as about $1000, which was very high for the affordability of the drone for private operators. Since the current legislative process is not completed, we do not know at the moment the formal administrative costs for licensing UAVs. However, the field research suggests that the administrative costs are expected to be affordable for commercial operators. • The cost of registration of land tenure can be high for poor citizens. The cost of appealing to the Court of Appeal is also high making appeals unaffordable to rural poor and the majority of the citizens[lxxvii]. UAVs can be useful to solve disputes in rural areas, but with higher appeal costs, citizens might prefer alternative mechanisms, which can reduce the	• The legislative process with UAV regulations is still in progress. • The present regulations are not prescriptive on the capture/use of aerial imagery[lxxviii]Furthermore, our pilot study suggests that the informal channels are common in the licensing of UAVs. Although this brings a certain level of flexibility, it does not suggest a reliable regulative framework. ***Low Compatibility***	• The legislation processes for surveying techniques and UAVs are still in progress. However, it is possible to get flight permits for UAV operations with the approval of KCAA. This suggests it might be possible for commercial operators to use UAVs for the surveying process. ***Moderate Compatibility***	• The legislative process of UAVs and surveying techniques are still in progress. Therefore, we do not know to what extent the final draft act will allow improvements in surveying techniques with UAVs. • However, the current draft law on UAV contains restrictive provisions on the upgradability of UAVs. For example, the rules on import and export of UAS states: "A person shall not import a UAS or a component thereof without a permit issued by the Authority." Similarly, the rules on manufacture, assembly and testing of UAVs state: "Any person intending to manufacture, assemble, test or sell a UAS or a component thereof shall apply for authorization from the Authority."[lxxix] ***Low Compatibility***

				applicability of the UAVs. ***Moderate Compatibility***			
Moderate Compatibility	contemplated by the Constitution is fast-tracked. This is a task for the Judiciary but one, which is also vested in the National Land Commission (NLC).[lxxi] • The recognition of alternative dispute mechanisms and general boundaries support the inclusiveness of the LAS. But an important challenge is that there is a lack of enforcement of laws and regulations and duplication of mandates for management of public lands.[lxxii] ***Moderate Compatibility***	land administration processes. • The former draft law on UAVs has been withdrawn in 2018 following the objections that it was unconstitutional because it was prepared on without participatory processes. The current legislative process on the civil aviation unmanned aircraft systems (UAS) regulations adopts participatory methods with stakeholders on legislation process[lxxvi]. However, this process is still going on and we do not know to what extent the consultation with stakeholders will be effective in the final version of the regulations. ***Moderate Compatibility***				
Political System	• The land data collection is decentralized in the Kenyan case. Here the main responsibility is on county government. The pilot study showed that county governments have the autonomy to implement UAV flights at their discretion. • However, the Ministry of Land has also field offices, which are	• The Constitution provides for recognition of land rights under customary land tenure, which would include rural land uses such as pastoralism. But land disputes concerning urban and rural lands where pastoral communities are present, are politically sensitive in terms of land administration.	• Certain interests are not fully recognized such as the rights of women and the rights of residents in informal settlements in rural settings.[lxxx] • According to the provisions of Land Law on guiding principles[lxxxi], public officials should encourage communities to settle land disputes through recognized local community initiatives. However, actual practices	• We do not expect a significant political cost for the stakeholders to implement UAVs in the land administration system. Contrary, implementation of UAVs can reduce the political tension about the land appropriation of the pastoral Maasai community. ***High Compatibility***	• A 2002 report of the Njonjo Land Commission[lxxxiv] suggests that citizens have low trust to the land dispute settlement mechanisms and institutions due to delays, incompetence, corruption, nepotism, political interference and overlap of roles and functions leading to conflict, confusion and unnecessary	• There have been some political tensions between agencies of national government and county governments in the past about the overlapping responsibilities. There have been some regulative changes in 2016, which has	• Our fieldwork suggests that the stakeholders recognize the legitimacy of the central government in deciding on the land administration policies. Despite delays in the political and legislative processes, we think there is enough political capital to

	involved in the data collection through their surveyors. There is limited cooperation between the field offices of the Ministry and country governments. Especially in the past, areas with richer natural resources have been an issue between national government and county governments. By taking into account the absence of formal procedures in issuing flight permits, it is possible to have certain political constraints and/or risks during the implementation of the UAV missions. **Moderate Compatibility**	• The informal tenures concerning certain tenures in peri-urban areas and tenures concerning Ten-Mile Coastal Strip are excluded at the moment by the land administration system. • UAVs can improve the inclusiveness of the system on capturing up-to-date aerial imagery to solve boundary disputes with social and customary tenures, but the politicization of boundary disputes concerning the pastoral lands suggests that there might be certain limitations. **Moderate Compatibility**	suggest that the system has been less participatory than the regulative framework suggests. For example, existing processes around the subdivision of group ranches have been by no means participatory or transparent, and have led to members within a group being dispossessed of their land, particularly women[lxxxii]. The Ministry has also recently been in the news[lxxxiii] about adopting a lack of participatory processes. **Moderate Compatibility**		bureaucracy especially when there is low participation of the local people in land dispute resolution mechanisms.[lxxxv]The current situation has improved after the enactment of National Land Policy and recognition of the alternative dispute mechanisms. • UAVs could provide rather high qualitative and up-to-date data to support the reliability of the system. **Moderate Compatibility**	empowered the role of the national government in land administration. We expect through an inter-agency consultation and consensus on collaborative relationships, it is possible to implement the system on a nation-wide scale. **Moderate Compatibility**	implement changes in the system if it is needed. **High Compatibility**
Operational Unit	• There are two responsible operational units in land data recording, the field office of the Ministry and county governments. • The operational units of the UAV flights can combine multiple strategies (i.e cost, accuracy, and resolution) with different UAV equipment.	• The operational capacities vary between counties and also between the field offices and county governments. This can affect the effectiveness of UAV operations in covering different land tenures. • Although during the fieldwork, the respondents did not point out capacity problems in terms of operating UAVs, we do not know the	• The field offices of the Ministry and county governments do not share their land data, which is an important problem in the land administration system. • Although the fieldwork suggests that the operational units are willing to include stakeholders in land recording processes, they do not have established	• The financial capacities of operational units, both field offices of the Ministry and county governments, vary case-based and depending on the region. Therefore we expect the affordability of UAV operations to vary between operational units. • The costs for UAVs and its flying are significant	• Although the field offices of the Ministry have usually better capacities, the personnel and material capacities of operational units vary case-based. However, in most units, the land data information is stored in paper format and the process of digitalization is in progress.	• There are limitations with human and financial resources, skills and knowledge to implement UAV operations at the local level. • Another weakness is that there is no clear training/certificatio	• The fieldwork suggests that the operational units lack the specialized knowledge and technical expertise to improve the operation of UAVs. There is a need for specialized training and capacity building programs for the sustainable

	• The operational units can also combine different fly strategies according to the size of the land area and the need for geographic accuracy[lxxxvi]. **High Compatibility**	extent of skilled UAV operators that are available for land surveying. However, we think that it is possible to build the necessary capacities with training by taking into consideration the past experiences in learning GIS skills and the presence of various private UAV operators. **Moderate Compatibility**	systems for participatory mechanisms at the local level. • The fieldwork suggests that there is a need for capacity building and additional resources to support participatory processes. For example, one interviewee stated: "If I may tell you the truth and the bitter truth, there is no capacity building [at least from the commission's point of view] so that the field has completely been overlooked or has been neglected by one reason or another. Because for example, we need to train the group ranch officials on how to manage land. We need to talk to women, whose rights are been violated by men. Their disputes come to us. Ok, we have issues of capacity building where you have to enlighten people on their rights about their land, land information. It is not there. So all this is a result of lack of resources. Even despite we like to propose, who is going to fund? There is a clear gap in the capacity; both for the staff as the capacity	**Moderate Compatibility**	• There is a lack of guidelines and training on how to operate the equipment. For example, the new equipment has been donated by UNDP to some county governments, but there is a lack of guidelines and training how to operate with and maintain them. Therefore there is a need for clear policies and guidelines on the maintenance of equipment. • The data quality acquired with UAVs is rather high **Moderate Compatibility**	n avenue for UAV pilots[lxxxvii]. • However, it is possible to start in places with better capacities and later to spread out to other cases with the support of donation programs and tailor-made capacity-building policies. **Moderate Compatibility**	deployment of UAV operations. **Low Compatibility**

			for people and other stakeholders too." *Low Compatibility*				
Social Norms	• There are alternative dispute resolution mechanisms and the legislative system recognizes the traditional mechanisms in land disputes[lxxxviii]. In that sense, we expect that it is possible to use UAV missions to supplement alternative dispute resolution mechanisms. *High Compatibility*	• Especially, in the community lands, there are some tensions between social norms and legal rights with customary tenure. An example is in Maasi culture, daughters are excluded from land inheritance, practicing subdivision but without the legal finality and evidence of a formal subdivision application. Or men can sell the lands to outsiders without telling their wives, contributing further to land disputes.[lxxxix] *Moderate Compatibility*	• Following the devolution of the land administration system, the ethnic diversities at the county level have become a source of violence and exclusion toward ethnic minorities. There have been reports on the displacement of certain ethnic and social groups (e.g. pastoralist or farmers), in rural and community-owned areas[xc]. *Low Compatibility*	• In rural areas, where the tribal and family relations are stronger, the social capital can facilitate the collaboration of communities in supporting UAV operations in land coverage and boundary disputes (e.g. Maasai community in Kaijado). • However, there are often intra-family disputes in rural areas where Maasai communities are residing concerning the subdivision of group ranches. In these cases, social capital can act against the affordability of UAV operations by complicating access to genuine qualitative data. *Moderate Compatibility*	• Many transactions take place outside the formal registration process. A common one is an inheritance according to customary norms where the title remains in the name of the original holder, who may be long deceased[xci]. This social norm can undermine the authoritativeness of data collected by UAVs. *Moderate Compatibility*	• The fieldwork suggests that the adaptation of new technologies take time in Kenyan case. Stakeholders prefer to see the added value of the new technologies and methods before adaptation. *Moderate Compatibility*	• The fieldwork suggests that new technologies and practices are not adopted right away and some stakeholders expressed to some degree distrust to the UAV technology[xcii]. It is important to show good practices as well as the added value to the processes. Furthermore, it is important for the government to promote new practices through an incentive mechanism. *Moderate Compatibility*
Land recording techniques (LRT)	• LRT with UAVs can be used for different purposes to support land administration system, such as to create spatial reference frameworks, to update the existing database, to	• In Kenya, the UAV missions can be utilized to cover unrecorded wide rural areas and also to solve boundary disputes. However, the effectiveness of LRTs depends on visible	• The UAV does not need the input from local stakeholders to capture spatial data, but additional ground control points improve the geometric accuracy of data	• The financial capacities of both private and state operators (i.e. county government and field offices of the Ministry) vary significantly. Therefore, we expect	• The accuracy and quality of data can be improved with supportive LRTs and equipment. • However, there is a challenge in terms of	• It is difficult to adapt available LRTs in most places with existing financial and HR capacities. *Low Compatibility*	• It is possible, to improve the performance of the UAVs with a modular design. However, at the moment it is difficult to automate

	create a base map to sketch qualitative land and user rights; to track the progress of land development in urban areas[xciii]. Especially, during our workshop, stakeholders identified that the high resolution and quality of information of a UAV-based image could significantly increase the transparency and openness of the boundary delineation procedure[xciv]. • Notwithstanding, in Kenya, the registry records and cadastral maps are digitalized about 15% and 70% respectively. Furthermore, most of the maps that support the registration of rural land parcels (Preliminary Index Diagrams) have distortions and inaccuracies that make them of little use for many land administration functions.[xcv] These factors limit the multi-purpose use of the UAV images. *Moderate Compatibility*	boundaries, which is usually low in Kenya, and it is time-consuming for larger areas. Furthermore, there are varying data quality due to the lack of standardized image capture/processing[xcvi]. • Furthermore, large counties like Kajiado will only be able to use UAVs for very site-specific applications[xcvii]. *Moderate Compatibility*	significantly. The input of local stakeholders is important on marking artificial ground reference points for geo-referencing as well as for quality control of the data.[xcviii] • Especially, in areas where invisible boundaries are high or object outlines do not match cadastral boundaries, the participation of local stakeholders can increase the effectiveness of LRTs. *High Compatibility*	only the actors with higher financial and material capacities to have the necessary resources to carry out available LRTs. *Moderate Compatibility*	data sharing between the county governments and the national government. The collected data are stored in different offices and they are not connected. Furthermore, there is a need for a centralized GIS system. Therefore, there are limitations to improve the reliability of UAV image with possible LRTs. *Moderate Compatibility*		the data collection with UAVs by given the limitations with digitalization and lack of technological capacities in most of the local offices. *Low Compatibility*
Software	• The UAV workflow includes various software programs for	• There is not a software-related restriction for capturing data with UAVs	• The software solutions for UAV-based orthoimages do not require input from	• The software for flight planning and flight execution is delivered	• Our experience with open source software suggests that in terms	• Many county governments and field offices lack	• Usually, each UAV requires a different software for the flight

different tasks (e.g. flight planning, densification, georeferencing, 3D modeling, data processing...etc.) and it is possible to use different strategies to improve data quality and processing. • There is a need for calibration of the UAV and selection of appropriate geo-referencing methods according to the data quality requirements of the flight mission. However, the software itself is highly flexible and there is no need of using different software for different circumstances. • It is possible to find open-source solutions for some tasks (e.g. open-source Mission Planner, Open Drone Map[xcix]) ***High Compatibility***	on different landscapes. However, there are different software solutions for image processing (e.g. open-source, Pix4D, Agisoft, Photoscan), and depending on the expertise of the users with the software, the choice of software can affect the final quality of orthoimages. In that sense, if the purpose of the orthoimage is to support cadastral mapping processes with boundary delineation (e.g. through the automated feature extraction), it is important that there is not a compliance problem of the software used in different processes and the software provides the required image quality. Especially, in case there is a need for 3D models (e.g. capturing vertical data on building walls or fences), the deviation is high among different software solutions. ***Moderate Compatibility***	local stakeholders for the final quality. However, permanent ground markers can be established to assess the accuracy and to involve geo-locations of the GCPs into photogrammetric processing.[c] Marking the permanent ground markers can involve local stakeholders as a means to support collaborative processes on defining boundary lines during the participatory mapping. • The effectiveness of image processing on UAV images relies on the delineator's knowledge, skills, and interpretation with boundaries. Especially, in rural areas where boundaries are delineated by landscapes, the input from local stakeholders is important for the effectiveness and accuracy of image processing software. For example, in rural areas of Kaijado, where pastoralists live, the subdivision of the group ranch is usually demarcated using a continuous arrangement of thorn bushes[ci]. ***High Compatibility***	with the UAV equipment and no additional costs are added. However, image-processing software is usually not part of this. There are both commercially and free software available. The price plans for commercial solutions can be subscription-based or one-time charge[cii]. • In Kenya, open-source solutions are rarely known and embraced[ciii]. Therefore, proprietary software for UAVs could be unaffordable for certain public and private operators. ***Moderate Compatibility***	of reliability the best open-source software, Open Drone Map (ODM) cannot compete at the moment with the proprietary alternatives (e.g. Pix4D). However, we expect ODM certainly to improve over time. ***Moderate Compatibility***	digital infrastructure and adequate HR capacities in terms of computer literacy. Therefore, for these organizations, there could be difficulties in installing and using the software with available capacities. ***Moderate Compatibility***	control and flight planning For the commercial software solutions, the update of the software is automatic and it does not require capacity development at the local level. • For upgradability, ODM allows extendable application and API for UAV image processing, as well as visualization, storage, and data analysis functionality [civ]. For the Its4Land project, the adoption of open source solutions is preferred for the upgradability. However, the local capacity for open-source solutions is limited [cv]. and therefore less preferred. In that sense, there is a need for capacity development on using open-source software. ***Moderate Compatibility***

GOVERNANCE SMARTSKEMA KENYA

Governance Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	• In Kenya, SSM has the most value on recording community lands. The tool can address both cadastral and non-cadastral data needs on community land[cvi]. • The county government has the responsibility to collect the data on community land and hold the trust of unregistered community lands on behalf of the community according to the Community Land Act (2016). Therefore, we expect the tool to be most useful to the county governments. • The county governments have gained decentralized autonomy with the 2012 law, but not all county governments have the same capacities to collect and process the land data. Especially, the ICT infrastructure and digitization of records vary case-based. ***Moderate Compatibility***	• The Constitution of Kenya recognizes four forms of land tenure, namely: public land, community land, wakf land, and private land. However, six land tenure systems are discernible in Kenya: the Public Tenure, Private Tenure, Customary Tenure, Wakf Tenure and two special types of tenure; the Informal Tenure and the Ten-Mile Coastal Strip.[cvii] • 67% of land in Kenya is held under communal tenure[cviii] and SSM can significantly increase the inclusion of communal tenure in the land administration system (LAS), However, SSM has poor geometric accuracy in cadastral mapping, therefore it is more useful before a professional survey[cix]. • SSM can also be used to include informal land tenure information in the LAS. SSM has the potential to supplement alternative dispute resolution mechanisms, which is the legislative system recognized to solve land	• SSM is by nature participatory and community-based. The land administration system on community lands integrates county governments and national government (i.e. Cabinet secretary) as well as community representatives in data collection and recording. ***High Compatibility***	• County governments have different financial capacities depending on their natural resources, commercial activities and revenue collection efficiencies. Yet, SSM being lower in cost than mainstream surveying methods, we expect the tool to be affordable in principle for all county governments to operate the system with its resources. ***High Compatibility***	• There are numerous cases of overlapping boundaries and double registrations in Kenya's land information management, clearly indicating that crosschecks are not sufficient[cx]. Although there are ongoing initiatives by the national government and the NLC to merge separate databases into a single standardized system, at the moment these systems are still under development. • SSM relies on data provided by the community. It is not clear how well data collected via the tool aligns with official records and how SSM processes align with official processes. The lack of geometric accuracy can be	• The entry cost for using SSM is relatively low and should be easily attainable, provided that the necessary training is foreseen[cxiii]. ***High Compatibility***	• Both the national government and NLC have their own bodies to innovate the land data management systems. Since SSM will be likely used by the county governments, we do not know to what extent it will be compatible with the data management systems developed by these two bodies. ***Moderate Compatibility***

	disputes in community lands. • The fieldwork suggests that there are differences in terms of digitization of records at the county level. This is, however, a prerequisite for the successful management of SSM. ***Moderate Compatibility***				seen as a drawback for cadastral uses[cxi]. • Due to high land fraud, IP and provenance of sketchmaps as a community document need to be established and recognized by all stakeholders[cxii], including the Ministry of Land and NLC. ***Moderate Compatibility***		
Actors & Networks	• Both counties and the field offices of the national government employ surveyors. Both surveyors have similar functions but they are part of the different governance structures. We expect SSM to be employed by county governments because county governments are in charge of community lands. • Yet, it is possible to shift the responsibilities of the surveyors of county government to the surveyors of the Ministry of Land at the county level in data collection in case there are problems	• Previous work on country needs assessment showed that there are land-related challenges on the ownership rights about women's right (especially in Maasai communities) and the environmental degradation[cxvi]. A strength of SSM is that it is adaptable to field conditions and community preferences for data production[cxvii]. ***High Compatibility***	• There is not a structured framework or signed memoranda to ensure the non-governmental actors partake in data acquisition and recording. But there are ad-hoc collaborations with private actors and civil society organizations. • The fieldwork suggests that the county governments are willing to engage with non-government actors and they are seeking collaboration with them in data collection. Especially, NGOs can play an important role in developing the visual language in conjunction	• On transfer of property, the cost of registration depends on the value of the property. On average, this cost is about 4% of the property value, which may be 'prohibitive' for many Kenyans[cxix]. The total cost of recording a property transfer is high by average Kenyan income levels. The high administrative costs discourage formal recording of land transfers, especially in rural areas[cxx]. • Outsourcing or co-producing SSM with NGOs who are trusted by local communities may be a good alternative, in principle, provided that	• The lack of cooperation between the national government and county government and the previous conflicts between NCL and national government suggest that there is a trust problem between different levels of government. • Our findings suggest that the county government is more trusted than the national government actors because the county government's	• If the necessary participatory frameworks are in place, the custodian organization is established, and required training is provided to the surveyors, in principle, it should be attainable to apply SSM with the present resources of stakeholders within a year. • There are, however, several challenges which we encountered during the pilot	• There are several and experienced private surveyors and international and local NGOs in the governance network. • The technological prerequisites of SSM are relatively low and the flexible usage of the tool allows improvements in the workflow of data collection processes. Therefore, we do not expect major problems in this regard, but we highlight the need to establish a trust relationship with (primarily rural) communities for

