The role of volunteered geographic information in land administration systems in developing countries

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Declaration

I hereby certify that the work presented in this thesis is my original research work. Due reference is given to literature and any research collaborations where appropriate. No part of this thesis has been submitted previously for a degree at this or any other university.

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Abstract

Developing countries, especially in Africa are faced with a lack of formally registered land. Available limited records are outdated, inaccurate and unreliable, which makes it a challenge to properly administer and manage land and its resources. Moreover, limited maintenance budgets prevalent in these countries make it difficult for organizations to conduct regular systematic updates of geographic information. Despite these challenges, geographic information still forms a major component for effective land administration. For a land administration system (LAS) to remain useful, it must reflect realities on the ground, and this can only be achieved if land information is reported regularly. However, if changes in land are not captured in properly administered land registers, LAS lose societal relevance and are eventually replaced by informal systems. Volunteered Geographic Information (VGI) can address these LAS challenges by providing timely, affordable, up-to-date, flexible, and fit for purpose (FFP) land information to support the limited current systems. Nonetheless, the involvement of volunteers, who in most cases are untrained or non-experts in handling geographic information, implies that VGI can be of varying quality. Thus, VGI is characterised by unstructured, heterogeneous, unreliable data which makes data integration for value-added purposes difficult to effect. These quality challenges can make land authorities reluctant to incorporate the contributed datasets into their official databases. This research has developed an innovative approach for establishing the quality and credibility of VGI such that it can be considered in LAS on an FFP basis. However, verifying volunteer efforts can be difficult without reference to ground truth, which is prevalent in many developing countries. Therefore, a novel Trust and Reputation Modelling (TRM) methodology is proposed as a suitable technique to effect such VGI validation. TRM relies on a view that the public can police themselves in establishing 'proxy' measures of VGI quality and credibility of volunteers, thus facilitating VGI to be used on an FFP basis in LAS. The output of this research is a conceptual participatory framework for an FFP land administration based on VGI. The framework outlines major aspects (social, legal, technical, and institutional) necessary for establishing a participatory FFP LAS in developing countries.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AFRD	Association for Rural Development
API	Application Programming Interface
ASPRS	American Society for Photogrammetry and Remote Sensing
BSMS	Botswana Surveying and Mapping Standards
CGDI	Canadian Geospatial Infrastructure
CLS	Customary Land Secretariats
CMV	Configurable Map Viewer
DSM	Department of Surveys and Mapping
EMA	Ethiopian Mapping Agency
FFP	Fit for purpose
FIG	International Federation of Surveyors
GIS	Geographic Information Systems
GLTN	Global Land Tool Network
GPS	Global Positioning Systems
GSDA	Global Sustainable Development Agenda
ICT	Information and Communication Technologies
IT	Information Technology
IP	Internet Protocol
ISO	International Standardization Organization
ISK	Institute of Surveyors of Kenya
KISIP	Kenya Informal Settlement Improvement Project
LAC	Land Administration Committee
LADM	Land Administration Domain Model
LAPCAS	Land Administration, Procedures and Capacity Building System
LAS	Land Administration Systems
LIS	Land Information System
LCA	Latent Class Analysis
MVP	Minimum Viable Product
MAST	Mobile Application to Secure Tenure
NED	Named Entity Disambiguation
NDP 11	National Development Plan of Botswana April 2017 – March 2023
NLP	Natural Language Processing
NGOs	Non-Governmental Organizations

OSM	OpenStreetMap
OS	Ordnance Survey
PIDs	Preliminary Index Diagrams
PIE	Prevention of Illegal Eviction and Unlawful Occupation of Land Act
PPP	Public Private Partnership
RTK	Real Time Kinematic
RDF	Resource Description Framework
RRR	Rights, Responsibilities and Restrictions
RMSE	Root Mean Squared Error
STDM	Social Tenure Domain Model
SOLA	Solutions for Open Source Land Administration
SDG	Sustainable Development Goals
SPARQL	SPARQL Protocol and Resource Description Framework Query Language
TLIMS	Tribal Land Information Management Systems
TRM	Trust and Reputation Modelling
UN-FAO	United Nations Food and Agricultural Organization
UN-Habitat	United Nations Human Settlements Programme
UB	University of Botswana
USAID	United States Agency for International Development
VGGT	Voluntary Guidelines on the Responsible Governance of Tenure
VGI	Volunteered Geographic Information
W3C	World Wide Web Consortium

Chapter 1. Introduction

1.1 Research context

Land administration is the process by which land and information about land are properly managed. A proper administration of land records is vital to provide a framework through which solutions to social, political and environmental problems can be devised and implemented (Dale and McLaughlin, 1988). Unfortunately, only about 30 percent of land across developing countries is formally documented in official records (Enemark, 2013); in rural Africa, the situation is worse, with only 10 percent of land formally registered (Cheremshynskyi and Byamugisha, 2014). Available records may well be outdated, inaccurate and unreliable, which makes it a challenge to properly administer and manage land and its resources. A large proportion of the population in developing countries depends on land and its resources for their sustenance. The reliance on traditional standards-based Land Administration Systems (LAS), characterised by expensive license fees, procedures, and maintenance structures is not feasible in developing countries (McLaren, 2011; Enemark *et al.*, 2014). A lack of capacity and financial constraints are the main inhibiting factors in adopting traditional LAS typically used in western countries.

Developing countries have in the past attempted to establish LAS without much success, mainly due to legal, institutional and political issues. Moreover, it had been costly, time-consuming and capacity demanding to implement western style LAS, hence the failures of previous attempts in countries like Botswana, Kenya and Ghana. Current solutions for delivering LAS have limited global reach: about 75% of the world's population lacks formal systems for registering and securing their land rights (Enemark *et al.*, 2014). The majority of these are the poor and vulnerable, who constantly live in fear of eviction. According to Deininger and Ali (2008) land grabbing by private entities and expropriation without adequate compensation occur regularly in customary and communal land holdings, which greatly disadvantages local communities.

This research has been motivated by challenges for LAS in developing countries, in particular, a lack of regular updates and maintenance of geographic information. This leads to inefficiencies in the administering of land in these countries. Limited maintenance budgets prevalent in developing countries make it difficult for organizations to conduct regular systematic updates of geographic information. Despite these challenges, geographic

information still forms a major component of effective LAS. For a LAS to remain useful, it must reflect realities on the ground and this can only be achieved if land information is reported regularly (Zevenbergen, 2002). Biraro *et al.* (2015) stress that if changes in the land are not captured in properly administered land registers, LAS lose societal relevance and are eventually replaced by informal systems. Current official systems are based on frameworks that are closed, expensive, and prone to abuse. For example, land information in current systems is not readily available to local communities and a lack of proper checks and balances makes it easy for officials to manipulate to their advantage or favour the elite and politically connected. It is proposed that an alternative geospatial data collection mechanism that is affordable, participatory, transparent, and inclusive of all stakeholders could provide a partial solution to land administration challenges in developing countries, especially in Africa.

The increase in collaborative initiatives like Wikipedia, OpenStreetMap (OSM) and Wikimapia is a positive sign that communities around the world are eager to create content of all types online using contemporary technologies and systems. These initiatives have shown that detailed geographic information can be provided in a timely and low-cost manner (Basiouka, 2010; Goodchild and Li, 2012; Fonte *et al.*, 2015). Furthermore, the increase in the use of the Web, Global Positioning Systems (GPS) units, smartphones, and wider and affordable internet access