	with the capacities of county government. • The responsibilities during the implementation of SSM can also be partly delegated to the NGOs[cxiv] that is familiar with the community. These organizations can facilitate the participatory processes in data collection, develop the visual language in conjunction with the community and support the county government to recognize sketchmaps for the particular domain in which they are working[cxv]. ***High Compatibility***		with the community and facilitating the participation of different segments of the community. • As for SSM, experts highlighted the need to consider age and gender issues in participations. Only by including groups that otherwise would not engage in the data collection can one gather land rights for all members of the community (Amsing, 2016: 37). However, to ensure the participation of all members of the community there is a need for strong local leadership[cxviii]. In Maasai communities where women have a vulnerable position with the land rights, it could be difficult to ensure the participation of all members of the community. ***Moderate Compatibility***	the necessary training is given. ***Moderate Compatibility***	financial revenues rely on local sources where land revenues are important. • Trust has to be rebuilt between land registration authorities and communities, and SSM can provide a useful tool in this regard, as it deliberately involves communities in the land registration process. The data collected via SSM may not always be considered authoritative, though, from a government point of view (Amsing, 2016: 38). [cxxi] ***Moderate Compatibility***	work with Maasai community (e.g. extreme variability in symbol usage; time-consuming engagement with the community; lack of writing skills of participants...etc.)[cxxii]. These challenges may affect the attainability of the tool. ***Moderate Compatibility***	effective SSM implementation. It is uncertain whether private actors meet this requirement. ***High Compatibility***
Problem perspective & Goal ambition	• While SSM has the potential to reduce conflicts related to communal tenure (e.g. issues concerning grazing rights and pathways), the explicit involvement of communities can also	• The land disputes are very common both in terms of ownership and the size of land area. Some of these disputes go back to the colonial period and the others result from the rapid urbanization of peri-urban areas. Especially,	• Section 15 of the Community Land Act (2016) expects a registered community to form a community assembly, which is composed of all adult members of the community, and to	• SSM seems to be more affordable than other field surveying solutions and may have the potential to reduce the costs of conventional methods. Though the affordability is mainly high in the field, the software has to be	• Since a sketch map is based on a person's spatial knowledge, errors are likely to arise, which is common to the qualitative information that SSM gathers. Errors	• An important advantage of SSM is its easy adaptation and cost-effectiveness in comparison to conventional field surveying techniques.	• The bureaucratic resistance towards digitization can impair the effective uptake of SSM in LAS. • A lack of trust in using cloud computing (rather than keeping the data

	create political constraints during the implementation. It is uncertain whether traditional dispute resolution mechanisms (TDR) suffice to resolve disputes at the local level. One should also take into account that SSM does not produce authoritative data from a governmental point of view. ***Moderate Compatibility***	public lands are disputed because of the concerns on historical injustice. • In that regard, SSM can be useful to address longstanding errors in cadastral data and capture of non-cadastral data to address boundary disputes concerning customary tenure. However, at the moment it is still not clear how SSM data will be incorporated into the existing data. • A weakness of SSM is poor geometric accuracy in cadastral mapping, which makes it less useful in comparison to other surveying techniques for the boundary disputes in peri-urban or urban areas where accuracy is vital. ***Moderate Compatibility***	choose seven to fifteen members of the assembly to a community land management committee (CLMC). The management of the community's land is allotted into the CLMC, which is expected to collaborate with the relevant authorities in the development of the community land use plans. • Furthermore, the Constitution recognizes alternative dispute resolution mechanisms. The role of the CLMS and recognition of the alternative dispute resolution mechanisms suggest that there are participatory mechanisms for stakeholders to address emergent problems during the implementation of SSM at the community level. ***High Compatibility***	supported with satellite or aerial imagery, which may nonetheless be costly[cxxiii]. • Updating spatial information over time may also be expensive in comparison to aerial surveying techniques. The system additionally requires Internet connection/coverage, which may as well be costly for some (mainly rural) areas. • Training costs should as well be considered at the initial stages. ***Moderate Compatibility***	can also occur due to the lack of writing and drawing skills of the participants. This reduces the reliability of SSM data for cadastral mapping. The information may, however, be conceived reliable from a community perspective. • Keeping the LAS up-to-date with SSM is a time-consuming process, which requires a continuous updating of the system with fieldwork. Once everything is in place, however, we expect that it will become faster to gather required information[cxxiv]. However, in that regard, SSM has clear disadvantages in comparison to UAVs. ***Low Compatibility***	• The SSM has strong added value in addressing land challenges in rural areas. However, uploading a sketch via a phone or web service may be a challenge for local communities, given the absence of stable Internet connections[cxxv]. These constraints can challenge the attainability of SSM in areas with the poor network coverage. ***Moderate Compatibility***	locally) can hinder upgrading the workflows of SSM. • Significant time is needed to apply SSM for large(r) areas. ***Low Compatibility***
Strategies & Approaches	• SSM is flexible and adaptable to field conditions and community preferences for data production[cxxvi].	• SSM captures qualitative data in mapping and transforms into digital data, which is utmost important to capture data	• SSM is particularly designed to involve stakeholders in land data acquisition process. A major hurdle to	• We estimate that the county governments can afford to operate SSM with available resources. We draw attention,	• SSM aims to capture a person's spatial knowledge, therefore data collected via SSM	• We expect the take-off to be relatively easy by taking into account the low	• We expect that the development of a universal 'Adaptor model' to facilitate the interoperability

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	• SSM data output suited for a range of cadastral and non-cadastral purposes. The fieldwork in Kenya found that SSM is suitable with needs in land tenure mapping, land use planning, and community land register. However, its shortcomings with accuracy limit its usefulness for the cadastral mapping[cxxvii]. *Moderate Compatibility*	on informal tenures in the LAS. • SSM proves especially useful for customary and informal tenures. Additionally, it should be pointed out that it is possible, in principle, to use SSM with different land tenure systems and land types. However, especially in densely populated areas, SSM can have limited applicability in comparison to other direct surveying techniques because of the time and labor needed for data collection. *High Compatibility*	overcome, however, is the inclusion of groups that are often not fully recognized (such as women, youngsters, etc.). Building trust is therefore of vital importance. Furthermore, it is essential that the government recognizes the data supplied by all groups of society. The legal recognition of CLMC is an important step in that regard, but it is important to follow up to what extent CLMC ensures the representation of vulnerable groups. *High Compatibility*	however, to the challenge of difficult Internet access and coverage in some areas. This might hamper data maintenance. *High Compatibility*	by all actors are geometrically not very accurate, which can particularly affect the reliability of data. • Another challenge is related to the symbology that is used, which should fit the communities' approach to land. • Reliability issues can also be due to persons' limited drawing/writing skills, which may result in varying data quality. *Moderate Compatibility*	start-up cost, the familiarity of local stakeholders with sketching practices, and the necessary participatory frameworks are already in place in communities. • For the effectiveness of smart solutions, there is a need for stable Internet connection, which might be challenging in rural areas. However, data acquisition is possible even without a proper Internet connection. *High Compatibility*	between the developed domain models and the land administration domain model (LADM)[cxxviii]. • In the 'Draw and Make' WP, we have demonstrated the functionality of the SSM to convert hand-drawn maps into computer-ready geo-referenced boundary maps through a web-based user interface[cxxix]. This suggests that the tool is upgradable to the changes in the LAS and compatible with improvements in digital technologies. *High Compatibility*
Resources	• County governments have fiscal autonomies to collect land/property taxes, and they are allowed to select a valuation rate up to 4% without a central government approval[cxxx]. Although not all county governments have the same fiscal capacities, we assess the county governments have the	• County governments have different financial capacities, but our fieldwork does not suggest that the available financial resources are not sufficient to implement SSM in different land terrains and areas. *High Compatibility*	• Some county governments have better access to financial resources from private and international donors. Therefore, it is possible using different financial resources to finance the operations at a local level independent from national government resources.	• The WB report[cxxxii] states: "The fees collected from registry services are generally sufficient to sustain operations". Since we do not expect a significant additional cost to the present practices, we expect the SSM operations at the county level to be affordable to sustain with the fees	• The county governments financially depend on the local resources, which suggest that the financial capacities might vary in different counties. However, SSMs will not bring a significant	• We expect that county government to be able to implement the SSM with their available financial resources without the need for additional budgeting processes.	• The fieldwork suggests that there are limited resources for innovation activities and we did not encounter a special budget, which can be used for the innovation activities. The national government has more innovations based on

	flexibility in covering the cost of operations with available resources. *High Compatibility*		• The county governments have the discretion to increase the nominal tax rate and they can higher their private valuers to assess the value of the land. But the revenue collection capacities of county governments vary case by case[cxxxi]. *High Compatibility*	collected from registration services. *High Compatibility*	additional cost to the surveying operations and the county governments have the autonomy in expenses, therefore we do not expect a problem with the reliability of financial resources. *High Compatibility*	*High Compatibility*	private companies and they receive more aid in comparison to county governments. In that sense, the county governments have disadvantages in innovation activities." *Moderate Compatibility*

CAPACITY SMARTSKEMA KENYA

Capacity Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	• In Kenya, SSM is most compatible with capturing the data in community lands. Therefore under the current legislative framework, the county governments are expected to be the likely technology owners. • The current regulative framework concerning the community lands is flexible and recognizes the prevalence of customary law about land disputes in community lands[cxxxiii]. *High Compatibility*	• The 2016 Community Land Act introduced customary tenure rights into the land administration system (LAS). County governments are in charge of registering the custom tenure. • Although the LAS does not recognize informal land tenures, SSM can also be used to include informal land tenure information in the LAS. SSM has the potential to supplement alternative dispute resolution mechanisms, which is the legislative system recognized to solve land disputes in community lands. *High Compatibility*	• While the Land Act and Community Land Act recognize the continuum of rights and the rights of communities, but secondary rights and rights of women, undocumented rights are difficult to establish as formal ownership recorded in documents is privileged[cxxxiv]. For the effectiveness of SSM collected data to support the participation of undocumented rights in the LAS, there is a need of clear provisions how the data will be integrated into the land registration and the dispute resolution processes. • The Community Land Act has participatory provisions[cxxxv], which allow participation of community representatives in the land administration processes.	• The cost of registration of land tenure can be high for poor citizens/stakeholders. The cost of appealing to the Court of Appeal is also high making appeals unaffordable to rural poor and the majority of the citizens[cxxxvi]. SSM can be useful to solve disputes in rural areas, and as such can reduce the number of appeals (and related appeal costs for citizens). • SSM is considered to be lower in cost than mainstream field surveying methods. Therefore, we do not expect any additional administrative cost or user fees after implementation. *High Compatibility*	• Although the current regulative framework recognizes the customary tenure, SSM does not necessarily produce authoritative data from a governmental point of view, since data is provided by the community and might differ from official sources[cxxxvii]. • SSM can serve as an entry point to issue a legal, authoritative document, which would be of added value to the LAS. The sketch maps can be used by surveyors to produce an actual legal record of the land and possibly issue a certificate to achieve tenure security. Relative accuracy is acceptable for this purpose; at a later stage the absolute accuracy can be improved[cxxxviii]. • It is not clear how well data collected using SSM aligned with official records and how SSM processes aligned with official processes[cxxxix]. *Low Compatibility*	• We think the current regulation is attainable for the implementation of the SSM at the county level. *High Compatibility* .	• Improvements in the operational and technical standards of the tool are possible without a need for additional legislation. *High Compatibility*

				Moderate Compatibility			
Political System	• The land data collection system is decentralized in the Kenyan case. Here the main responsibility is on county government concerning the community lands. However, the Ministry of Land has also field offices, which are involved in the data collection through their surveyors. And there is limited cooperation between the field offices of the Ministry and country governments. Especially in the past, areas with richer natural resources have been an issue between national government and county governments. • SSM is community-based by nature. While having the capacity to reduce conflicts, the explicit involvement of	• The Constitution provides for recognition of land under customary land tenure, which would include rural land uses such as pastoralism. • The informal tenures concerning certain tenures in peri-urban areas and tenures concerning Ten-Mile Coastal Strip are excluded at the moment by the land administration system. SSM can facilitate the involvement of both pastoral land and the excluded tenure types in the LAS. ***High Compatibility***	• The field offices of the Ministry and county governments do not share their land data, which is a source of political tension in LAS. • At Maasai tribes, the land ownership rights of women are often disputed. Although the Community Land Act establishes a participatory mechanism for the involvement of communities in the LAS, the Act does not elaborate how to secure the participation of specific actors (i.e. women) rather it treats the community as a whole. • Despite recent regulative changes to secure the land rights of pastoral groups, the political system is in general exclusionary to the pastoral groups in LAS. ***Moderate Compatibility***	• The tool can help to reduce the risk of conflicts emerging after land zoning or subdivision since the entire community is involved and issues can be resolved early in the process[cxl]. This requires, however, a major commitment of political stakeholders to include all relevant local communities. ***Moderate Compatibility***	• A 2002 report of the Njonjo Land Commission[cxli] suggests that citizens have low trust to the land dispute settlement mechanisms and institutions due to delays, incompetence, corruption, nepotism, political interference and overlap of roles and functions leading to conflict, confusion and unnecessary bureaucracy especially when there is low participation of the local people in land dispute resolution mechanisms.[cxlii] The current situation has improved after the enactment of National Land Policy and recognition of the alternative dispute mechanisms. • Community involvement inherently fosters trust between community members and also between communities and external organizations including public institutions such as land planning departments[cxliii]. • The fieldwork suggests that the county government is more trusted than the national government actors	• There have been some political tensions between agencies of national government and county governments in the past about the overlapping responsibilities. However, concerning the community lands the main responsibility is with the county government, therefore we expect less political risk on that matter. • There have been some regulative changes in 2016, which has empowered the role of the national government in land administration. We expect through an inter-agency consultation and consensus on collaborative relationships, it is possible to implement the system at a nation-wide scale. ***High Compatibility***	• The fieldwork suggests that the stakeholders recognize the legitimacy of the central government in deciding on the land governance policies. Despite delays in the political and legislative processes, we think there is enough political capital to implement changes in the system if it is needed. ***High Compatibility***

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	communities can also bring certain political constraints especially-in relation to the boundary conflicts between the public lands and community land. ***Moderate Compatibility***				because the county government's financial revenues rely on local sources where land revenues are important. • SSM precisely can reduce the risk of conflicts. The lack of geometric accuracy can, however, be seen as a drawback for cadastral uses[cxliv]. ***Moderate Compatibility***		
Operational Unit	• We expect the county governments to be the operational units for SSM[cxlv]. But it is also possible private surveyors to adapt SSMs in surveying processes. • SSM data output suited for a range of cadastral and non-cadastral purposes. The fieldwork in Kenya found that SSM is suitable with needs in land tenure mapping, land use planning, and community land register. However, its shortcomings with geometric accuracy limit its usefulness for the cadastral mapping[cxlvi].	• Kenya has a long history of surveying and land tenure registration and there are experienced public and private surveyors. Yet, there is a need for further training to implement SSM as part of the field surveying processes. • SSM further requires that the system be deployed by a custodian organization, which will be responsible for developing the visual language in conjunction with the community[cxlvii]. It is possible local NGOs can take over the role of custodian organization[cxlviii]. • There is also a need for further guidelines	• The Community land management committee (CLMC) can facilitate the participation of the community members during the implementation of the SSM. • Our fieldwork suggests that there is a need for capacity development in participatory processes. For example, one interviewee stated: "If I may tell you the truth and the bitter truth, there is no capacity building [at least from the commission's point of view] so that the field has completely been overlooked or has been neglected by one reason or	• The financial capacities of county governments vary case-based and depending on the region. SSM is, however, very affordable by nature, and lower in cost than the mainstream direct data collection methods. The respondents in the fieldwork did not expect any issues with affordability. ***High Compatibility***	• SSM has a low barrier of entry in terms of technical knowledge. No special skills were required to use the system once it was set up. This means communities play the central role in documenting their land information[cxlix]. • However, there is a need of custodian organization, which is familiar with the local culture, to assist in turning the qualitative representation of land information into authoritative data for the domain model. ***Moderate Compatibility***	• The operational units need limited training in accustoming with the SSM in land data collection. But it is possible to implement SSM without the need for further resources as long as there is enough Internet coverage in the field to use the web-based applications of the tool. ***High Compatibility***	• For organizations that use the SSM system a recommended model is one where selected members of the community are trained to be the community's mappers. A mapper in the community can continuously produce maps, which can then be collected periodically to become part of a rich dataset. The dataset would then be used to generate further samples for training SSMs object classifiers[cl]. • The system must also be deployed within a custodian organization, which will be responsible for developing the visual language in conjunction with the community and this organization

	Moderate Compatibility	at county level how to integrate smart sketches into the official recording processes. ***Moderate Compatibility***	another. Because for example, we need to train the group ranch officials on how to manage land. We need to talk to women, whose rights are been violated by men. Their disputes come to us. Ok, we have issues of capacity building where you have to enlighten people on their rights about their land, land information. It is not there. So all this is a result of lack of resources. Even despite we like to propose, who is going to fund? There is a clear gap in capacity; both for the staff as the capacity for people and other stakeholders too." ***Moderate Compatibility***				can also train the operational unit to recognize sketch maps for the particular domain in which they are working[cli]. ***High Compatibility***
Social Norms	• There are alternative dispute resolution mechanisms and the legislative system recognizes the customary law in land disputes in community lands. It is possible to use	• Especially, in the community lands, there are some tensions between social norms and legal rights. An example is in Maasi culture, daughters are excluded from land inheritance,	• SSM may be hindered by the existence of certain social norms among communities or tribal groups, which can reduce the participation of certain groups in the LAS (e.g. women; youngsters; people	• In rural areas, where the tribal and family relations are stronger, the social capital can facilitate the collaboration of communities in data collection and boundary disputes (e.g. Maasai	• Many transactions take place outside the formal registration process. A common one is the inheritance of agricultural land according to customary norms where the title remains in the name of the original holder, who may be long	• The fieldwork revealed that it is strongly required to develop a relationship with the community that is conducive to sketch mapping research purposes. This can be time-intensive though[clv].	• The fieldwork suggests that the adaptation of new technologies take time in Kenyan case. Stakeholders prefer to see the added value of new technologies and methods.

	SSM to supplement alternative dispute resolution mechanisms. ***High Compatibility***	practicing subdivision but without the legal finality and evidence of a formal subdivision application. Or men can sell the lands to outsiders without telling their wives, contributing further to land disputes.[clii] • In the fieldwork, it was found that many participants from Maasai tribes did not find the concept of a map particularly interesting or were not familiar with it. It took several visits and discussions with the community before many were convinced of what a map could be used for[cliii]. ***Moderate Compatibility***	from different clans…etc.) ***Moderate Compatibility***	community in Kaijado). • However, there are often intra-family disputes in areas where Maasai communities are residing concerning the subdivision of group ranches. In these cases, social capital can act against the affordability of the SSM by complicating access to genuine qualitative data. ***Moderate Compatibility***	deceased[cliv]. • SSM aims to produce an outcome that the community agrees upon, which then, is perceived to be legitimate and reliable from the communities' point of view, though not necessarily from the government's point of view. However, SSM can provide, more authoritative information in comparison to other surveying techniques on customary and informal tenure, as long as participatory frameworks are well established and monitored. ***High Compatibility***	• Furthermore, many participants from tribes were not familiar with the concept of a map. During the fieldwork, it took several visits and discussions with the community before many were convinced of what a map could be used for[clvi]. • It is also possible that some people might have a lack of trust on using cloud computing since they prefer to hold their data locally[clvii]. ***Moderate Compatibility***	• The Maasai community uses a variety of symbols to express themselves, and some participants during the fieldwork preferred different symbols to describe the same landmarks. There was not enough data for training a sophisticated recognition system such as neural networks[clviii]. This suggests that upgrading the system to capture all variety of expressions may require more computing power and thus expensive hardware. Alternatively, there may be a need for community training a joint agreement upon the symbolic description of certain elements to improve the workflow of the system. ***Moderate Compatibility***
Land recording techniques (LRT)	• SSM records land tenure information based on hand-drawn sketch maps, geo-localizes the main elements in the maps using an	• In the general domain of land tenure mapping, the SSM was considered to be useful by the stakeholders for capturing information	• The LRT of SSM heavily rely on the input of the individual participants from communities.	• There are several factors concerning LRT, which may affect the affordability of SSM for county governments. First,	• The replication of data collection processes is time-consuming, and it is possible that gathered qualitative data to be become quickly outdated	• The fieldwork revealed that the lack of writing skills among participants could hinder the qualitative	• The design of SSM (i.e. using Open Source Computer Vision technology, and based on the qualitative data) allows LRT to be

existing base map as a reference, and provides the means to further visualize and further annotate the maps with relevant concepts. This way, it fills the gap that has been left by traditional GIS systems[clix]. • Its flexibility in recording the qualitative data can support multiple purposes in the LAS (e.g. environmental protection; grazing rights, land injustices …etc.). *High Compatibility*	about actual land-use practices and relations. In this respect, the domain model can capture information that currently has no counterpart in official land information systems[clx]. *High Compatibility*	• Furthermore, the development of the inclusion of the common symbology of each community into the domain model requires a custodian organization. Local NGOs can be a custodian organization. Working with experts in the area can also maximize the volume and quality of data collected[clxi]. *High Compatibility*	not all county governments have the same financial and material capacities. This can affect the scope of SSM in land recording operations. Second, the areas those county governments are responsible for may have differences in land recording needs (e.g. coverage vs. accuracy) and infrastructural capacities. Third, some rural areas may be lacking metric maps to be used for map alignment with sketch maps. In that case, the affordability of the SSM should take into account the cost of acquiring metric maps. *Moderate Compatibility*	and therefore unreliable[clxii]. • Furthermore, we expect difficulties in adopting cloud computing into data maintenance. Mainly because of the low availability of Internet connection in many rural areas. Yet, one can make use of the cloud servers and still store data locally. Updates can be processed when there is an Internet connection available. This might pose a challenge with regards to data maintenance since data cannot always be up-to-date[clxiii]. • The choice of spatial representation has a severe impact on the outcome of map alignment between a sketch map and metric map[clxiv]. Especially, in community lands, there are several possible impeding factors (e.g. lack of writing skills of the participants; availability of the metric map…etc.), which may affect the reliability of the final data. *Low Compatibility*	representation of input maps[clxv]. • Furthermore, the extreme variety in symbols encountered during the fieldwork prevented the development of a sophisticated recognition system such as neural networks[clxvi]. This has limited the attainability of more advanced LRTs. • Conventional surveys can be quicker in data acquisition than smart sketchmaps because the latter requires more extensive societal processes for its successful use. Due to its participatory and democratic nature, smart sketchmaps will be more intensive to establish though[clxvii]. *Moderate Compatibility*	upgraded according to the emerging needs. • Smart sketchmaps can be used as an entry point to issue legal document and they can be updated with surveys. The need for geometric accuracy in future may, however, outweigh the benefits of smart sketchmaps[clxviii]. *High Compatibility*
Software	• SSM's software is developed based on Open Source	• The current workflow of the software can work with poor	• The sketching process for the software relies on the	• The SSM software is completely based on open source	• Although there have been several methods used for the object recognition, the	• Many county governments lack digital infrastructure	• The SSM software is developed based on Open Source Computer

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	Computer Vision (OpenCV) technology, and the usage of domain model allows calibrating the object matching processes according to the common symbology of the community. ● Furthermore, the system allows using different sketching modalities[clxix] (e.g. simple pen and paper sketching, using stamps for sketch annotation, and sketching in the ground) depending on the context. ***High Compatibility***	quality maps as input, where the results can be corrected at post-recognition. ***High Compatibility***	participation of the community to provide the input maps. ● Local communities may never have the capacity (physical or technological) to access post-processed sketched data. This may result in disincentivized participation[clxx]. ***Moderate Compatibility***	solutions, therefore we expect them to be affordable. ***High Compatibility***	findings from the fieldwork suggest that it is important to work with local experts during validation and sketching processes for the reliability of data produced by the software[clxxi]. ***Moderate Compatibility***	and adequate HR capacities in terms of computer literacy. Therefore, for many county governments, it could be difficult to install and use the software with available capacities. ● Furthermore, open-source solutions are not prevalent in Kenya; this may exacerbate the skill gap in HR capacities. ***Low Compatibility***	Vision 4 that is released under a BSD license and hence it is free for both academic and commercial use[clxxii]. This suggests that software can be easily upgradable for commercial and other purposes in the LAS. ● However, the fieldwork suggests that there are limited HR capacities in using open source solutions. Therefore, there may need further capacity building action to transfer the necessary skills to upgrade the system. ***Moderate Compatibility***

GOVERNANCE AFE- RWANDA

Governance Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	• The multilevel governance of land administration is Rwanda assigns clear responsibilities to each level (i.e. central, district, sector and cell) in land recording, registration, and development of land management policies. Here the role of the institutions at the national government is to coordinate and manage the system, but except some special cases (e.g. big investments), the district level has full autonomy in data acquisition and recording. At the district level, District Land Bureaus (DLBs) are charged with monitoring, land surveying, valuation, and land use. • The fieldwork suggests that both central and local governments would be interested in implementing AFEs. Especially, the stakeholders at the sector level identified AFE would significantly contribute to their daily work. The fieldwork suggests it might be possible to implement the tool at the sector level but the district level has	• Over 90% of the individual lands in rural and urban areas are mapped, and 70-90% of individual lands in urban and rural areas are recorded[clxxiii] .The collected data are digitized and a hardcopy is saved in state ledgers. In that sense, the system is inclusive in covering different land and tenure types. • Currently, the AFE can only identify clear physical boundaries and social boundaries are out of its scope. AFE has also limitations on areas, which are registered with general boundaries. However, the Land Tenure Regularization Programme (LTRP) turned most of the general boundaries into fixed boundaries. Therefore, we think that there are no significant challenges with the inclusiveness	• There is a participatory system among the levels of government in land registry system and the different levels of government participate in in the processes of land adjudication and conflict resolution[clxxiv]. • At the national level, there is the National Land Commission which provides guidance on the National Land Centre (NLC), which is the highest level of the land registration institution administering and issuing leases, title deeds and certificates on land in all categories; and managing all land-related activities in the country, including those related to information and mapping. • Other institutions at the national level are; the Office of the Registrar of Land Titles (ORLT) and the 5 zonal Deputy Registrar Land Titles (DRLT) are responsible in registering and maintaining records for land ownership through the country. • The District Land Commission (DLC) coordinates land use	• The central government and the district levels are the most capable among the different governmental levels to afford the AFE for the implementation. Cell levels and some sector-level governments still face many challenges with resources and the infrastructure including the lack of digitalized information. *Medium compatibility*	• The rapid urbanization in Rwanda led to widespread boundary disputes in urban and peri-urban areas. AFE can provide authoritative data on boundaries and this way it can improve the reliability of district and sector level government in solving land disputes. However, the reliability of AFE depends on the quality (up-to-date and high resolution) of the available aerial images. At the moment, the available aerial images are from 2009 and with mixed image qualities. • The fieldwork suggests that the stakeholders trust the government for the implementation of AFE. Although the fieldwork does not suggest a particular trust problem with private surveyors, they expect this service to be expensive if delivered by the commercial actors. *Medium compatibility*	• In Its4Land project, AFE should support the UAV cadastral mapping on identified boundaries. Therefore, its attainability is partially dependent on the availability of UAV orthoimages and it responds to the UAV multi-level structure, which is still in progress. However, AFE can also be used independently from UAVs with other types of orthoimages (e.g.Satellite images or classical aerial images) as long as they align with accuracy requirements. • LTRP used 96% aerial images captured in 2008 and 2009 and 4% satellite imagery as base data to demarcate and adjudicate parcel boundaries in the development of a national cadastral map[clxxv]. These base data has not been updated ever since. By taking into account the rapid urbanization at urban and peri-urban areas, we think that the available aerial imagery would be out-of-date and have a little use for	• AFE is based on open-source software for boundary delineation and the improvements in the workflow of the system require operators to have a certain skill in geodata processing with open source GIS solutions • Both district and sector levels of government have surveyors with specialized training. However, the fieldwork suggests that scaling at lower levels of government will require training[clxxvii]. Furthermore, the fieldwork suggests that public operators are not used to working with open-source software that could be a hindrance for the upgradability of the system. *Medium compatibility*

better resources to use and implement AFE at the local level. ***High compatibility***	of the LAS concerning AFE. ***High compatibility***	management and administration at national/district level and ensures that land committees are directly involved in land adjudication and conflict resolution • DLBs are the main responsible body to maintain the land-related records; they authorize and approve surveys and plans. DLBs report to DLCs and also train and provide support to sector land offices, cell-land committees, and other stakeholders. • Sector land offices and Cell land committees are responsible for land allocation in their respective administrative units and they are also part of the land adjudication committee. The importance of cell level is they are usually the first entry points on land disputes for the local stakeholders. • The fieldwork suggests that AFE can significantly contribute to the processes of land adjudication and conflict resolution. The multilevel governance system in LAS is participatory and different levels of government have access to a digital open-platform of land registry.			cadastral mapping even with high-resolution. • The national government is in charge of the aerial operations and it is possible to have future aerial missions to provide more up-to-date data. However, we expect this option to be less attainable considering the time and money is required. Even in this case, there is no guarantee the aerial images will provide the necessary image resolution for the AFE. Therefore, we think that the limitations associated with the UAVs' implementation in Rwanda can affect the attainability of the AFE. • According to the 2017 data, 145 out of 416 (35%) sector offices are connected with the Internet and other 293 sectors have been connected with LAN infrastructures. Laptops have been distributed to Sectors and Cell executive secretaries have been provided with smartphone[clxxvi]. This suggests that although it might be possible to implement AFEs at the sector level, material	

						capacities are in overall limited. *Medium compatibility*	
			Therefore, for the effectiveness of the system, we recommend that the DLBs, sector and cell level organizations to adopt the AFE. Here the decision will depend on the question of capacity. *High compatibility*				
Actors & Networks	• The fieldwork suggests that it is possible both profit and non-profit (e.g. public universities) organizations to take part in the operation of the AFEs. *High compatibility*	• Evidence-based customary rights and land rights of vulnerable groups (e.g. Batwa community; women's land ownership) are largely recognized and recorded by the land registration system. Therefore, the system is mostly inclusive to the specific groups and actors.[clxxviii] • We do not expect a particular challenge with the inclusiveness of the system if AFE is implemented. *High compatibility*	• The AFE is as a method by itself an autonomous tool led by machine-learning algorithms. In that sense, it does not necessarily require input from local stakeholders. However, in case there are limitations with identifying the boundaries, it is possible to implement semi-automated features where the involvement of local stakeholders could be valuable for outlining the boundaries. Yet, the findings in Rwanda suggest that there are limited participatory practices toward local stakeholder in urban planning and development[clxxix]. *Medium compatibility*	• The fieldwork suggests the operational units do not require additional investment to adopt AFE as long as they possess basic computer infrastructure. Since the system operates mostly[clxxx] on open-source solutions, we do not expect an additional cost to current registration services. • It is also possible to have co-production schemes between academic institutions and the government to implement AFEs. This way the cost of training needs could be minimal. • Outsourcing to private surveyors is also an option, but we expect this service to be more expensive than government sources. Furthermore, private surveyors largely work with licensed software	• Governmental actors (i.e. central, provincial, district, cell levels) and non-governmental actors (e.g. private surveyors, universities) are used to working together in land recording. In that sense, the fieldwork does not suggest a particular problem for the reliability of data provided by non-governmental actors. *High compatibility*	• There are some challenges for the government to adopt the AFE in the LAS. The most significant challenges are related to the availability of UAV orthoimages and with the HR resources such as training needs with geodata processing and acquaintance with open-source systems. In the latter, the fieldwork suggests that non-governmental actors can provide training and support with the implementation of the system. Especially, the University of Rwanda can provide the necessary training to the government officials. • For the former, CharisUAS is at the moment the only licensed private UAV operator in Rwanda. CharisUAS is already working with government officials for surveying. We think that	• There are academic institutions with specialized programs on land information systems that can support the upgradability of the system with specialized training to government officials and by including automatic feature extraction into their curriculum. *High compatibility*

				programs, that could be a disincentive for them to adopt an open-source-based tool. ***High compatibility***		it is attainable to establish the system with the involvement of these non-governmental actors. ***High compatibility***	
Problem perspective & Goal/ ambition	• The main external risks that can affect the flexibility of the AFE are related to the quality of the available UAV orthoimages. For the quality of orthoimages, the risks associated with UAV operations can affect the flexibility of the AFE as well. Several external factors can affect the quality of the orthoimages, e.g. weather conditions, wind, the quality of the equipment, flying techniques…etc. But overall there are alternative means to overcome these limitations. • However, for effective implementation of the AFE system, the UAVs should be easily accessible and operable to provide the orthoimages. In that regard, there are certain limitations as there is only one licensed private UAV operator and the process with the government is still in progress. ***Medium compatibility***	• The AFE can work effectively as long as there are visible boundaries in the orthoimage. This feature may limit its functionality in some rural areas. • AFE works best on high-resolution orthoimages. Therefore the areas where it is difficult to obtain high-resolution UAV images (e.g. difficult terrains, areas affected by severe weather conditions) would present a challenge to the inclusiveness of the system. ***Medium compatibility***	• Since AFE is mostly relevant for boundary disputes, AFE can support dispute resolution mechanisms. However, the fieldwork suggests that there are limitations with participatory practices in dispute resolution, especially in peri-urban and urban areas. In the absence of participatory mechanism, the function of AFE to effectively solve boundary disputes could be limited. • The AFE incorporates an interactive QGIS plugin, which allows users directly to edit the data on cadastral boundaries. However, this would require users to have a certain level of computer literacy. ***Medium compatibility***	• We do not expect a significant cost to occur during the implementation of the AFE. In case there are problems with system operation, there may be a need for external expertise but this expertise can be covered with available resources. ***High compatibility***	• In the current system, the aerial images are either old (i.e. from 2008) or rely on Google Earth images. Therefore, there is a need for new UAV orthoimages for the reliability of the system. • Various parameters are interconnected and influence the final data quality of UAV-derived orthomosaics. That also affects the reliability of the boundary delineation with AFE. • AFE tool requires more development and adaptation before being reliably included in real-world cadastral mapping procedures. ***Low compatibility***	• We expect the take-up of AFE to be relatively easy once professionals are trained[clxxxi]. However, if the plug-in would be available only for QGIS, we expect it to be less attainable[clxxxii] considering the public stakeholders' reluctance to operate with open-source systems. ***Medium compatibility***	• The code can be developed for country-specific conditions[clxxxiii], therefore we do not expect significant challenges for the upgradability of the system in case of emergent problems or changing goal ambitions. ***High compatibility***

Strategies & Approaches						
	• Although the software prototype of the AFE is still being developed, the aim is to develop the tool on open source solutions (e.g. QGIS and GRASS GIS). The fieldwork suggests that developing the software only operable with open-source plugins can present a challenge during implementation. • However, the machine learning algorithms can also work with ArcG[clxxxiv], therefore we do not think there is a significant challenge with flexibility in terms of strategies. *High compatibility*	• The AFE software is being developed for the UAV-based surveys in cadastral mapping. At the moment, there is a lack of government strategies and user guidelines on how to support the inclusiveness of the land administration system with UAV technology. Therefore, we think that for Rwanda, there are minor challenges with the inclusiveness of the AFE concerning the absence of the UAV strategies. *Medium compatibility*	• AFE will include an interactive QGIS plugin to include local stakeholders (e.g. GIS operators, surveyors…etc.) to define what visible boundary is a cadastral boundary. This feature allows the user to interactively finalize detected contours to cadastral boundaries by connecting subsets of superpixels, whose collective boundaries correspond to object contours in the image[clxxxv]. To facilitate the participation process, it is possible to disseminate the information via a YouTube video explaining how to install the plugin and to use the software[clxxxvi]. *High compatibility*	• The current approach with developing AFE on open-source solutions makes the strategies for the implementation highly affordable. *High compatibility*	• During the testing the workflow of the AFE, the method selected for initial detection of visible boundaries, i.e.globalized probability of boundary (gPb) contour detection was found unable to process large images. Therefore, the UAV data were reduced in resolution, which consequently led to a reduced localization quality[clxxxvii]. To improve the localization quality, a new workflow is adopted combining gPb contour detection with SLIC superpixels. It was also found that cadastral boundaries demarcated through physical objects often coincide with the outlines of SLIC superpixels. This approach has both improved the reliability of the AFE for image processing with large data and also reduced the processing time[clxxxviii]. *High compatibility*	• The cadastral system in Rwanda is standardized and largely digitized with the LTRP and it includes close to 90% of urban and rural areas. Although not all available aerial imageries are up-to-the standards for the effective uptake of AFE, we think that there are only minor challenges to the attainability of AFE with the existing cadastral data[clxxxix]. *Medium compatibility*	• The workflow is modular and can thus easily be upgraded when better methods emerge in image analysis/computer vision or machine learning • The current approaches to the AFE can be improved in time according to the country conditions. For example, it is possible to modify the workflow to include boundary delineation on smart sketchmaps. This way it is possible to integrate local spatial knowledge and to delineate socially perceived boundaries, which are not visible to optical sensors[cxc]. *High compatibility*
Resources	• After decentralization reforms, the district governments have been granted the financial autonomy and the discretion for expenditures. Although	• We do not expect a particular challenge with financial resources that can affect the inclusiveness	• The fieldwork suggests that non-governmental actors, primarily universities, can partake in the implementation of the AFE such as providing training to government officials or	• We expect low start-up and ongoing costs that can be accommodated in the current budget.[cxci] *High compatibility*	• We do not expect any significant challenge with the reliability of the financial resources that can affect the operations	• We think that it is possible to implement the system without a need for additional budget. Therefore we do not expect a significant	• Upgrading the AFE mostly concerns with the software development costs (e.g. costs for development, fieldwork, prototype,

not all district governments have equal financial resources, we do not expect a significant challenge at the district level to cover the cost of the AFE. • The financial resources are scarcer at sector and cell levels to purchase the computer hardware and software needed for the implementation. *Medium compatibility*	of the LAS during the operation of the AFE. *High compatibility*	working with the tool. Therefore, it is possible to reduce the cost of implementation through the schemes of co-production. • Our analysis on the UAVs suggested that there are certain governance challenges associated with the availability of participatory systems in the financing of the UAV missions. In case these structural challenges are not addressed, the cost to operate with AFEs might be inflated with the cost of the commercial UAV operators. *Medium compatibility*		at the district and national level. *High compatibility*	challenge with the attainability. *High compatibility*	and implementation). Yet, scaling up the system would require further investment in training surveyors with GIS skills, computerizing cadastral data capture, data storing and managing, and knowledge transfer/teaching costs on how the approach works. Nevertheless, there are special funding options available both from national and also international sources that can support new projects to improve the system. *Moderate compatibility*

CAPACITY AFE- RWANDA

Capacity Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	• We do not expect a direct challenge associated with the regulations that can affect the capacity of the AFE operators. However, regulative restrictions associated with the capacity of the UAV operators can indirectly affect the capacity of the AFE operators by limiting their access to the UAV images. ***Medium compatibility***	• Land tenure regularization program (LTR) has standardized most of the informal and customary tenure under formal tenures. Furthermore, LTRP turned most of the general boundaries into fixed boundaries. Therefore, we do not expect a significant challenge associated with regulations that can directly affect the inclusiveness of the system. • However, regulative restrictions associated with the UAV operations can indirectly affect the inclusiveness of the AFE operations by limiting their access to the available UAV images. ***Medium compatibility***	• The regulations are mostly participatory in providing access for vulnerable people (e.g. women, poor population…etc.) into the system. For example, the land rights of vulnerable people are recognized through the issuance of a land title in their name and those who could not afford and who were registered in the list of poor households were exempted to pay registration fees.[cxcii] Therefore we do not expect a significant challenge associated with the regulations that can limit the participation of certain stakeholders in the AFE workflow. ***High compatibility***	• In 2019, Rwanda was ranked 2nd in the world in terms of regulatory performance with property registration, with 0.1% of the property value as registration fees[cxciii]. With this score, Rwanda has one of the most affordable land registration systems in the world. • However, regulative restrictions associated with the affordability of the UAV licenses can indirectly affect the affordability of the AFE operations by limiting the access to the cost-effective UAV images. ***Medium compatibility***	• The Land Act (2013) is mostly reliable and authoritative on the land rights and processes with land transactions and registrations. However, Act.34 states that the State can expropriate the landowners in case it is for the public interest. However, the law does not specify the compensation for expropriation. This has led to significant public protests, especially in Kigali in areas that are subject to urban renewal projects. The fieldwork suggests that there are at the moment several cases at the court. These limitations with the law can influence the reliability of the AFE to support land adjudication processes.	• There is not a particular piece of legislation, which regulates the analysis of the image records. But we do not expect there is a need for further regulation to adopt AFE in the LAS. ***High compatibility***	• We do not expect a significant challenge associated with regulations that can directly affect the upgradability of the operational and technical standards with the AFE operations. ***High compatibility***

					Medium compatibility		
Political System	• Rwanda has a strong presidential political system (i.e. little independent power for judiciary and parliament) and hierarchical political traditions, which situates the central government at the core of the political system. • The current government has a progressive agenda towards sustainable development goals and supported fiscal, administrative, and political decentralization toward district level without relinquishing its political control[cxciv]. Therefore we do not expect particular political constraints that can affect the implementation of the AFE at the district level. ***High compatibility***	• Social tenures are out of the scope of the AFE. However, the LTRP transitioned all customary tenure to private or state tenure. Therefore, we do not expect the implementation of AFE to affect the inclusiveness of the system. ***High compatibility***	• The LTRP was implemented on a participatory system of boundary adjudication and strengthened the gender equality in the LAS. Furthermore, the LTRP adopted open-data policy and the land registries are available on an open database for public access and use. • There are no particular marginalized groups by the political system in the LAS, which can affect the implementation of the tool. ***High compatibility***	• The fieldwork does not suggest a particular political cost for the stakeholders (e.g. colliding political interests; political unrest in a certain part of the country) that can affect the affordability of the AFE technology in the LAS. ***High compatibility***	• The fieldwork suggests that stakeholders expect national and district level administrations to be capable of implementing the system, and also the national government to provide the necessary training to lower tiers of government. ***High compatibility***	• The political system has high legitimacy and control over the public sector to implement the AFE technology at a national scale. ***High compatibility***	• The political system is supportive of new technologies (e.g. cloud-based systems, blockchain technology) and progressive to implement technological and operational improvements in the LAS. ***High compatibility***
Operational Unit	• The AFE allows flexibility in boundary delineation by allowing semi-automatic/interactive selection and editing of	• For the inclusiveness and efficiency of the system, it is important that the tool is adopted at a governance level that is closest to the	• During the operation of the tool, there may be a need for collaboration with non-governmental actors (e.g.	• We expect a low start-up and ongoing cost depending on the state of the ICT infrastructure at	• The surveyors need certain skills in geodata processing and in using open-source software programs for	• We assess that there is a need for further training on geodata processing with open source programs (i.e QGIS)	• The system operates with open-source programs, which are not common among operators. Therefore, we expect the skills to improve the

	the object outlines to digitize final cadastral boundaries. However, in order AFE successfully delineate boundaries, the image data should align with local accuracy requirements. For that, the UAV images have the highest compatibility with the accuracy standards. However, it is possible to work on other aerial and satellite images, which would be still an improvement than completely relying on manual methods. • In Rwanda, most of the land data is digitized and there are available aerial images with different image quality. Therefore, the system has flexibility in combining a machine-based automatic feature extraction with a delineator-based interactive delineation. *High compatibility*	people. This way, local stakeholders can be easily involved during the semi-automatic boundary delineation processes. • Considering the technical capacities required for the AFE operation, we expect the main operational unit for the AFE tools to be the District Land Bureau (DLB), but it is also possible the tool can be adopted at sector level in certain administrations with adequate capacities. • The inclusiveness of the AFE is also closely related with the access to UAV images. For that, our analysis suggests that district level has more capacities to operate with UAVs either through its resources or by outsourcing to the private operators. Therefore, we think that there are capacity limitations to adopt AFEs lower than district level. *Medium compatibility*	Universities or private sector organizations) to acquire high-quality orthoimages or for training purposes. The fieldwork suggests that district level and sector level authorities have experiences with working non-governmental actors. *High compatibility*	district and sector level[cxcv]. • We expect district level administrations to have the necessary resources to afford the system, but we do not expect all sector level administrations to have the necessary resources to invest in the ICT infrastructure if needed. *Medium compatibility*	editing data. Although the surveyors at district and sector levels have previously received training on operating with the ArcGIS system, the fieldwork suggests that there is a need for further training for the implementation of the AFE. *Medium compatibility*	for the implementation of the AFE. *Medium compatibility*	system will be limited inside the operational units. *Medium compatibility*
Social Norms	• The Rwandese government embraced	• The Rwandese government is	• Previous projects and the fieldwork suggest	• The AFE can significantly facilitate	• The Rwandese land administration	• We do not expect a significant	• The current government has a clear political

	a strategy called 'Home Grown Solutions' to combine traditional practices with sustainable development goals. One of them is the *Imihigo*[cxcvi], where an individual commit to deliver certain act within a specific period. These social practices are embraced in the performance contracting of the land administration system. • In Rwanda, previous experiences in land administration system also suggest that governance actors have a culture of exploring innovative solutions and implementing changes to the processes. • The combination of the 'homegrown solutions' and embracement of innovative solutions can facilitate the implementation of the AFE albeit not necessarily affecting the way the tool is adopted. ***High compatibility***	implementing a pro-active policy in achieving social equality among different ethnic groups and the empowerment of women. In line with it, recently the inheritance law has been revised to allow women to inherit more easily. • However, traditionally sons are preferred over daughters in heritage rights, which may cause discriminatory acts against women in rural areas and land disputes about the ownership. • Furthermore, a 2018 report prepared by the National Institute of Statistics of Rwanda[cxcvii] (NISR) shows only a small percentage of formal transactions are recorded in LAIS[cxcviii]. By law, parcels of less than one hectare cannot be subdivided, yet the subdivision of land among family members is common as part of the inheritance practices. Especially, in urban areas with a high level of population density, it is possible that the practice with informal transactions	that the land administration organizations have an organizational culture to collaborate with NGOs, local actors, and international organizations. Therefore, we expect them to be able to collaborate with non-governmental actors during the implementation of the tool concerning capacity building activities. ***High compatibility***	land adjudication processes by allowing the operators to directly edit the cadastral data and providing authoritative information. The social capital in these processes is important because it can facilitate the collaboration and thus supports the affordability of the tool in solving land conflicts. The fieldwork does not suggest a significant challenge with social capital, which can affect the affordability of the system. ***High compatibility***	authorities have a high legitimacy in society. Therefore, we do not expect social norms to undermine the authoritativeness of the system. ***High compatibility***	challenge about social norms, which can postpone the implementation of the AFE in the land administration system. ***High compatibility***	agenda to turn Rwanda in the innovation hub of Africa[cc]. The rate of young population and the citizen's support to the innovation policies of the government suggest that social norms are supportive of the improvements in the LAS. ***High compatibility***

		can further boundary disputes. • The current prototype of AFE does not capture socially perceived boundaries so it could have limited functionality if the government addresses the problems with informal transactions. However, it is possible to combine AFE with smart sketch maps and thus to attribute boundary delineation with non-spatial data as long as the social boundaries are visible[cxcix]. ***Medium compatibility***					
Land recording techniques (LRT)	• The LRTs with AFE can support the land administration system in multiple ways by improving its efficiency and effectiveness in cadastral mapping, in land adjudication and dispute resolution mechanisms. ***High compatibility***	• At the moment, the AFE cannot process the information with social tenure. Although we do not expect to be an important challenge after the implementation of the LTRP, the workflow with AFE may need modification if the government decides to increase the inclusiveness of the LAIS by addressing the informal transactions in the system. ***Medium compatibility***	• The AFE does not need input from non-governmental actors for its operations. • However, the uptake of UAV-based surveying missions by the non-governmental actors would facilitate the availability of UAV-based imageries. ***Medium compatibility***	• We do not expect a significant challenge with the affordability of AFE tool at the district level as they have the required hardware and software equipment as well as adequate online infrastructure. • There might be some limitations at sectoral level with hardware and software equipment, as well as Internet coverage.	• The AFE allows directly editing the cadastral maps and this way keeps them up-to-date. However, the reliability of the AFE depends on the availability of visual boundaries and high-quality aerial images in the registries. In the case of Rwanda, there may be certain limitations	• We assess that there is a need for further training on geodata processing with open source programs (i.e QGIS) for the implementation of the AFE. • Furthermore, at the sectoral level, there may be a need for further investment in the ICT infrastructure. ***Medium compatibility***	• AFE workflow is easily upgradable because of the modularity of the workflow. However, there may need external expertise to train the operators in using the new features. But we do not expect this to significantly challenge the upgradability of LRTs. ***High compatibility***

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					concerning the latter. ***Medium compatibility***		
				Medium compatibility			
Software	• AFE's open-source software basis allows the workflow of the tool to be easily calibrated according to the cadastral mapping practices in the country. • Although the current AFE prototype is developed on the QGIS plugin, it is also possible to use ArcGIS plugin, which is commonly used in the case of Rwanda. Yet, the software still needs to be developed to be ArcGIS compatible. Also, the QGIS plugin only covers the last of the three workflow steps. The rest relies on open source code in C++ and Python but is currently not user-friendly to use. ***Medium compatibility***	• The software of the AFE is developed to process 2D cadastral maps and cadastral representations in 3D are excluded[cci]. • During automatic extraction, vegetation is named as the most limiting factor since they often obscure the view of the actual boundary[ccii]. This can limit the visual detection of cadastral boundaries automatically. Yet, the interactive QGIS plugin option allows the operator manually to enter the missing data. • In Rwanda, most land tenure is based on fixed boundaries and digitized. Therefore, we do not expect a significant challenge with the inclusiveness of LAS about the software. ***High compatibility***	• The software allows the operators directly to edit the cadastral information through an interactive QGIS plugin. In this sense, it is highly participatory ***High compatibility***	• Open source solutions (e.g. QGIS) make the purchase of the AFE affordable. But the lack of HR capacities on open-source software suggests that the cost of training, maintenance and adaptation should be taken into account for the affordability. ***Medium compatibility***	• The AFE software is developed on data from the case locations and compared to cadastral reference data, but the reliability of the software is not tested in a real-world cadastral mapping procedure. ***Medium compatibility***	• The AFE workflow is based on open-source solutions and requires a certain skillset to operate with geodata processing with open source solutions. Therefore, we expect a certain time and allocation of resources to train the operators. ***Medium compatibility***	• The fieldwork suggests that the commercial software licenses that are purchased as part of a project funded by donor organizations are rarely renewed when the project ends. However, since the AFE tool mostly based on open source solutions, we do not expect significant challenges with the renewal of licenses. However, we do not expect that in the short-term, the operators to have the skillset to improve the software. • The fieldwork suggests that open-source solutions are not common in Rwanda, and if it is decided to develop AFE with ArcGIS plugins, the system might be more expensive and more difficult to upgrade. ***Medium compatibility***

GOVERNANCE AFE- KENYA

Governance Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	• There are three key actors (i.e. Ministry of Land, county government, and NLC) in the governance of land administration system (LAS), and their responsibilities overlap in certain areas mostly concerning the public land. • The Ministry of Land and its field offices at the county level have the responsibility to give the ownership document (i.e the title deeds) and they are responsible to collect the information on the private ownership. The national government also deals with boundary disputes. AFE can most significantly contribute to the boundary disputes and therefore, the national government is expected to be involved in the governance structure of the AFE operations. • The county government has the responsibility to collect data on community land. The county governments have gained	• The Constitution of Kenya recognizes three forms of land tenure, namely: public land, community land, and private land. However, five land tenure systems are discernible in Kenya: the Public Tenure, Private Tenure, Customary Tenure, and two special types of tenure; the Informal Tenure and the Ten-Mile Coastal Strip.[cciii] The latter two are also called social tenure. • While the customary tenure dominates most of the rural lands in Kenya, the private and public tenure systems control land in the urban areas. The informal tenure is dominant in the urban areas as well as in several large-scale farms in the country in the form of squatters. The Ten Mile Coastal Strip is found only in the Coast Province of the country and has the longest history of all the tenure systems in Kenya.[cciv] • Rapid urbanization means that increasingly, customary tenure needs	• The 2016 amendments with land laws have made changes in the land registration system. Accordingly, the areas that the registration units are responsible to be decided by the Cabinet Secretary in consultation with the NLC and county governments. Land registration units (LRU) are established at the county level and other levels are expected to provide access to land administration and registration services. Furthermore, each LRU should include a Community Land Register to manage the cadastral information of the registered community lands. The unregistered community lands are held in trust by the county government. • However, actual practices suggest that the system has been less participatory than the regulative framework suggests. For example, existing processes around the subdivision	• The affordability of the AFE operations is closely linked with the affordability of acquiring high-resolution visual images on the targeted area and digitizing the land administration system, as most cadastral maps are paper-based and there is not a centrally managed land information management system (LIMS) to access high-resolution image data. Consequently, we think that the affordability of the AFE is limited only to the authorities at the national level or to certain county governments with adequate digital records and infrastructure, and resources to afford UAV operations. ***Low Compatibility***	• There are numerous cases of overlapping boundaries and double registrations in Kenya's land information management, clearly indicating that crosschecks are not sufficient[ccviii]. Although there are ongoing initiatives by the national government and the NLC to merge separate databases into a single standardized system, at the moment these systems are still under development. • Most of the land data are stored in paper-form and the data are often not up-to-date. Therefore, there are significant challenges with the reliability of data in state ledgers. This suggests that not only digitization of paper-based data but also a more streamlined governance structure in land information management system	• There are currently 52 different land registries in Kenya, which the Ministry of Lands have been trying to integrate through the large-scale digitization of land records. The digital land registry was launched in 2018, operational for Nairobi, and the rest of the country by 2019. • There are several governance challenges (e.g. ongoing process with digitization, lack of a functioning LIMS, the pending process of UAV regulations), which prevent the attainability of AFE by the government administrations in a short time. However, depending on the availability of digitized records and infrastructure, it might be possible to pilot AFE in	• AFE is based on open-source software for boundary delineation and the improvements in the workflow of the system require operators to have a certain skill in geodata processing with open source GIS solutions [ccix]. • Both county and national levels of government have often surveyors with GIS training and sometimes personnel with education on geospatial technologies. However, the fieldwork also suggests that public operators are not used to working with open-source software that could be a hindrance for the upgradability of the system. ***Moderate Compatibility***

decentralized autonomies with the 2012 law, but not all county governments have the same capacities to collect and process the land data. • The National Land Commission (NLC) is created in 2012. Initially, NLC was supposed to play a larger role in the management of the public lands and lead the land administration system towards a depoliticized, reliable system. However, following an amendment in 2016, NLC's role is replaced by the Cabinet Secretary and NLC is now in charge of the management of the public land without any field offices. • The analysis of the multilevel governance structure suggests that all three actors can use AFE to support their role in the LAS. The fieldwork suggests yet the county level is the right level of government to implement the AFE operations. However, the overlapping responsibilities in certain areas and the lack of digitized records	to be considered, e.g. in the project's case study site, Kajiado, where most of the county is Maasailand (i.e. customary tenure, currently still held as Communal Group Ranches. Communal group ranches were mainly imposed in ASAL areas of Kenya. • Both the county government and the national government collect and store the data about their respective tenure types. However, the public land tenure that corresponds to 10% of lands in Kenya is delineated in two broad areas, in which both the national government and local government have responsibilities in recording the land data[ccv]. The fieldwork suggests there is limited data sharing between the ledgers of county government and national government, and there are differences in terms of digitalization of records. This suggests that not only the collection of data but also the management of data can be a challenge for the governance of the AFE system.	of group ranches have been by no means participatory or transparent and have led to members within a group being dispossessed of their land, particularly women[ccvi]. The Ministry has also recently been in the news[ccvii] about adopting a lack of participatory processes. *Moderate Compatibility*		(LIMS) is needed in LAS to successfully implement AFE. *Low Compatibility*	certain selected land administrations. *Low Compatibility*	

	in the state registries suggest that there might be limited flexibility in the implementation of AFE in different levels of government. ***Moderate Compatibility***	• Currently, the AFE can only identify clear physical boundaries and socially perceived boundaries are out of its scope. In Kenya, this can limit the inclusiveness of the LAS concerning some customary and informal lands. ***Moderate Compatibility***					
Actors & Networks	• Both counties and the field offices of the Ministry employ surveyors. Both types of surveyors have similar functions but they are part of the different governance structures. • The distinctions between the roles of the surveyors are unclear and this has caused in the past problems about overlapping responsibilities and jurisdiction. The fieldwork suggests that the situation is solved through a status quo, where both actors conduct surveys and data recording separately. • Since both county governments and field offices of the Ministry of Land collect data, it is possible to shift the roles from one actor to another in collecting the	• The Kenyan LAS does not recognize the rights of informal communities, and given the dominance of informal tenure (due to weak land market), this suggests the propensity for many to be excluded if AFE is implemented in cadastral surveying. • Women's access to land is still a significant issue[ccx]. • Indigenous land rights continue to be an issue in Kenya. • Despite institutional reform, a legacy of patronage and clientelism indicates difficulties in achieving true transparency and inclusion in the land sector. ***Low Compatibility***	• There is not a structured framework or signed memoranda to ensure the non-governmental actors partake in data acquisition and recording. But there are ad-hoc collaborations with private actors and civil society organizations. • AFE itself as a tool does not require input from non-governmental actors, but private sector organizations and non-profit organizations in Kenya can support in providing high-resolution image data or UAV image data for public officials or if they are authorized they can use the tool directly to delineate the borders and to share the result with government officials. The fieldwork suggests that some public officials would be	• On transfer of property, the cost of registration depends on the value of the property. On average, this cost is about 4% of the property value, which may be prohibitive for many Kenyans[ccxi]. The total cost of recording a property transfer is high by average Kenyan income levels. The high administrative costs discourage formal recording of land transfers, especially in rural areas[ccxii]. • The fieldwork suggests that there are private operators that would be interested in implementing AFE for their surveying activities. ***Moderate Compatibility***	• The lack of cooperation between the national government and county government, and the widespread land conflicts between pastoralists, farmers, and conservationists[ccxiii]suggest that there is a trust problem in the system. • The fieldwork suggests that the county government is more trusted than the national government actors because the county government's financial revenues rely on local sources where land revenues are important. • However, there are distinct capacity differences among county governments, which can reduce	• There are several challenges for private surveyors to adopt AFE, such as completion of the regulative framework for UAV, completion of the digitization of paper-based cadastral maps, and implementation of a LIMS, which allows editing and uploading cadastral maps through an online platform. Although there are on-going initiatives in each one of them, we do not expect the procedures to be completed within a short time. ***Low Compatibility***	• The governance network includes private actors (e.g. GEOIT) and international organizations (e.g. GLTN), which have expertise in land administration systems and new technologies. For example, GLTN works mostly with county governments, while GEOIT mostly works with the national government. This suggests that if the government addresses the preconditions for the AFE's implementation, it is possible for stakeholders to support the improvement of the system.

	image data for the AFE. There are however capacity differences concerning ICT infrastructure between county governments and also between county government and field offices of the Ministry of Land in the same region. Furthermore, the availability of using UAV operations is another factor, which can limit the flexibility among different types of public surveyors. • The fieldwork suggests that county governments would be interested in including private surveyors in the governance of AFE operations. Similarly, the fieldwork suggests that geospatial technology companies working with government authorities would be interested in adapting AFE to their operations. *Moderate Compatibility*		interested in receiving the services of private sector organizations in that regard. *High Compatibility*		their reliability in providing authoritative data. *Moderate Compatibility*		*High Compatibility*
Problem perspective & Goal ambition	• The evolution of the land administration laws in Kenya suggests that there are some political risks, which can affect the operation of the UAV and AFE.	• The land disputes are very common both in terms of ownership and the size of land area. Some of these disputes go back to the colonial period and the others result from the rapid urbanization of peri-	• AFE can have an added value on land adjudication processes. The Land Adjudication Act has participatory characteristics in recognizing the customary law in	• AFE itself has a low start-up and ongoing costs as it operates mostly on open-source solutions. However, the affordability of the system is dependent on the availability of the	• There are limitations in using maps in land registries, as general boundaries are common. AFE can be applied with general boundaries, but there are limitations	• The bureaucratic resistance towards digitization and legal uncertainties with UAVs can impair the effective uptake of the AFEs with UAV-based	• As an alternative to the UAV images, it is possible to upgrade AFE to extract boundaries from smart sketchmaps. However, this idea

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	• There are overlapping responsibilities at the county level and the data are collected in separate ledgers of the county and devolved national government. During the fieldwork, we found that these local authorities don't share their data. In the presence of multiple conflicting records, AFE cannot effectively be implemented to solve boundary disputes, which is a severe political problem. • Furthermore, the limitations with the digitization of maps suggest that the AFE would have limited functionality until the data is transferred into a digital format. • There are vested interests in the management of the public lands and there are reasons to suspect that the political interests can cause transactions costs on the operation of the tools. However, at the moment it appears that there is a *status quo* between the actors about not intervening in their operations, which suggests that it is	urban areas. Especially, public lands are disputed because of the concerns on historical injustice. For example, during fieldwork one interviewee said: "Like in Kajiado we have a lot of issues over land, a lot of acres has been taken away. I saw 10 to 20 acres of land that has been taken away and I saw people manipulating the document to have 50 acres of land. These are disputes that raise". AFE can contribute to the solution of land disputes in rural areas but for that, there is the need for aerial or satellite images and visible boundaries as general boundaries are common in rural areas. • There are also limitations with the inclusiveness of the UAV missions if the government decides to capture new aerial images in rural areas. For example, during the pilot work, there were difficulties in accessing suitable landing sites, all UAV and GNSS equipment had to be carried by foot to the area of interest because the vehicles could not pass the river[ccxiv]. ***Moderate Compatibility***	decisions and the arbitration committees and boards include different governmental levels as well as local and community stakeholders in its composition. The participatory mechanism of the land adjudication processes can support the legitimacy and reliability of AFE data in revising cadastral map information. • Since AFE is mostly relevant for boundary disputes, AFE can support dispute resolution mechanisms. However, the fieldwork suggests that there are limitations with participatory practices in dispute resolution, especially in peri-urban and urban areas. In the absence of participatory mechanism, the function of AFE to effectively solve boundary disputes could be limited. • The AFE incorporates an interactive QGIS plugin, which allows users directly to edit the data on cadastral boundaries. However, this would require users to have a certain level of computer literacy.	high-resolution image data. Therefore, there are limitations with the affordability of the tool • The digital infrastructure is not stable in every region, which can reduce the effectiveness of AFEs in seamlessly feeding data in the land recording system. We do not expect each county has adequate financial resources to develop the infrastructure. ***Moderate Compatibility***	(visible boundaries, clear landscapes that form the general boundaries...etc.) for the reliability of the output. • There are also limitations with the quality of the aerial images. The Kenyan government at the moment uses simple tracings from the photos to produce temporary and interim maps called the Preliminary Index Diagrams (PIDs) for the first registration[ccxv]. These PIDs are still being used for registration of land adjudicated areas to the present day[ccxvi]. We expect limitations in automatically extracting the boundaries from these images. ***Low Compatibility***	orthoimages. As one interviewee stated: "The legal requirement to submitting work on the operational level is still manual or still old school. This blocks innovation. Why would I as a surveyor bother to do digital things if the government doesn't need it? It makes it easier for me to use the old tools. Another one is the legality. So, for example, the title deed is legally only valid because of the green card until a digital title is legal. We will not go that way. A survey plan, If I want to reassemble a boundary, I need to use a legal survey plan, which is paper-based at the moment. It will not make sense to have a digital map in the governmental office when it is legally not recognized. Those are some of the challenges."	is on a theoretical level at the moment, it is difficult to upgrade the AFE for that goal during the implementation of the its4Land project. ***Moderate Compatibility***

			High Compatibility			• Yet, the requirement about financial and HR resources is relatively easy for the take-up. However, if the plug-in would be available only for QGIS, we expect it to be less attainable[ccxvii] considering the public stakeholders' reluctance to operate with open-source systems. *Moderate Compatibility*	
possible to have alternative ways of governing the UAV and AFE operations in case of political risks. *Moderate Compatibility*							
Strategies & Approaches	• Although the software prototype of the AFE is still being developed, the aim is to develop the tool on open source solutions (e.g. QGIS and GRASS GIS). The fieldwork suggests that developing the software only operable with open-source plugins can present a challenge during implementation. • However, the machine learning algorithms can also work with ArcG[ccxviii], therefore we do not think there is a significant challenge	• The AFE software is primarily being developed for the UAV-based surveys in cadastral mapping. At the moment, the legislative framework with UAVs is still progressing even though it is possible to have UAV flights with the special permit of aviation safety agency. However, we expect the availability of UAV-based image data to be limited at the moment. *Moderate Compatibility*	• AFE will include an interactive QGIS plugin to add local stakeholders (e.g. GIS operators, surveyors…etc.) if the software cannot delineate the boundaries automatically. This feature allows the user to interactively finalize detected contours to cadastral boundaries by connecting subsets of superpixels, whose collective boundaries correspond to object contours in the image[ccxix]. To facilitate the participation process, it is possible to	• The current approach with developing AFE on open-source solutions makes the strategies for the implementation highly affordable. *High Compatibility*	• During the testing of the initial workflow of the AFE, the method selected for initial detection of visible boundaries was found unable to process large images. The current workflow of AFE includes image segmentation, boundary classification, and interactive delineation processes. This approach has both improved the reliability of the AFE for image processing	• There are still legal uncertainties on the rules of UAV flights and there is a lack of centralized land information system, which impairs the effective adaptation of available AFE strategies. *Low Compatibility*	• The current approaches to the AFE can be improved in time according to the country conditions. For example, it is possible to modify the workflow to include boundary delineation on smart sketchmaps. This way it is possible to integrate local spatial knowledge and to delineate socially perceived boundaries, which are not visible to

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	with flexibility in terms of strategies. ***High Compatibility***		disseminate the information via a YouTube video explaining how to install the plugin and to use the software[ccxx]. ***High Compatibility***		with large data and also reduced the processing time[ccxxi]. ***High Compatibility***		optical sensors[ccxxii]. For the case of Kenya, improving the AFE workflow compatible with smart sketch would be highly valuable. ***High Compatibility***
Resources	• County governments have fiscal autonomies to collect land/property taxes, and they are allowed to select a valuation rate up to 4% without a central government approval[ccxxiii]. Furthermore, there is a weighted formula[ccxxiv] to arrange the intergovernmental transfer shares to the county governments without the discretion of the central government. However, not all county governments have the same fiscal capacities and not all of them have updated valuation roles, which affects their ability of revenue generation. • The field offices of the Ministry do not have flexibility in expenditure decisions and their budget has to be	• The fiscal and administrative capacities at county government differ from region to region, which could affect their material capacities to implement AFE tool. Furthermore, the fieldwork suggests that land data is often registered manually based on paper-based maps. The financial resources needed for the digitization of paper maps can limit the inclusiveness of the system. ***Moderate Compatibility***	• Some county governments have better access to financial resources from private and international donors. Therefore, it is possible using different financial resources to finance the operations at a local level independent from national government resources. • The county governments have the discretion to increase the nominal tax rate and they can hire their private valuers to assess the value of the land. But the revenue collection capacities of county governments vary case by case[ccxxv]. ***High Compatibility***	• The WB report[ccxxvi] states: "The fees collected from registry services are generally sufficient to sustain operations but since this money must first go to the Exchequer, there is no guarantee that it will be available when needed to sustain services." This suggests that it might be possible to finance the cost of maintenance with the revenues from the land registration system, but weak administrative capacities concerning the transfer of revenues to field offices can hinder the affordability of operations at the county level. The county governments, on the other hand, have financial autonomy over their resources, but varying financial capacities among county governments can affect the	• The county governments financially rely on the local resources, which suggest that the reliability of their resources depends on their financial and local capacities (e.g. efficiency in revenue collection, the land value…etc.) • The financial resources of the field offices are dependent on the transfers from the central budgets, but there are uncertainties about the availability of the funds to maintain the system when needed[ccxxvii]. ***Moderate Compatibility***	• We expect a low start-up cost depending on the state of ICT infrastructure and availability of the image data with visible boundaries. However, there are many challenges with the latter two conditions, and we do not expect it is financially attainable for many county governments to overcome these challenges in a short time. ***Moderate Compatibility***	• The fieldwork suggests that there are limited resources for innovation activities and we did not encounter a special budget, which can be used for the innovation activities. • We expect that in Kenya the workflow of AFE can be improved to process smart sketch maps. However, upgrading the workflow requires digitization of land records, and further investment in HR and technical capacities. Considering the available resources, we do not assess there are sufficient means to upgrade the system.

				affordability of operations.			*Low Compatibility*
	Moderate Compatibility			*Moderate Compatibility*			

CAPACITY AFE- KENYA

Capacity Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	• The Land Registration Act (2012) is the main legislative document that regulates the rules in land registration. The Act is clear in terms of what needs to be provided, but not prescriptive over how it is provided, therefore it is flexible enough on the user's capacities to implement the AFE. • But the land management and registration laws contain provisions that can be difficult to interpret and navigate. This leads often to coordination problems among different initiatives and reduces the cohesion in recording the land data. *Moderate Compatibility*	• The 2016 Community Land Act introduced customary tenure rights into the LAS. County governments are in charge of recording and registering the custom tenure. However, the law does not define a clear process on recording land information for unregistered community land held in trust by county governments. Therefore, it is difficult to apply AFE for boundary disputes concerning unregistered community lands. *Moderate Compatibility*	• While Constitution recognizes the continuum of rights and has provisions recognizing rights of communities, secondary rights and rights of women, undocumented rights are difficult to establish as formal ownership recorded in documents is privileged[ccxxviii]. Without including social boundaries as part of the workflow, it is not possible AFE to address these challenges. • Traditional community-based land disputes resolution mechanisms are replaced by other structured processes like courts and quasi-judicial tribunals, and boundary dispute resolution processes under land registrars. These new processes are not well understood and tend to work against the poor due to time/resources/costs involved[ccxxix]. AFE can contribute to dispute resolution processes but the practices with	• In 2019, Kenya was ranked 122th in the world in terms of regulatory performance with property registration, with 6% of the property value as registration fees[ccxxx]. With this score, Kenya is slightly above the Sub-Saharan average (7,6 %) but far worse than comparable countries such as Botswana (ranked 80th) and Rwanda (ranked 2nd). Therefore, it is possible that the regulations can discourage some people from registering property transactions. *Moderate Compatibility*	• There is a lack of enforcement of laws and regulations and duplication of mandates for management of public lands.[ccxxxi] This leads to sometimes conflicting state records. The unreliability of state records would challenge the implementation of AFE. *Low Compatibility*	• We do not expect a need for further regulation for the implementation of the AFE. But the legislation processes for surveying techniques and UAVs are still in progress. *Moderate Compatibility*	• The legislative process of UAVs and surveying techniques are still in progress. Therefore, we do not know to what extent the final draft act will allow improvements in surveying techniques with UAVs. This can indirectly affect the implementation of AFE, but we do not expect a significant challenge on the upgradability of AFE due to the legal framework. *High Compatibility*

			socially-perceived boundaries can limit AFE's functionality. ***Moderate Compatibility***				
Political System	• The land registration system is decentralized in the Kenyan case. Here the main responsibility is at the county level. However, there is a limited level of data sharing and collaboration between the field offices of the Ministry and county governments. Especially in the past, areas with richer natural resources have been an issue between national government and county governments. • Therefore, it is possible to have certain political constraints and/or risks during the implementation of the AFE. ***Moderate Compatibility***	• The Constitution provides for recognition of land under customary land tenure, which would include rural land uses such as pastoralism. However, extracting the boundaries in customary tenure areas is difficult for AFE because they are built on general boundaries. • The informal tenures concerning certain tenures in peri-urban areas and tenures concerning Ten-Mile Coastal Strip are excluded at the moment by the land administration system. ***Moderate Compatibility***	• Certain interests are not fully recognized such as the rights of women and the rights of residents in informal settlements in rural settings.[ccxxxii] • According to the provisions of Land Law on guiding principles[ccxxxiii], public officials should encourage communities to settle land disputes through recognized local community initiatives. However, actual practices suggest that the system has been less participatory than the regulative framework suggests. For example, existing processes around the subdivision of group ranches have been by no means participatory or transparent, and have led to members within a group being dispossessed of their land, particularly women[ccxxxiv]. The Ministry has also recently been in the news[ccxxxv] about adopting a lack of participatory processes. • Devolution has increased a sense of ethnic-based land ownership but the land is currently already in the hands of external	• Findings from other studies in Kenya suggest that making spatial data freely available threatens the relative power that governments and other entities (e.g. Survey of Kenya) maintain by keeping data private or available for a high cost[ccxxxviii]. • Although it is difficult to estimate at the moment, yet some governance actors may be reluctant in implementing an automated workflow in the cadastral boundary delineation. ***Moderate Compatibility***	• A 2002 report of the Njonjo Land Commission[ccxxxix] suggests that citizens have low trust to the land dispute settlement mechanisms and institutions due to delays, incompetence, corruption, nepotism, political interference and overlap of roles and functions leading to conflict, confusion and unnecessary bureaucracy especially when there is low participation of the local people in land dispute resolution mechanisms.[ccxl] That situation has improved after the enactment of National Land Policy and recognition of the alternative dispute mechanisms. But there is often political unrest in different parts of the country about land issues that suggests there are challenges with the reliability of the government's role in	• There have been some political tensions between agencies of national government and county governments in the past about the overlapping responsibilities. There have been some regulative changes in 2016, which have empowered the role of the national government in land administration. We expect through an inter-agency consultation and consensus on collaborative relationships, it is possible to implement the system on a nation-wide scale. ***Moderate Compatibility***	• Our fieldwork suggests that the stakeholders recognize the legitimacy of the central government in deciding on the land administration policies. Despite delays in the political and legislative processes, we think there is enough political capital to implement changes in the system if it is needed. ***High Compatibility***

			owners so local ethnic communities are not easily included[ccxxxvi]. For example, in Kajiado, which is a Maasai majority county, much land is owned by non-Maasai, leading to tensions between the communities. Furthermore, 'winner takes all' policies at county level lead ethnic majorities in power to excluding minorities from accessing to the state resources[ccxxxvii]. These exclusionary practices at the county level can affect the implementation of the AFE at the county level. *Low Compatibility*		the LAS. *Moderate Compatibility*		
Operational Unit	• The fieldwork suggests that there are two possible operational units for AFE inside the government, the field office of the Ministry of Land and county governments. • The AFE allows flexibility in boundary delineating by allowing automatic and semi-automatic options and combining the AFE with direct and indirect techniques in field surveying. However, for AFE to successfully delineate borders, the image data should be in	• The operational capacities vary between counties and also between the field offices and county governments. This can affect the effectiveness of AFE and UAV operations in covering different land tenures. • The fieldwork suggests that respondents do not expect capacity problems in operating with AFE. We think that it is possible to build the necessary capacities with training by taking into consideration the past	• During the operation of the AFE, we expect there will be a need for collaboration with non-governmental actors (e.g. Universities or private sector organizations) to acquire high-quality UAV-orthoimages or for training purposes. • The fieldwork suggests that collaboration with non-governmental actors take place on an ad-hoc basis, and there are not well-established participatory mechanisms at the local level. • The fieldwork suggests that there is a need for	• We expect a low start-up and ongoing cost depending on the state of the ICT infrastructure in the operational unit. • The financial capacities of operational units, both field offices of the Ministry and county governments, vary case-based and depending on the region. The affordability of AFE is also closely related with the affordability of UAV missions. *Moderate Compatibility*	• Although the field offices of the Ministry have usually better capacities, the personnel and material capacities of operational units vary case-based. However, in most units, the land data information is stored in paper format and the process of digitalization is in progress. • There is a lack of guidelines and training on how to operate the equipment. For	• We assess that there is a need for further training on geodata processing with open source programs (i.e QGIS) for the implementation of the AFE. • Not all county governments have adequate material capacities. Therefore, we expect some challenges for attainability. *Moderate Compatibility*	• The system operates with open-source programs, which are not common among operators. Therefore, we expect the skills to improve the system will be limited inside the operational units. *Moderate Compatibility*

	high resolution and with clear boundaries. For that, the UAV images have the highest compatibility with the technical requirements. However, it is still possible to work on other aerial images as well through semi-automatic methods, which would be still an improvement than completely relying on manual digitization/delineation. • However, the methods used in Kenya in recording aerial images[ccxli] suggest that the existing aerial images will be highly likely less useful. Furthermore, the low level of digitized maps suggests that there will be challenges for the operational units to combine multiple strategies in using aerial images. ***Moderate Compatibility***	experiences in learning GIS skills. ***High Compatibility***	capacity-building programs at the county level in data collection processes. For example, one interviewee stated: "If I may tell you the truth and the bitter truth, there is no capacity building [at least from the commission's point of view] so that the field has completely been overlooked or has been neglected by one reason or another. Because for example, we need to train the group ranch officials on how to manage land. We need to talk to women, whose rights are been violated by men. Their disputes come to us. OK, we have issues of capacity building where you have to enlighten people on their rights about their land, land information. It is not there. So all this is a result of lack of resources. Even despite we like to propose, who is going to fund? There is a clear gap in the capacity; both for the staff as the capacity for people and other stakeholders too." ***Low Compatibility***		example, the new equipment has been donated by UNDP to some county governments, but there is a lack of guidelines and training how to operate with and maintain them. Therefore, there is a need for clear policies and guidelines on the maintenance of equipment. ***Moderate Compatibility***		

| Social Norms | • Although we do not expect a significant challenge regarding social norms that can affect the flexibility during implementation, we think that the widespread informalities in land registration and practices with social tenures, complicate the automatic extraction of the boundaries in rural and peri-urban areas.

Moderate Compatibility | • Especially, in the community lands, there are some tensions between social norms and legal rights with customary tenure. An example is in Maasi culture, daughters are excluded from land inheritance, practicing subdivision but without the legal finality and evidence of a formal subdivision application. Or men can sell the lands to outsiders without telling their wives, contributing further to land disputes.[ccxlii] On the contrary, in the Swahili communities, the social norms on inheritance prioritize female line over men and the husbands stay at the pleasure of the wife[ccxliii].
• These informal practices can limit the inclusiveness of AFE by automatically extracting the boundaries to update the cadastral information.

Moderate Compatibility | • Following the devolution of the land administration system, the ethnic diversities at the county level have become a source of violence and exclusion toward ethnic minorities. There have been reports on the displacement of certain ethnic and social groups (e.g. pastoralist or farmers), in rural and community-owned areas[ccxliv]. These societal challenges can hinder the implementation of AFE.

Moderate Compatibility | • We do not expect social norms directly to affect the affordability of AFE operations, but it can indirectly affect the cost of UAV missions.
• In that sense, in rural areas, where the tribal and family relations are stronger, the social capital can facilitate the collaboration of communities in supporting UAV operations in land coverage and boundary disputes (e.g. Maasai community in Kaijado). Therefore, it can help the operators to access UAV-based images.
• However, there are often intra-family disputes in rural areas where Maasai communities are residing concerning the subdivision of group ranches. In these cases, the bonding social capital can act against the affordability of UAV operations by complicating the access to genuine qualitative data.

Moderate Compatibility | • Many transactions take place outside the formal registration process. A common one is an inheritance according to customary norms where the title remains in the name of the original holder, who may be long deceased[ccxlv]. This social norm can undermine the authoritativeness of data registry by AFE.

Moderate Compatibility | • The fieldwork suggests that the adaptation of new technologies takes time in Kenyan case. Stakeholders prefer to see the added value of the new technologies and methods before adaptation.
• However, many stakeholders in the case of Kenya have named AFE a useful tool to address the boundary conflicts. Therefore, we expect to be less challenging to convince the stakeholders about the added value of AFE.

Moderate Compatibility | • The fieldwork suggests that new technologies and practices are not adopted right away and some stakeholders expressed to some degree distrust to the UAV technology. It is important to show good practices as well as the added value to the processes.

Moderate Compatibility |
| Land recording | • The LRTs with AFE can support the land | • At the moment, the AFE cannot process the | • The AFE does not need input from non- | • Operating AFE itself does not cause a | • The AFE allows directly editing the | • We think that the field offices of | • AFE workflow is easily upgradable as |

techniques (LRT)	administration system in multiple ways by improving its efficiency and effectiveness in cadastral mapping, in land adjudication and dispute resolution mechanisms. ***High Compatibility***	information with social tenure. Considering the extent of informal tenure and unregistered community lands, we expect the inclusiveness of the LRTs to be limited. However, it might be possible in the future to modify AFE to process smart sketch maps. ***Moderate Compatibility***	governmental actors for its operations. ● However, the uptake of UAV-based surveying missions by the non-governmental actors would facilitate the availability of UAV-based imageries. ***Moderate Compatibility***	significant cost as it is mostly built on open-source software. However, operating with AFE requires good quality base-images, i.e. UAV orthoimages that could be more difficult to afford for certain operators. ● In Kenya, the cadaster system is mostly on paper-based and the current workflow of AFE requires digitized maps. The cost needed for the digitization of paper maps can limit the affordability of AFE. ***Moderate Compatibility***	cadastral maps and this way keeps them up-to-date. However, the reliability of the AFE depends on the availability of visual boundaries and high-quality aerial images in the registries. This is not the case in Kenya. Therefore, we expect challenges AFE to provide reliable data at this current situation. ***Low Compatibility***	Ministry and certain county governments have the necessary financial and HR capacities to implement AFE. ● However, AFE's effectiveness relies on the access to digital cadastral maps as well as the availability of high-quality aerial images. Both of these conditions are not common in Kenya. Therefore we expect the attainability low. ***Low Compatibility***	it is based on open-source software. However, there may need external expertise to train the operators in using the new features. But we do not expect this to significantly challenge the upgradability of LRTs. ● It is possible to upgrade the current workflow to digitize the paper-based maps, as the lines can be considered as visible boundaries. ***High Compatibility***
Software	● AFE's open-source software basis allows the workflow of the tool to be easily calibrated according to the cadastral mapping practices in the country. ● Although the current AFE prototype is developed on the QGIS plugin, it is also possible to use ArcGIS plugin, which is commonly used in Kenya[ccxlvi]. ***High Compatibility***	● The software of the AFE is developed to process 2D cadastral maps and cadastral representations in 3D are excluded[ccxlvii]. ● During automatic extraction, vegetation is named as the most limiting factor since they often obscure the view of the actual boundary[ccxlviii]. This can limit the visual detection of cadastral boundaries automatically. Yet, the interactive QGIS plugin option allows the operator manually to enter the missing data	● The effectiveness of image processing with AFE on UAV-based images relies on the delineator's knowledge, skills, and interpretation with boundaries. In this process, the local knowledge is rather needed to know which visible boundary is a cadastral boundary and which one just marks different land use/cover. ● The extraction of visible boundaries with AFE allows participatory mapping more than	● Open source solutions (e.g. QGIS) make the purchase and the use of the AFE affordable. ***High Compatibility***	● The AFE software is currently being developed; therefore, we did not test the robustness of the software in a real-life scenario. However, based on the software's prototype, we do not expect major issues than can affect the reliability of the AFE. ***Moderate Compatibility***	● The AFE workflow is mostly based on open-source solutions and requires a certain skillset to operate with geodata processing with open source solutions. Therefore, we expect a certain time and allocation of resources to train the operators. ***Moderate Compatibility***	● In AFE, it is possible for the user to update the software according to the needs (e.g. upgrading the software to be compatible with smart sketch map). However, during the fieldwork, we found that there is possible resistance to open-source solutions and limited IT and HR capacities inside the operational units. [ccxlix] This suggests that there is a low capacity

		and machine learning algorithms to improve the effectiveness of the software in time. • Especially in rural areas the boundaries are visible and can be extracted by the software. In densely build areas, the boundaries are mostly covered by (fragmented) building blocks, which limits the effectiveness of automatic extraction. ***Moderate Compatibility***	traditional direct surveying techniques with GNSS equipment. ***High Compatibility***			to improve software solutions if needed. • If it is decided to develop AFE with ArcGIS plugins, the system might be more expensive and more difficult to upgrade. ***Moderate Compatibility***

GOVERNANCE PUBLISH&SHARE RWANDA

Governance Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	• The Rwandan Land Management and Use Authority (RLMUA) is the land administration entity for Rwanda in charge of organizing, coordinating and monitoring collection, use and dissemination of geo information in the country under the National Spatial data Infrastructure Framework. RLMUA manages the Rwanda Geoportal[ccl] and Land administration information system (LAIS)[ccli]. • Under the LAIS, District Land Officer (DLO) is responsible for preparing documents evidencing land transactions for submission to the Registrar of Land Titles, which in turn is responsible for issuing leasehold certificates, i.e. 'titles'. District Land Bureaus (DLBs) are also charged with monitoring land surveying, valuation, and land use. • The modeling of the interfaces for the P&S platform follows the	• LAIS covers 11 million parcels of land, or 2.07 million hectares (ha) as of 2018. Rwanda's national territory is 2.49 million ha, including inland water bodies (160,508 ha), natural parks (258,067 ha), and areas of public infrastructure, such as roads[ccliii]. These areas are not included in LAIS, because they are not part of the national land registration system.[ccliv] • Access to national land information systems is contingent on ICT infrastructure and capacities, which is non-existent at cell level government offices, and similarly limited for people living in more rural areas. • Since the P&S platform allows combining mobile and geocloud solutions as well as includes qualitative data processing, it is highly inclusive to land tenure types. Nevertheless, its effectiveness is	• The Rwanda Geoportal facilitates spatial data sharing among public, private and non-governmental institutions as well as the general public. • Under the LAIS, District Land Officer (DLO) are responsible for preparing documents evidencing land transactions for submission to the Registrar of Land Titles, which in turn is responsible for issuing leasehold certificates, widely referred to as "titles."[cclv] • The P&S platform is expected to improve the participation of lower levels of government in comparison to current systems (i.e. LAIS and GNSS) as it allows direct access to cadastral information in the field and reworking with topographical data in line with the other its4Land tools. • However, at the moment we lack case data to test the effectiveness of the system in the field. ***Moderate compatibility***	• The financing of the operation for the government still needs to be defined[cclvi], but there will be likely ongoing costs (e.g. maintenance of server, IT services). • We expect a medium to high start-up costs depending on the state of ICT infrastructure.[cclvii] ***Moderate compatibility***	• LAIS aims to systematize land registration and maintains up-to-date data and records on land parcels, size, location, ownership, and other factors. The system is maintained and updated regularly as land transactions are recorded.[cclviii] • Our fieldwork suggests that the users trust the data provided by LAIS despite some occasional network problems, and trust the role of national government in the management of the system. • However, we need more time to assess the reliability of the RLMUA and the new organizational structure of land management. ***High compatibility***	• Our fieldwork suggests that the governance of P&S platform at national level is attainable, since the IT unit at national government is already in charge of the current information sharing operations and they possess the required HR capacities and server equipment. • However, reorganisation of organizational processes and migration of data may delay adoption efforts.[cclix] • Lower levels of government will need appropriate ICT infrastructure and Internet connectivity to access cloud services.[cclx] ***Low compatibility***	• The RLMUA has the Management Information System & IT Support Unit as part of the organizational structure. The Unit has the responsibility to support the LAIS if there is a technical problem. The Unit also has one Database and Application specialist and software development senior[cclxi]. This suggests that the national government has certain some IT personnel to upgrade the P&S system but we need further information to verify the capacities of the IT personnel to upgrade an open-source system. ***High compatibility***

	concepts introduced by land administration domain model (LADM). External systems like land administration system or planning systems can use the service interfaces to integrate data into their own processes, based on specific national rules.[cclii] **High compatibility**	dependent on the implementation of other recording tools such as AFe, UAV, and SSM. **Moderate compatibility**				
Actors & Networks	• Tools, which are capable of calling a REST API, can make use of any kind of P&S service, like public APIs or storage services. However, it is the responsibility of the 3rd tool vendor or creator to adapt their tools to P&S[cclxii]. Therefore, the actors have the flexibility to use the system with different tools. **High compatibility**	• The adaptability of the P&S platform with various tools and with the land administration system, and having both offline and online options suggest that the P&S system can be used even to integrate customary rights in natural parks, that are not registered in the LAIS. • The system works with qualitative data and off-line systems, which are suitable for rural areas with lower IT infrastructure, lower socio-economic parameters (e.g. lower literacy rate, lower computer literacy…etc.), and cultural barriers (e.g. Batwa community).	• The P&S platform provides a framework for integrating the algorithms for (semi) automated extraction of landmarks and boundary delineation from UAV data into standard open source GIS. The in-field processing is an important aspect of the image-processing system. This allows direct and immediate participation of local people.[cclxiv] In that sense, the P&S platform can enhance the participation processes. **High compatibility**	• Reliance on open-source solutions, adaptability of the P&S with different tools and low registration fees suggest that partaking in the P&S system should be affordable for users under the current governance network. However, the affordability of the system is contingent on the state of the ICT infrastructure, as access to cloud requires Internet connectivity. **Moderate compatibility**	• Governmental actors (i.e central, provincial, district, cell levels) and non-governmental actors (e.g. private surveyors) are used to working together in data recording. Furthermore, the government actors are open for crowd-sourced data[cclxv]. However, governance actors require training to develop the necessary IT skills for the reliability of the data-sharing platform. **Moderate compatibility**	• The system allows registering qualitative data and for that local actors can play an important role if this function is used with sketch mapping. However, this option requires medium to high computational power and thus more expensive hardware, as well as training for the field staff[cclxvi]. • Given most of the land tenure information in Rwanda is already recorded, there is less reliance on qualitative data, which makes P&S platform more	• There are academic institutions with specialized programs on land information systems and specialized private sector organizations (e.g. ESRI-Rwanda, Leica Geosystems) that have been involved in the previous projects for the development of the information sharing systems and supported training activities. **High compatibility**

		However, most parts of the qualitative data processing require significant computing capacities and hardware devices (large format scanner) that are not suitable for in-field usage.[cclxiii] Therefore, the advantages of the P&S in relation to the current system can be limited. ***Moderate compatibility***				attainable for the implementation. ***Moderate compatibility***	
Problem perspective & Goal/ ambition	• An important obstacle for the effective use of the P&S platform in Rwanda is that the spread of network connection. Especially, in areas with low Internet coverage access to Geocloud can be hindered. ***Moderate compatibility***	• We do not expect a specific risk in using the P&S platform, which is associated with a certain type of land tenure. However, the inclusiveness of the platform is dependent on the effective implementation of other land recording tools (e.g. UAV, AEF and SSM), which may limit the goal/ ambition of the system. ***Moderate compatibility***	• The P&S platform allows in-field participation of the users in correcting the stored data in real-time as well as working on topographical maps. Therefore, through direct participatory mechanisms it is possible to mitigate the problems with data registry. ***High compatibility***	• The financing of the operation still needs to be defined[cclxvii]. At the moment, we do not have information about the cost of maintenance. • According to the SMART Rwanda 2020 National Plan (p.17), the ICT ecosystem is currently at a low maturity level, and still requires government support to provide access to ICT. This suggests that in terms of affordability there are some challenges. ***Moderate compatibility***	• In the current data sharing system, the actors use LAIS and GNSS services. However, both of these systems have their shortcomings. LAIS does not allow control of information in real-time during field survey, and if there is a need of updating the information they need the involvement of IT department of RLMUA. Furthermore, occasional network problems (e.g. collapse of the system for a few hours) limit the reliability of LAIS. In the GNSS system, the users cannot	• The Internet and broadband coverage is restricted in certain areas of the country. Considering the financial incapacities in these areas, we may expect the attainability of the Geocloud services to be low in the short time. • Path dependency around existing systems may be too great to overcome[cclxviii]. ***Low compatibility***	• The problems associated with AFE and UAV can limit the inclusiveness of P&S platform and its effectiveness. However, the design of the platform is expected to be compatible with existing systems and tools hence to be operable. Therefore, it is important to control the interoperability and user-friendliness of the P&S platform with existing data sharing platforms. • There is hardly any local support for open source technologies, and the GIS skills, particularly at local government levels, tend

				access to the topographical map information and rework on the boundaries. This limits the reliability of information in the current system. • The P&S platform can improve these shortcomings of the existing system by combining with geocloud solutions, as well as facilitating whole-of-government data sharing. ***High compatibility***		to be low. Geocloud services may be easier to use in a streamlined mobile app version (which is also the format desired by the stakeholders)cclxix. • Requires the implementation and substantiation of the approved 'Data Revolution Policy' and application to the technology.cclxx ***Low compatibility***
Strategies & Approaches	• The P&S platform is adaptable for the tools developed in its4land and also for existing land administration system (LAS) and other tools. The platform will be accessible via service interfaces based on standards from Open Geospatial Consortium (OGC) and World Wide Web Consortium (W3C).cclxxi ***High compatibility***	• The P&S platform is designed to integrate the its4Land tools with open source software and it is compatible with existing land registration systems. This allows the platform to be inclusive in the way to integrate various land tenure types. • Our previous analysis suggested that Rwanda's challenge is in leveraging its cadastral data capital and focusing on combining cadastral data with other development related	• The P&S platform foresees interoperability with existing LAS, geocloud solutions and integration of qualitative data. This wide array of strategies allows participation of local and community partners in multiple ways. Yet, the extent of the participation into the system is dependent on primarily on the ICT infrastructure and capacity of local and private surveyors. In Rwanda, there are certain limitations with the latter. ***Moderate compatibility***	• The P&S platform aims to be fully applicable for open-source software, but our fieldwork suggests that the migration of data and adaptation to open-source software solutions can create administrative burden for operators of the system. In that case, the cost of maintenance of the system could be less affordable than anticipated. ***Moderate compatibility***	• We did not have a pilot study to test the reliability of the strategies for the P&S system. Therefore, at the moment we lack information to assess this dimension.	• We expect the platform to be attainable with the existing LAS and the tools for data recording. However, its effectiveness will be limited and its geocloud function will depend on the Internet coverage of the areas. • The platform is less attainable for the use of the Its4Land tools because it depends on the implementation	• The P&S platform includes machine-learning algorithms and open-source solutions, which supports the performance improvement and the system's upgradability in the long run. • Different strategies with usage models (i.e. application vs. integration and tools vs. platform extension) provide a base for a later commercialization and use of the its4land suite by addressing different stakeholders in a commercial settingcclxxiii.

	datasets[cclxxii]. The algorithmic basis of the P&S platform allows the integration of the cadastral and non-cadastral data toward multipurpose cadasters. ***High compatibility***				of the UAVs and AEF. ***Low compatibility***	***High compatibility***
Resources	The implementation of the P&S is expected to be the under the RLMUA. The Board of Directors approves the draft budget proposal of the Authority and monitors the use of budget and its execution[cclxxiv]. Therefore, RLMUA has the flexibility on how to allocate its resources. ***High compatibility***	• We do not know at the moment the exact cost of operations for the implementation of the P&S and whether there is a need for a new server, but we expect the cost to be budgeted into the annual budget of the RLMUA. • The cost for mobile solutions (especially for qualitative data) might be unaffordable for certain local and private operators. This can limit the inclusiveness of the system in the areas with weak network connections and financial capacities. ***Low compatibility***	• The Art. 28 of the Law Nº05/2017 defines six financial sources for the operations of RLMUA. These are state budget allocations; state or development partners' subsidies; income from services rendered; interests from its property; loans granted to the Authority as approved by the Minister in charge of finance; and donations and bequests. • There have been multiple projects[cclxxv] to improve LAIS and the associated capacities, which have been co-funded by the central government and international donor organizations. This suggests that international donors can be alternative funding mechanisms to finance the implementation of the system. ***High compatibility***	• We expect a medium to high start-up costs depending on the state of ICT infrastructure for the effective use of geocloud solutions.[cclxxvi] • As of 2018, the land registration fees in Rwanda have been reduced to 0.1% of the property value, which is one of lowest in the world[cclxxvii.] (World Bank, 2019). Therefore, in the areas with lower property values we do not expect the registration fees to cover the cost of operations. ***Moderate compatibility***	• We expect the national government to be at the head of the operations, thus the financial sources would come from the central budget. Therefore, we do not expect any unreliability in terms of financing the operations. ***High compatibility***	• Likely there will be ongoing costs that will need to be budgeted annually, which will require budgetary approval. Therefore, it is less attainable to implement the system with the existing budget.[cclxxviii] ***Moderate compatibility***	• The government has a specialized ICT budget, which provides funding for projects according to the strategic importance (socio-economic impact), priority, and input resources (capacity and capability to execute the project [cclxxix]. It is possible that the government can support future ICT-related innovative projects through this funding option. • Previous projects on data sharing platform have been funded by international donor organizations such as Department of International Development (DFID)[cclxxx], the EU, and Swedish International Development Cooperation Authority (SIDA). These international donor

							organizations can support innovation of the system. ***High compatibility***

CAPACITY PUBLISH & SHARE RWANDA

Capacity Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	• Art.31 of the Land Law (2013) defines: " Land registration, issuance of land title and maintenance of land register, land management, geo-information services shall be carried out by the competent national institution.". Although, the law does not specify which national institution should be in charge of the geo-information services, at the moment the Land Administration Information System (LAIS) is managed by Rwandan Land Management and Use Authority (RLMUA)[cclxxxi]. • Except this article, the Land Law does not specify any restriction on the registry and use of the geo-information services. ***High compatibility***	• There is technically not a particular restriction on the inclusiveness of P&S platform in registering various tenure types in relation to the existing regulations as long as they comply with the land tenure regularization program (LTRP). ***High compatibility***	• Art.7 of the Land Law (2013) defines that ' Statistical data should be published and made available to all users in the simplest manner. They must not be in contradiction with each other or partial.' We conclude from this statement as long as the collected data complies with the land tenure regularization framework, we do not expect any regulatory restriction with participation of user in the system. ***High compatibility***	• In 2019, Rwanda was ranked 2th in the world in terms of regulatory performance with property registration, with 0.1% of the property value as registration fees[cclxxxii]. With this score, Rwanda has one of the most affordable land registration systems in the world. ***High compatibility***	• Rwanda has already enacted legal, policy and regulatory regimes guiding access to information in general and personal data protection, privacy and confidentiality matters[cclxxxiii]. Regarding hosting, a Ministerial order N°001/MINICT/2012 of 12/03/2012 law provides that all critical information data within Government should be hosted in one central national data center[cclxxxiv]. Therefore, we assess the regulative framework is reliable for the implementation of the P&S in LAS. ***High compatibility***	• The present legislations provide a clear regulative framework for land data management, sharing, privacy and security. Therefore, we assess the P&S platform can be implemented in the LAS within the existing legislative framework. ***High compatibility***	• The Art. 8 of Ministerial order N°001/MINICT/2012 assigns the Rwandan Development Board (RDB) the responsibility to ensure, that the specifications for ICT systems and products meet interoperability requirements. Therefore, any interoperability needs of the P&S platform might occur following improving in the system should be addressed by the RDB without a need of further regulations. ***High compatibility***

Political System	• Rwanda has a strong presidential political system (i.e. little independent power for judiciary and parliament) and hierarchical political traditions, which situates the central government at the core of the political system.
	
	• In 2017, the RLMUA is established following the dissolution of Rwandan Natural Resource Authority (RNRA). The latter used to be under the direct control of the Prime Ministry, but the new authority is under the organizational structure of the Ministry of Environment (Minirena).[cclxxxv] Furthermore, the law on the establishment of the RLMUA sets the Prime Ministry as the supervising administration and in charge of determining
		• The LTRP reformed the land tenure system to be inclusive, but in the process, transitioned all customary tenure to private or state tenure.
		
		• In relation to this, the only exclusionary practice might occur toward indigenous groups that are settled in swamp areas. The Art. 19 of the Land Law defines the swamp tenures as state property but the regulation also mentions that it may be lent to a person based on an agreement concluded between two parties. However, this article leaves the discretion on ownership to the state authorities, which may hinder the inclusiveness of the system.
		
		   Moderate compatibility
			• The LTRP was implemented on a participatory system of boundary adjudication and strengthened the gender equality in the LAS.
			
			• There are no particular marginalized groups by the political system in the LAS, which can affect the implementation of the tool.
			
			   High compatibility
				• The P&S platform can help to introduce greater transparency and access to different types of ownership evidence in land tenure recording process. Although this can empower the LAS in the long-run, in the short run it is possible there could be an increase in the boundary dispute and appeal cases. Rwanda is in a transition stage with challenges in data management capabilities[cclxxxviii], it is possible that the implementation of the tool can be politically costly for local governments with lower capacities, especially at cell-level.	• The fieldwork suggests that the actors in the land administration governance network expects national government to manage the P&S system and enable trainings (either directly or through outsourcing) to the lower tiers of government.
					
					   High compatibility
						• Currently, all institutions and servers about geo-information services are located in Kigali under the authority of the national government's agencies.
						
						• The political system has high legitimacy and control over public sector to implement the P&S at a national scale.
						
						   High compatibility
							• The political system is supportive of new technologies (e.g. cloud-based systems, blockchain technology) and progressive to implement technological and operational improvements in relation to the geo-information services.
							
							   High compatibility

	the functions of executive organ of the authority[cclxxxvi], but set the Presidency to appoint the members of the Board of Directors, which is the decision-making body of the RLMUA[cclxxxvii]. These organizational changes with the leading authority of land administration may present challenges during the implementation of the P&S platform. ***Moderate compatibility***			***Moderate compatibility***			
Operational Unit	• We expect RLMUA to be the operational unit in charge of the P&S platform. RLMUA is the land administration entity that is in charge of organizing, coordinating and monitoring collection, use and dissemination of geo information in the country under the National Spatial data Infrastructure Framework. • RLMUA has a specialized IT department and this department already manages the Rwanda Geoportal[cclxxxix] and Land administration information system	• RLMUA has experience with managing geo-data information systems and provides IT support to the field operators. The P&S platform can publish different tenure information as long as they comply with the LTRP. However, the delays on the technical support during field operations with LAIS and GNSS services suggests that there may be a need of investing in a bigger server to manage the data and employing more personnel depending on the scale of the services. ***Moderate compatibility***	• We expect RLMUA to collaborate with district agencies and private operators during the operation of the tool. Especially, collaboration with district government during the implementation of its4land recording suit is essential because we expect the tenure information with new orthoimages to be fed in by the district government[ccxci]. Here not only the data management capacity of the RLMUA but also the data analysis and management capacities of the units at district,	• We expect medium to high start-up costs depending on the state of the ICT infrastructure at national and district level[ccxciii]. • There will be likely on-going costs for maintenance, which need to be budgeted and approved by the national government[ccxciv]. ***Moderate compatibility***	• The previous experiences of the RLMUA in managing LAIS and Geoportal suggest that the operational unit has the technical capacities to manage the P&S platform. However, the fieldwork suggests that there may be a need for further investment to the material and HR capacities at RLMUA. • The reliability of the platform also depends on the quality of data and for that there is a need for training and	• The central government, possibly with the assistance of donor organizations, will need to provide the financial and human resources and the training to implement and sustain the P&S platform. • Reorganization of organizational processes and migration of data may delay adoption efforts[ccxcv]. • Lower levels of government will need appropriate ICT infrastructure	• The P&S platform is designed to be interoperable with existing data processing systems that would feed the platform. Therefore, we do not expect a significant challenge with upgrading the P&S platform if there are changes in the data processing workflow of the system. • However, P&S platform operates on open-source programs, and the fieldwork suggests that there is a limited HR capacity for open-

	(LAIS)[ccxc]. P&S will have compatibility with existing systems, and therefore RLMUA would have the flexibility to decide on which systems to integrate in the P&S platform. ***High compatibility***		sector and cell levels are important. The fieldwork[ccxcii] suggests that there are material and HR capacity limitations especially at sector and cell level. ***Moderate compatibility***		investment to the ICT infrastructure at district level. • There is also a need for guidelines on the data management processes for the reliability of data. ***Moderate compatibility***	and Internet connectivity to access cloud services[ccxcvi]. ***Low compatibility***	source solutions. This can limit the ability of the operational unit to improve the system if needed. ***Moderate compatibility***
Social Norms	• We expect the social norms in relation to the inter- and intra-organizational share of information, transparency in governance processes, and innovation can affect the data management and the implementation of the P&S platform. • In Rwanda, previous experiences in land administration system suggest that governance actors have a culture of exploring innovative solutions and implementing changes to the processes. ***High compatibility***	• The tenure system in Rwanda has been mostly registered in the LAIS following the implementation of the LTRP. However, the P&S system can be used even to integrate customary rights in natural parks that are not registered in the LAIS. • The system works with qualitative data and off-line systems, which are suitable for rural areas with lower IT infrastructure, lower socio-economic parameters (e.g. lower literacy rate, lower computer literacy…etc.), and cultural barriers (e.g. Batwa community). ***High compatibility***	• The implementation of the previous projects suggests that RLMUA has an organizational culture to collaborate with NGOs, local actors and international organizations. Therefore, we expect them to be able to collaborate with non-governmental actors during the implementation of the P&S platform in relation to the capacity building activities. ***High compatibility***	• We expect the P&S platform to be implemented and managed at the national level. Therefore, we do not anticipate a significant relationship between the affordability of the system and the social capital at local level. ***High compatibility***	• Rwandese central government has a high legitimacy in society. Therefore, we do not expect social norms to undermine the authoritativeness of the system. ***High compatibility***	• Migration of the whole organizational systems may pose a cultural challenge for the attainability[ccxcvii]. Therefore, the effective implementation of the system may require longer time. ***Moderate compatibility***	• The current government has a clear political agenda to turn Rwanda in the innovation hub of Africa[ccxcviii]. The rate of young population and the citizen's support to the innovation policies of the government suggest that social norms are supportive for the improvements in the LAS. ***High compatibility***
Land recording techniques (LRT)	• P&S is not a recording tool but it can support LRTs of other tools. The platform provides	• P&S can technically share any tenure information as long as it complies with	• The data sharing capabilities in the P&S platform allows the participation of	• The effectiveness of the P&S platform relies on the data fed in the system.	• The P&S platform allows access to different ownership evidences through a	• For the effective implementation of the application or workflows on the	• The P&S architecture is built on open-source solutions, therefore it allows

	services such as: runtime environment for executing and managing tools; storage services for alphanumeric, geo spatial, binary and image data; OGS services for spatial data access; and authentication and authorization services[ccxcix]. This way it can support the use of the land data for multiple purposes (e.g. environmental management, disaster management…etc.). ***High compatibility***	the formalization standards of the LADM. ***High compatibility***	stakeholders even in the cases with limited ICT infrastructure. • The in-field processing is an important aspect of the image-processing system. This allows direct and immediate participation of local people. ***High compatibility***	Here the affordability of the other tools (e.g. UAV or AFE) at district level can affect the effectiveness of the system. ***Moderate compatibility***	set of online services. This way the application can provide authoritative and up-to-date information to users. ***High compatibility***	P&S platform, there is a need for the implementation of the UAVs and AFE at land recording processes. • Furthermore, the P&S platform relies on open-source GIS system. This requires a different skillset than the one that exists currently at local level. ***Moderate compatibility***	improvements if needed. However, lack of preferences of public officials and commercial operators with the open-source solutions in land recording tools can hinder the upgradability of the workflows with the P&S platform. ***Moderate compatibility***
Software	• The implementation of the P&S platform follows a toolbox approach and will provide a framework of common APIs and services used by all its4land tools. From this toolbox, a user can select those its4land tools fitting his tasks best. Therefore, the software has a high flexibility to fit-in the country specific conditions. ***High compatibility***	• During the testing of the its4Land tools, the image processing workflow of the P&S made use of two COTS software (Pix4D and Matlab). Although the architecture of P&S can integrate tools using COTS software through the runtime environment and the Public API, an adaptation of the COTS software to use the P&S API directly is not possible[ccc]. Open-source alternatives to COTS software can improve the inclusiveness of the system, but at the moment open-source solutions are not much preferred in Rwanda, especially among	• Depending on the access rights, the P&S software allows input and editing by different stakeholders. ***High compatibility***	• The testing of the P&S platform has been done with the Amazon Web Services (AWS) for the geocloud approach. Although the system works well at AWS, there are various factors (e.g. cost of the hosting services for operation and implementation, technical suitability with planned scenarios, transparency and security issues, privacy and compliance	• The technical framework of the P&S platform operates in a better compatibility if the tools in the image processing, i.e. UAV and AFE, use open source solutions. Although there are open source solutions available for them, at the moment the commercial software (e.g. Pix4D) have better reliability in comparison to the open source alternatives (e.g. OpenDroneMap). However, in the long run, we expect the reliability of open-	• There are limitations in implementing open-source solutions in LAS due to established practices with using commercial software in UAVs and GIS systems (e,g ArcGIS is common instead of QGIS). Therefore, institutional change to open source systems would require time, technical and policy support as well as further training with open-source software.	• The fieldwork suggests that the commercial software licenses that are purchased as part of a project funded by donor organizations, are rarely renewed when the project ends. • The P&S platform operates on open-source software and has a better compatibility with open source supported tools. However, the fieldwork suggests that open-source solutions are not

		the private operators. For example, the only licensed private operator, CharisUAS, uses Pix4D in image processing. These software-related limitations can reduce the inclusiveness of the system. ***Moderate compatibility***		policies)[ccci] that can affect the choice and affordability of the software. ***Moderate compatibility***	source software solutions to improve. • The fieldwork suggests that it is common to use pirate or cracked GNSS software at sector level, sometimes without even being aware of the licenses are expired or illegal. These practices affect the reliability of the current practices with commercial software, as they cannot be upgraded and they risk security breach. ***Low compatibility***	***Low compatibility***	common in Rwanda, and operators lack technical capacities to work with open source programs. ***Moderate compatibility***

GOVERNANCE PUBLISH & SHARE (P&S) KENYA

Governance Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Levels & Scales	• After the 2016 amendments of the Land Act, the Cabinet Secretary was appointed as in charge of the coordination of the National Spatial Data Infrastructure (NSDI) and coordinate the development and implementation of the NSDI in collaboration with the National Land Commission (NLC)[cccii]. However, the establishment of the Kenyan NSDI has been ongoing since 2001. To date, not much has happened[ccciii]. • According to the same law, NLC is responsible for the management of spatial data concerning public lands. Here NLC is expected to keep a database of all public lands[ccciv], which are geo-referenced and authenticated by the statutory body responsible for survey[cccv]. NLC is also responsible for sharing the data with the public and relevant institutions. In Kenya, the statutory bodies responsible for survey in public lands are the field office of the Ministry of Lands and Physical Planning and the county government. Interviews in the field indicate that these bodies	• The Constitution of Kenya recognizes four forms of land tenure, namely: public land, community land, and private land. However, six land tenure types are discernible in Kenya: Public Tenure, Private Tenure, Customary Tenure, Wakf Tenure and two special types of tenure; Informal Tenure and Ten-Mile Coastal Strip Tenure. The latter two fall under the broad category of 'social' tenure. In ASAL areas, two models of regulated tenure dominate over customary land – trust lands (pastoralists) and group ranches. • While customary tenure dominates most of the rural lands in Kenya, private and public tenure systems control land in the urban areas. Rapid urbanization though means that increasingly, customary tenure	• The regulative framework of the Kenya LAS includes participatory clauses, such as pursuing participatory practices in the land development[cccviii]; making the public information accessible according to the needs of people (e.g. disability, cost, the local language)[cccix], and making the land registers electronically or in any other means accessible to the public access[cccx]. • However, actual practices suggest that the system has been less participatory than the regulative framework suggests. For example, existing processes around the subdivision of group ranches have been by no means participatory or transparent, and have led to members within a group being dispossessed of their land, particularly women[cccxi]. The Ministry has also recently been in	• It is estimated that to relaunch the NSDI, Kenya will need about 7 billion Kenyan shillings (about US$ 70 million or 0.1% of GDP in 2016) over a five-year period[cccxv]. • County governments have different financial capacities depending on their natural resources, commercial activities and revenue collection efficiencies. The fieldwork suggests that there are big discrepancies in terms of ICT infrastructure and equipment at the county level. Furthermore, the fieldwork shows that most land maps are kept in paper format and they are not digitalized. • The spatial definition of counties in new planning regulations has often meant that county governments are hugely under-resourced to take on	• There are numerous cases of overlapping boundaries and duplicate registrations in Kenya's land administration. This is a known issue in ongoing widespread corruption[cccxvii]. In our case study area of Kajiado, the county government's own perception (Office of Surveyor) is that the entire country needs to be resurveyed as the information errors are so significant[cccxviii]. • Most of the land data are stored in paper-form and the data are often not up-to-date. • Recent findings of corruption regarding NLC Commissioners have also threatened the legitimacy of the organization (ironically established to improve transparency)[cccxix]. • The P&S platform can help to build the trust of the institutions by making the land information available to the public supported by different means of	• There are currently 52 different land registries in Kenya, which the Ministry of Lands have been trying to integrate through the large-scale digitization of land records. The digital land registry was launched in 2018, operational for Nairobi, and the rest of the country by 2019. • The numerous geoportal initiatives and the implementation of an open data portal are positive drivers for adopting the P&S platform. However, due to numerous laws governing land registration in Kenya (deed and title), it is difficult to have unified standards and data models in land registration,	• The ongoing dispute between the Ministry and NLC in terms of oversight and mandate create risks for innovation. For example, both the Ministry and NLC have their own bodies to innovate the land data management systems and although there are ongoing initiatives by the national government and the NLC to merge separate databases into a single standardized system, at the moment these systems are still under development. • This suggests that the upgradability of the P&S platform should take into account its interoperability with different land administration information systems. • The fieldwork suggests that some government officials are hesitant to use cloud solutions because of concerns around data security. For the upgradability of the system and

collect land data separately and keep the data in their respective registries. There is a limited share of information between them. • The 2016 amendments have changed the land registration system as well. Now, the Cabinet Secretary in consultation with the NLC and county governments decides on the administrative areas where the land registration units (LRU) are responsible with. LRU is established at the county level and other levels are expected to provide access to land administration and registration services. Furthermore, each LRU should include a Community Land Register to manage the cadastral information of the registered community lands. The unregistered community lands are held in trust by the county government. • Under the County Government Act 2012, county governments are responsible for collecting and managing spatial data for planning and establishing a GIS-based system. It was intended that county-level info would feed into national land	needs to be reconsidered, e.g. in the project's case study site, Kajiado, where most of the county is Maasailand (i.e. customary tenure, currently still held as communal Group Ranches. Communal group ranches were mainly imposed in ASAL areas of Kenya. • Informal tenure is dominant in urban areas as well as in several large-scale farms in the country in the form of squatters. The Ten Mile Coastal Strip is found only in the Coast Province of the country and has the longest history of all the tenure systems in Kenya.[cccvi] • Both the county government and the national government collect and store the data about their respective tenure types. However, the public land tenure, that corresponds to 10% of lands in Kenya, is delineated in two broad areas, in which both the national government and county government	the news[cccxii] about adopting a lack of participatory processes. • In terms of the open-data policy, ICT Kenya, the communications authority of Kenya, manages the Kenya Open Data portal that makes public government datasets accessible for free to the public in easy reusable formats[cccxiii]. The Kenya Open Data Fellows Programme run by the ICT Kenya aims to help national and county institutions to open up and share their datasets, Kenya Open Data is placing data fellows, experienced in data mining and presentation, in these institutions[cccxiv]. • The P&S platform can make land data accessible to people in line with open data policy and thus can support participation in the LAS. *Moderate compatibility*	urban management activities, including land administration[cccxvi]. Therefore, we don't think it is affordable to introduce the system at county governments. • A lack of resources at county government, yet the need to establish a GIS system at the county level may provide an opportunity for the P&S platform to be afforded by the national budget. Here, it might be possible to introduce the system at the county level through the field offices of the Ministry given their financial resources are allocated from the central budget. However, we do not know at the moment how affordable is this option for effective implementation of the P&S system. *Low compatibility*	evidence. However, past experiences with corruption cases with all levels of government suggest that the system should be backed by different actors (i.e. Ministry, NLC, county governments) to be trusted by the general public. *Moderate compatibility*	which impacts the ability to implement a LIMS[cccxx] • Therefore, even though it might be possible to adopt the P&S platform following the digitization of land records, existing limitations with overlapping responsibilities and authoritativeness of the data in state ledgers mean effective implementation is difficult to achieve. *Moderate compatibility*	implementation of geocloud solutions, it is important to convince government officials both at the county and national level about the security of the system. *Moderate compatibility*

	information management system (LIMS). • Overall, there are separate organizations in the land information management that represent entry points to different networks: NLC – public land; Min. of Land – freehold land; county governments – freehold and communal land. The responsibilities in land information management are partially decentralized in certain areas (e.g community lands, public lands in county areas) but overlapping responsibilities, longstanding distrust between land institutions and limited share of information at both national and county level suggest that the system has limited flexibility in data management. ***Moderate compatibility***	has responsibilities in recording the land data[cccvii]. There is limited data-sharing between the ledgers of county government and national government, and there are differences in terms of digitalization of records. Collection and management of data remain a challenge and it is an area that the P&S platform can contribute in terms of access. ***Moderate compatibility***					
Actors & Networks	• ICT Kenya is developing a GIS-based ICT coverage system, although the system is not operational yet. ICT Kenya also manages the e-citizen portal, which is planning to include certain land services in future (e.g. land rent clearance certificate, application for an official copy)[cccxxi], and the open data portal, which includes some spatial data	• The Kenyan LAS does not recognize the rights of informal communities, and given the dominance of informal tenure (due to weak land market), this suggests the propensity for many to be excluded.	• There are numerous land-related NGOs in Kenya who produce land information that may not fit in land registries but are important for resolving planning and land-related conflict, e.g. GROOTS Kenya, FAO, etc. Such information could be stored and made accessible via the P&S platform (if LADM	• On transfer of property, the cost of registration depends on the value of the property. On average, this cost is about 4% of the property value, which may be prohibitive for many Kenyans[cccxxiv]. • The fragmented nature of NSDI makes	• Land administration in Kenya is conflict-ridden and rife with corruption. The Ministry and NLC do not work well together, and not all county governments are adequately resourced to fulfill their mandated responsibilities. These factors reduce the reliability of the land administration	• We found the attainability of an open-source P&S platform rather low, as there are ongoing projects to develop GIS-based information sharing systems at the national level. At the county level, however, there is a lack of resources	• University of Nairobi and Technical University of Kenya are important actors as they have the only surveying/land admin programs in the country. • There are various specialized intergovernmental organizations (ICPAC;

on land resources and environment. • There are also other geoportals available in Kenya which are managed by private or intergovernmental organizations (e.g. ICPAC geoportal) • Survey of Kenya, also often regarded as the de facto national mapping organization, is also an important actor in land information management. It is possible to obtain spatial data through the Survey of Kenya, but this is still limiting because of the cost and the strict licensing agreements involved with obtaining this information[cccxxxii]. • These suggest that the system is flexible for other actors to support the implementation of the P&S platform. *__High compatibility__*	• Women's access to land is still a significant issue[cccxxxiii]. • Indigenous land rights continue to be an issue in Kenya. • Despite institutional reform, a legacy of patronage and clientelism indicates difficulties in achieving true transparency and inclusion in the land sector. *__Moderate compatibility__*	permits the storage of the data). However, this would purely be voluntary and a case would need to be made to do so (e.g. overcoming internal barriers to change such as proprietary systems). *__Moderate compatibility__*	it difficult for governance actors to access GIS data. Survey of Kenya is a possible option to access the data but it is very costly. A former research conducted by another project showed that the cost is $50.000 per dataset with restrictions on sharing the data[cccxxxv]. The implementation of the P&S platform by the government can reduce the cost of accessing GIS data significantly in Kenya. • It is possible to outsource surveying activities to private operators (e.g. GEOIT). However, most private companies do not use open-source solutions and the image-processing workflow in the P&S platform works better if the open-source solutions are adopted with UAV and AFE technologies. *__Moderate compatibility__*	information system for governance actors. • Paper-based maps are widespread, and the practice with data registry in both county and national ledgers has proven to be unreliable to provide authoritative information. • There are experienced and qualified private and non-profit organizations specialized in GIS systems. The fieldwork suggests that the national and county government work frequently with private sector organizations in the land sector. This suggests that PPP solutions could be preferable for the reliability of the system. *__Moderate compatibility__*	(financial and HR) available. *__Low compatibility__*	Global Policy Centre on Resilient Ecosystems and Desertification (GC-RED) of the UNDP) and private sector organizations (e.g. GEOIT) located in Nairobi. *__High compatibility__*

Problem perspective & Goal ambition	• There are several potential risk factors, which may affect the implementation of the P&S platform. First of all, Internet coverage and the ICT infrastructure is an impeding factor. Especially, in areas with low Internet coverage access to Geocloud can be hindered. • Secondly, the limitations with the digitization of maps suggest that the P&S platform would have limited functionality until the data is transferred into a digital format. • Thirdly, the conflicting data on land tenure stored both in county government and in the field office of the Ministry suggest that there is a need for a quality assurance system for the information to be published in the platform. Here the role of governance actors is not clear. The P&S platform can publish multiple types of tenure information, but the platform cannot verify the validity of that information. ***Low compatibility***	• The platform can publish information about any type of tenure, as long as it complies with the Constitution. Especially, adopting smart sketch mapping (SSM) can highly improve the inclusiveness of the system concerning customary and social tenures. • The limitations with the UAV regulations and the absence of governance framework for the UAVs suggest that relating tenure sketch maps to new orthoimages could be difficult to achieve[cccxxxvi]. ***Moderate compatibility***	• NLC has a participatory governance structure and works on creating new platforms such as national spatial data platform, through participatory methods. These participatory governance bodies can be used to mitigate problems in land data information management. However, NLC has a centralized governance structure following the dissolution of its field offices. The Community Land Bill passed on 31 August 2016, dismantled the county land management boards (CLMB), the county-level agencies of the NLC[cccxxxvii]. This can limit the effectiveness of NLC given its dependence to the other county-level information sources for the land information management. In that sense, the adoption of P&S platform can significantly improve and facilitate the work of NLC to create a reliable LIMS. ***Moderate compatibility***	• Likely to have high setup and medium-term costs since existing systems (workflows and cognitive models) are manual. • Governments and other third party stakeholders need to bear the cost/burden of adapting their systems/tools to P&S. • Desire to use the P&S platform online will require network infrastructure – which is poor and limited in Kenya, although there is almost 100% mobile penetration[cccxxxviii]. However, non-smart phones still dominate, mobile broadband is only available to two-thirds of the regional population, and mobile data is expensive[cccxxxix]. ***Moderate compatibility***	• The reliability of the P&S platform largely depends on the level of collaboration among the actors in LAS, and who the custodian organization for the implementation will be. Especially, there is a need for clear governance and policy guidelines for the integration of different portals into the system. • Most geospatial data sets are manual, are not regularly updated[cccxxx] and the processing and storage of land data are manual[cccxxxi]. ***Low compatibility***	• There are several political (i.e. corruption scandals, and low cooperation among state actors), technological (i.e. lack of HR capacities with open-source solutions, prevalence of paper-based maps), infrastructural (i.e. limited material capacities at county level, network infrastructure at counties) and financial (i.e. limited resources at county level, the high setup cost) problems that hinder the attainability of the system within a short period. ***Low compatibility***	• Kenya is a technology hub of sub-Saharan Africa and leader in digitization [cccxxxii]in African countries. Furthermore, it has a vibrant market with several technology providers for the land sector, experiences private surveyors and NGOs working on different areas of land and environment policies. All these suggest that if the system is adopted, it is possible to collaborate with non-governmental actors in technology development and adoption of an external system in the P&S platform. • There are ongoing initiatives to create cloud solutions for land data systems at the county level. However, the fieldwork suggests that there are still hesitations among decision-makers to upload land data in clouds due to security concerns. To address concerns with data security, there are project and policy

							documents are being developed to introduce blockchain-based solutions. The P&S platform's open-source basis allows improvements in the algorithms and workflows. The deployment of cloud systems in LAS would facilitate the improvement of the P&S platform. *High compatibility*
Strategies & Approaches	• The P&S platform is adaptable for the tools developed in its4land and also for ongoing land information management systems and other geoportals outside of government. The platform will be accessible via service interfaces based on standards from Open Geospatial Consortium (OGC) and World Wide Web Consortium (W3C).[cccxxxiii] • Since P&S is a runtime environment for other its4land tools, the strategy will be reliant on what is decided with UAVs, AFE, and SSM. *Moderate compatibility*	• The P&S platform is designed to integrate the its4Land tools with open source software and it is compatible with existing land registration systems. This allows the platform to be inclusive in the way to integrate various land tenure types. • In Kenya, we expect tenure sketch map captured by SSM to improve the inclusiveness of the system, by cross-matching the social and customary tenure information with existing maps and new orthoimages	• The P&S platform foresees interoperability with existing systems and integration of the qualitative data into LIMS with smart sketch maps. These strategies allow the participation of local and community partners in multiple ways. Yet, the extent of the participation into the system is dependent on the actual practices of local officials as well as the capacity of people to use the system. On both of these areas, the fieldwork suggests that there are limitations. • Furthermore, user-friendliness is another important factor to governmental and non-	• Geocloud option relies on the availability of smartphones and access to the Internet. There are limitations with access to mobile data and not all field operators have the equipment to access the P&S platform. • Open-source solutions of the P&S platform can improve the affordability of the system, but it would require lots of human resource development in using open-source GIS and investment in the hardware and software systems at county governments.	• We did not have a pilot study to test the reliability of the strategies for the P&S system. Therefore, at the moment we lack information to assess this governance dimension.	• Although the available strategies with P&S platform would inevitably improve the problems with current LAS, it is unclear whether, given the current level of investment into developing a LIMS, the government would adopt an open-source platform. *Moderate compatibility*	• The P&S platform includes machine-learning algorithms and open-source solutions, which supports the upgradability of the system in the long run. • Different strategies with usage models (i.e. application vs. integration and tools vs. platform extension) provide a base for later commercialization and use of the its4land suite by addressing different stakeholders in a commercial setting[cccxxxiv]. *High compatibility*

		captured by UAVs. Of course, this would require the digitization of the maps and the adoption of the UAV in the LAS. **_High compatibility_**	governmental actors to adopt their systems with the technical requirements of the P&S platform. The fieldwork suggests that stakeholders are reluctant to modify their systems to make it compatible with open-source systems. **_Moderate compatibility_**	**_Moderate compatibility_**			
Resources	• County governments have fiscal autonomies to collect land/property taxes, and they are allowed to select a valuation rate up to 4% without a central government approval[cccxxxv]. Furthermore, there is a weighted formula[cccxxxvi] to arrange the intergovernmental transfer shares to the county governments without the discretion of the central government. However, not all county governments have the same fiscal capacities and not all of them have updated valuation roles, which affects their ability of revenue generation. • The field offices of the Ministry do not have flexibility in expenditure decisions and their budget	• The fiscal and administrative capacities at county government differ from region to region, which would affect their material capacities to support the P&S system. Furthermore, the fieldwork suggests that both land data is registered manually based on paper-based maps. The financial resources needed for the digitization of tenure information can limit the inclusiveness of the tenure information in the platform. • It is financially much easier to implement SSM tools in the data recording processes at county level given	• Some county governments have better access to financial resources from private and international donors. Therefore, it is possible using different financial resources to finance the operations at a local level independent from national government resources. • The county governments have the discretion to increase the nominal tax rate and they can higher their private valuers to assess the value of the land. But the revenue collection capacities of county governments vary case by case[cccxxxvii]. **_High compatibility_**	• The WB report[cccxxxviii] states: "The fees collected from registry services are generally sufficient to sustain operations but since this money must first go to the Exchequer, there is no guarantee that it will be available when needed to sustain services." This suggests that it might be possible to finance the cost of maintenance with the revenues from the land registration system, but weak administrative capacities concerning the transfer of revenues to field offices can hinder the affordability of operations at the	• We expect the system to be implemented with a top-down approach, likely with a special government fund to finance the implementation of the system. • The county governments financially rely on the local resources, which suggest that the reliability of their resources depends on their financial and local capacities (e.g. efficiency in revenue collection, the land value…etc.) • The financial resources of the field offices are dependent on the transfers from the central budgets, but there are uncertainties about the availability of	• We expect a medium to high start-up costs depending on the state of ICT infrastructure for the effective use of geocloud solutions.[cccxl] • In addition to the national government resources, there are also several international donor organizations, which have supported the financing of the NSDI infrastructure. Therefore, we think that financially the system is attainable despite	• The fieldwork suggests that there are limited resources for innovation activities and we did not encounter a special budget, which can be used for the innovation activities. The national government has more innovations based on private companies and they receive more aid in comparison to county governments. In that sense, the national government has more advantages in innovation activities. **_Moderate compatibility_**

has to be approved by the Ministry. *Moderate compatibility*	the cost-effective setup cost and its relevance to capture qualitative data at the community level. *Moderate compatibility*		county level. The county governments, on the other hand, have financial autonomy over their resources, but varying financial capacities among county governments can affect the affordability of operations. *Moderate compatibility*	the funds to maintain the system when needed[cccxxxix]. *Moderate compatibility*	the high start-up cost. *Moderate compatibility*	

CAPACITY PUBLISH & SHARE (P&S) KENYA

Capacity Dimensions	Flexible	Inclusive	Participatory	Affordable	Reliable	Attainable	Upgradable
Regulations	• The responsibility for the collection, publicization, and accessibility of land-related information is documented in the Constitution and land policies (e.g. Kenya Vision 2030, National Land Commission Act 2012, County Government Act 2012, Land Registration Act 2012, etc.). These are clear in terms of what needs to be provided, but not prescriptive over how it is provided, therefore they are flexible enough on the user's capacities to	• The Community Land Act (2016) does not define a clear process on recording land information for unregistered community land held in trust by county governments. • Constitution and current land policy encourage the use of alternative dispute resolution mechanisms, e.g. negotiation, mediation, and arbitration. For example, the Environment and Land Court Act allows parties to adopt any alternative methods of dispute resolution	• While Constitution recognizes the continuum of rights and has provisions recognizing rights of communities, secondary rights and rights of women, undocumented rights are difficult to establish as formal ownership recorded in documents is privileged[cccxli]. • Traditional community-based structures for resolving land disputes replaced by other structured processes like courts and quasi-judicial tribunals, or boundary	• In 2019, Kenya was ranked 122th in the world in terms of regulatory performance with property registration, with 6% of the property value as registration fees[cccxliii]. With this score, Kenya is slightly above the Sub-Saharan average (7,6 %) but far worse than comparable countries such as Botswana (ranked	• Due to numerous laws governing land registration in Kenya (deed and title), it is difficult to have unified standards and data models in land registration, which impacts the ability to implement a land information management system (LIMS)[cccxliv] • There is a need for a clear regulative framework outlining the responsibilities of government actors concerning the share of data with other	• With the 2016 amendments in land acts, the Cabinet Secretary is appointed in charge of the coordination of the National Spatial Data Infrastructure (NSDI) and coordinates the development and implementation of an NSDI in collaboration with the National Land Commission (NLC)[cccxlv].	• At the moment, there are no clear regulations about the implementation of the cloud systems in the LIMS. The National ICT Masterplan 2017 is the only policy document which mentions anything about cloud computing. Accordingly, the Government Data Center (GDC) infrastructure, which is being developed to ensure security for

implement the P&S platform. • But land management and registration laws contain provisions that can be difficult to interpret and navigate. This leads often to coordination problems among different initiatives and reduces the cohesion in the development and management of land information management systems. ***Moderate compatibility***	including reconciliation, mediation and also traditional mechanisms; Community Land Act incorporates the use of alternative dispute resolution. • P&S could play a role in alternative dispute resolution by making other types of land-related data available to the parties to support claims of tenure ***Moderate compatibility***	dispute resolution processes under land registrars. These new processes are not well understood and tend to work against poor due to time/resources/costs involved[cccxlii]. • The Act on Access to Information (2016) is the main piece of legislation that regulates access to public data. The article 5(2) defines that 'Information shall be disseminated taking into consideration the need to reach persons with disabilities, the cost, local language, the most effective method of communication in that local area, and the information shall be easily accessible and available free or at cost taking into account the medium used.' This article is suggestive in the way that the P&S platform should be designed for higher participation (e.g. language settings, the cost of services…etc.). • According to Art. 10 of the Land Registration Act (2012), the Registrar shall make information in the register accessible to the public by electronic means or any other means as the Chief Land Registrar	80th) and Rwanda (ranked 2nd). Therefore, it is possible that the regulations can discourage some people from registering their property to support the P&S. ***Moderate compatibility***	government agencies. ***Moderate compatibility***	• Under the National Land Commission Act 2012 (S.5/2d), the NLC has to develop and maintain a national LIMS. The National LIMS directorate was established for this purpose. The NLC also has to develop a public land LIMS. However, the fieldwork suggests that there are separate ongoing projects in NLC and in the Ministry to develop a LAIS for the use of other agencies. Although P&S platform is interoperable with other systems, the current regulative framework is not clear enough who should be in charge of the platform. ***Moderate compatibility***	government data and applications will also provide an environment for cloud computing to offer for the services delivered by County governments. In the absence of regulative criteria on cloud computing standards, it is difficult to upgrade geocloud solutions. ***Low compatibility***

			prescribes. ***Moderate compatibility***				
Political System	• The land registration system is decentralized in the Kenyan case. Here the main responsibility is at the county level. However, there is a limited level of data sharing and collaboration between the field offices of the Ministry and county governments. Especially in the past, areas with richer natural resources have been an issue between national government and county governments. Therefore, it is possible to have political constraints against sharing data through the P&S platform in case of political disputes between national and county governments. ***Moderate compatibility***	• The informal tenures in peri-urban areas and tenures concerning Ten-Mile Coastal Strip are excluded from the land administration system. • P&S platform alongside with the implementation of its4Land tools can publish informal tenure information. However, Kenya's Ten-Mile Coastal Strip has a history of complicated land rights and tenure arrangements and land rights remain highly political in the area. Due to high rates of absenteeism from landowners, informal settlements have become dominant[cccxlvi]. Therefore, even though P&S can publish informal tenure information, the politicization of the issue suggests challenges for the implementation. ***Moderate compatibility***	• Certain interests are not fully recognized such as the rights of women and the rights of residents in informal settlements in rural settings.[cccxlvii] • According to the provisions of Land Law on guiding principles[cccxlviii], public officials should encourage communities to settle land disputes through recognized local community initiatives. However, actual practices suggest that the system has been less participatory than the regulative framework suggests. For example, existing processes around the subdivision of group ranches have been by no means participatory or transparent, and have led to members within a group being dispossessed of their land, particularly women[cccxlix]. The Ministry has also recently been in the news[cccl] about adopting a lack of participatory processes. • Devolution has increased a sense of ethnic-based land ownership but the	• Findings from other studies in Kenya suggest that making spatial data freely available threatens the relative power that governments and other entities (e.g. Survey of Kenya) maintain by keeping data private or available for a high cost[cccliii]. ***Low compatibility***	• A 2002 report of the Njonjo Land Commission[cccliv] suggests that citizens have low trust to the land dispute settlement mechanisms and institutions due to delays, incompetence, corruption, nepotism, political interference and overlap of roles and functions leading to conflict, confusion and unnecessary bureaucracy especially when there is low participation of the local people in land dispute resolution mechanisms.[ccclv]The current situation has improved after the enactment of National Land Policy and recognition of the alternative dispute mechanisms. However, there are still challenges with the reliability of both national and county governments in the LAS. • Recent findings of corruption regarding NLC Commissioners have also threatened	• The land administration system is fragmented, and there are overlapping tasks and coordination problems in the development of LIMS. Although P&S is scalable to work with multiple systems, inter-agency consultation and consensus on collaborative relationships can improve its attainability. ***Moderate compatibility***	• The Kenya Vision2030[ccclvi] establishes the need for a GIS-based land information management system (LIMS). This suggests that the national GIS platform has political priority in the development agenda. • The fieldwork suggests that the stakeholders recognize the legitimacy of the central government in deciding on the land governance policies. Despite delays in the political and legislative processes, we think there is enough political capital to implement changes in the system if it is needed. ***Moderate compatibility***

			land is currently already in the hands of external owners so local ethnic communities are not easily included[cccli]. For example, in Kajiado, which is a Maasai majority county, much land is owned by non-Maasai, leading to tensions between the communities. Furthermore, 'winner takes all' policies at county level lead ethnic majorities in power to excluding minorities from accessing to the state resources[cccliii]. These exclusionary practices at the county level can affect the implementation of the P&S application. *Low compatibility*		the legitimacy of the organization in the management of spatial data concerning the public lands. These findings suggest that low trust to the public officials can affect the perception of the P&S as a reliable source of information. *Low compatibility*		
Operational Unit	• The flexible architecture of the P&S platform allows all operational units that are taking part in land data recording to share their data in the platform through online and offline options. However, the flexibility in data sharing methods depends on the level of digitization with the paper-based maps. The fieldwork suggests that there are significant limitations at the county	• The fieldwork suggests that all three actors in the LAS, i.e. NCL, the Ministry, and county governments (e.g. Kajiado) are developing or have developed a GIS system for data management. However, most county governments do not have the financial and HR capacities to establish or operate a GIS lab. Furthermore, following the 2016 regulations, the field offices of the NLC have been abolished.	• The fieldwork suggests that there are specialized NGOs and private sector organization, which provide GIS services to government agencies as well as support government organizations (both national and county) in terms of capacity building activities. This suggests that it is possible that governmental organizations can collaborate with NGOs	• Financial capacities of operational units vary case by case. For example, Kaijado county government was able to establish a GIS lab with its resources and later with the financial support of the Ministry of Land. But the fieldwork suggests that financial (in)capacities are the biggest	• The fieldwork suggests that at the county level, many government organizations have outdated paper-based maps, which do not present the reality on the ground. Therefore, for the reliability of the system, there is a need for resurveying activities to provide up-to-date digital records. Furthermore, not all county	• We expect for certain county governments (e.g. Kaijado) it is possible to implement the P&S with available financial resources. However, we expect that there will be a need for training to operate with open-source solutions. *Moderate compatibility*	• The presence of specialized private sector organizations which are collaborating both national and county level organizations suggest that it is possible for operational units to acquire the services and/or training in case there is a need to improve the system. • The open-source basis of the P&S platform allows the

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	level with the digitization of maps. *Moderate compatibility*	Consequently, in terms of operational capacities, the Ministry of Land is in a better position to operate with the P&S platform. • Nevertheless, the fragmented nature of the LAS suggests that for the inclusiveness of the P&S, there is a need for effective collaboration among government organizations as well as non-governmental organizations. Successful cases (e.g. GIS lab in Kaijado) suggest that it is possible to develop collaborative working schemes between national and county governments as well as private organizations. *Moderate compatibility*	(both profit and non-profit) in the operation of the P&S. • Even in relatively better cases in terms of data management (e.g. Kaijado), there is a need for better managerial systems and guidelines to enhance data sharing among different stakeholders (e.g. different departments and units of government agencies) for the effectiveness of the system. *Moderate compatibility*	challenges in terms of transforming the paper-based information into GIS systems. This can affect the functionality of the P&S for operational units. *Moderate compatibility*	governments have GIS labs to support the reliability of the data. *Low compatibility*		operational units to upgrade the system if needed. However, there is a need a certain critical mass of knowledge to advance open-source systems in a locally responsive way. The fieldwork suggests that the capacities of the operational units are limited in that regard. *Moderate compatibility*
Social Norms	• There are alternative dispute resolution mechanisms and the legislative system recognizes the traditional mechanisms in land disputes concerning the community lands[ccclvii]. In that sense, we think that the system is flexible in using social and cultural institutions to support the land information management system.	• Especially, in the community lands, there are some tensions between social norms and legal rights with customary tenure. An example is in Maasai culture, daughters are excluded from a land inheritance from their fathers or men can sell the lands to outsiders without telling their wives.[ccclviii]　On the contrary, in the Swahili communities, the social	• Following the devolution of the land administration system, the ethnic diversities at the county level have become a source of violence and exclusion toward ethnic minorities. There have been reports on the displacement of certain ethnic and social groups (e.g. pastoralist or farmers), in rural and community-owned areas[ccclx].	• In rural areas, where tribal and family relations are stronger, social capital can facilitate the collaboration of communities in solving land disputes through alternative dispute resolution mechanisms. • However, there are often intra-family disputes in areas where Maasai	• Many transactions take place outside the formal registration process. A common one is an inheritance according to customary norms where the title remains in the name of the original holder, who may be long deceased[ccclxi]. This social norm can undermine the authoritativeness of data in the P&S platform. But with an appropriate	• The fieldwork suggests that the adaptation of new technologies take time in Kenyan case. Stakeholders prefer to see the added value of the new technologies and methods before adaptation. *Moderate compatibility*	• The fieldwork suggests that new technologies and practices are not adopted right away and it is important to show good practices as well as the added value to the processes. This social approach toward new technologies/practices can hinder the upgradability of the P&S system.

	High compatibility	norms on inheritance prioritize female line over men and the husbands stay at the pleasure of the wife[ccclix]. In these cases, there are widespread subdivision practices but without the legal finality and evidence of a formal subdivision application. *Moderate compatibility*	*Low compatibility*	communities are residing, concerning the subdivision of group ranches. In these cases or for registering unregistered communities in the LAS, the social capital can act against the land recording efforts in terms of the access to genuine qualitative data. *Moderate compatibility*	application on P&S and P&S as a supporting system to LAS, this social practice can be more transparent. *Moderate compatibility*		*Moderate compatibility*
Land recording techniques (LRT)	• P&S is not a recording tool but it can support the LRTs of other tools. The platform provides services such as runtime environment for executing and managing tools; storage services for alphanumeric, geospatial, binary and image data; OGS services for spatial data access; and authentication and authorization services[ccclxii]. This way it can support the use of the land data for multiple purposes (e.g. environmental management, disaster management…etc.). *High compatibility*	• P&S can technically share any tenure information as long as it complies with the formalization standards of the LADM. • For the case of Kenya, we expect that adoption of SSM and UAV tools will enhance the inclusiveness of the system by matching qualitative data in customary and informal tenures with georeferenced orthoimages *High compatibility*	• The data-sharing capabilities in the P&S platform allow the participation of stakeholders even in the cases with limited ICT infrastructure. • In-Field processing is an important aspect of the image-processing system. This allows direct and immediate participation of local people. *High compatibility*	• The effectiveness of the P&S relies on the data fed in the system. Here the affordability of the other tools (e.g. UAV or AFE) at the county level can affect the effectiveness of the system. *Moderate compatibility*	• The P&S platform allows access to different ownership evidence through a set of online services. This way the application can provide authoritative and up-to-date information to users. *High compatibility*	• For the effective implementation of the application or workflows on the P&S platform, there is a need for the digitization of records and adoption of the UAVs and SSM (and preferably AFE) at land recording processes. • Furthermore, the P&S platform relies on the open-source GIS system. This requires a different skillset than the one that exists currently at the local level.	• The P&S architecture is built on open-source solutions, therefore it allows improvements if needed. However, the reluctance of public officials and commercial operators to adopt open-source solutions in land recording tools can hinder the upgradability of the workflows with the P&S platform. *Moderate compatibility*

						Considering the financial and human resources need to address these limitations, we think there are significant challenges for attainability. *Low compatibility*	
Software	• The implementation of the P&S platform follows a toolbox approach and will provide a framework of common APIs and services used by all its4land tools. From this toolbox, a user can select those its4land tools fitting his tasks best. Therefore, the software has high flexibility to fit-in the country-specific conditions. *High compatibility*	• During the testing of the its4Land tools, the image processing workflow of the P&S made use of two COTS software (Pix4D and Matlab). Although the architecture of P&S can integrate tools using COTS software through the runtime environment and the Public API, an adaptation of the COTS software to use the P&S API directly is not possible[ccclxiii]. Open-source alternatives to COTS software can improve the inclusiveness of the system, but at the moment open-source solutions are not much preferred in Kenya, especially among the private operators. These software-related limitations can reduce the inclusiveness of the system. *Moderate compatibility*	• Depending on the access rights, the P&S software allows input and editing by different stakeholders. *High compatibility*	• The testing of the P&S platform has been done with the Amazon Web Services (AWS) for the geocloud approach. Although the system works well at AWS, there are various factors (e.g. cost of the hosting services for operation and implementation, technical suitability with planned scenarios, transparency and security issues, privacy and compliance policies)[ccclxiv] that can affect the choice and affordability of the software. *Moderate compatibility*	• Although the architecture of P&S can integrate tools using COTS software (e.g. UAV and AFE) through the runtime environment and the Public API, it has better compatibility with open-source software. Although there are open source solutions available for UAV and AFE, at the moment the commercial software (e.g. Pix4D) have better reliability in comparison to the open-source alternatives (e.g. OpenDroneMap). However, in the long run, we expect the reliability of open-source software solutions to improve. *Moderate compatibility*	• There are limitations in implementing open-source solutions in LAS due to existing GIS systems operate with ArcGIS instead of QGIS (e.g. the GIS platform of the NCL). Therefore, institutional change to open source systems would require time, technical and policy support as well as further training with open-source software. *Low compatibility*	• The P&S platform operates on open-source software and has better compatibility with open source supported tools. However, the fieldwork suggests that open-source solutions are not common in Kenya, and operators lack technical capacities to work with open source programs • Although it is possible to receive the support of specialized companies for government organizations, these companies usually develop their proprietary software and applications; therefore they could be reluctant to support the implementation of

							open-source software at land recording processes. Alternatively, international donor organizations and non-profit based organizations can support the capacity building activities with open-source systems. *Moderate compatibility*

i Deliverable 4.1, p26.
ii World Bank, Land Governance Assessment Framework Final Report-Rwanda, p.45.
iii Deliverable 4.1, p.9.
iv According to the Transparency International's Corruption Perception Index 2017, Rwanda is ranked in the top 3 least corrupt countries in Africa.
v World Bank, Land Governance Assessment Framework Final Report-Rwanda, p.44.
vi Deliverable 4.1,p.11
vii World Bank, Land Governance Assessment Framework Final Report-Rwanda, p.38.
viii Deliverable 4.2, pp. 42-43.
ix Deliverable 4.1, p.10
x With larger areas we refer to a few extra km^2. In the pilot study, it took 2 entire days and 25 flights to cover almost $3km^2$.
xi Those that are unmapped are particularly in the high mountains (e.g. volcano range in the north), which is also impossible for UAVs.
xii see http://minict.gov.rw/policies-publications/strategy/
xiii The total costs of fees for flight permissions are about 8,5 Million RWF (~8500 EUR). See Deliverable 4.1, p.26
xiv SMART Rwanda Master Plan, p.24.
xv The 2016 Ministerial regulation N°01/MOS/Trans/016 regulates the licensing procedure and the rules of operation for UAVs and the law N°20/2018 of 29/04/2018 'Establishing Regulations Governing Civil Aviation' legislates the rules of civil aviation rules for UAVs.
xvi Deliverable 4.2, p.16
xvii World Bank, Land Governance Assessment Framework Final Report-Rwanda, p.44.
xviii Deliverable 4.1,p.23
xix https://uavcoach.com/drone-laws-in-rwanda/
xx Deliverable 4.1, p.26.

xxi Deliverable 4.1, p.26-27.
xxii See p.10, the definition of 'Maintenance'.
xxiii See part III, reg.36 of 2016 Ministerial regulation N°01/MOS/Trans/016
xxiv Chemouni, B. (2014). "Explaining the design of the Rwandan decentralization: elite vulnerability and the territorial repartition of power". Journal of Eastern African Studies. 8 (2): 246–262. DOI:10.1080/17531055.2014.891800
xxv World Bank, Land Governance Assessment Framework Final Report-Rwanda, p.44.
xxvi see Deliverable 4.2, pp. 42-47. We identified four possible flight scenarios for different purposes.
xxvii Imihigo is the plural Kinyarwanda word of Umuhigo, which means to vow to deliver. Imihigo also includes the concept of Guhiganwa, which means to compete with one another. Imihigo describes the pre-colonial cultural practice in Rwanda where an individual sets targets or goals to be achieved within a specific period. The person must complete these objectives by following guiding principles and be determined to overcome any possible challenges that arise. (see http://rgb.rw/home-grown-solutions/rwandas-hgs-good-practices/imihigo/)
xxviii see Smart Rwanda 2020 Master Plan.
xxix Deliverable 4.2, pp. 42-43
xxx Deliverable 4.2, pp.44
xxxi ibid
xxxii Deliverable 4.2, p.16
xxxiii Deliverable 4.2, p.48.
xxxiv ibid
xxxv Deliverable 4.2, p.12
xxxvi During the pilot work in Germany on automatic extraction of UAV orthoimage, the Pix4DMapper software was used (see D.5.1, p.13). Pix4DMapper software is also used by CharisUAS.
xxxvii see Rijsdijk, M.; Hinsbergh, W.H.M.V.; Witteveen, W.; Buuren, G.H.M.; Schakelaar, G.a.; Poppinga, G.; Persie, M.V.; Ladiges, R. In *Unmanned aerial systems in the process of juridical verification of cadastral border,* ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Rostock, Germany, 2013; *XL-1/W2,* p. 329.
xxxviii Deliverable 4.2, p47.
xxxix Maurice, M.J.; Koeva, M.N.; Gerke, M.; Nex, F.; Gevaert, C. In *A photogrammetric approach for map updating using UAV in Rwanda,* GeoTechRwanda, Kigali, Rwanda, 2015; pp 1-8.
xl See the pricing options for Pix4DMapper. One time charge is as of 2019 is $4990 or a monthly subscription is $292.
xli, See the website of ODM.
xlii Kenya Land Assessment Governance Report- World Bank- p.19
xliii ibid
xliv ibid
xlv Kenya Land Assessment Governance Report- World Bank- p.58, 59
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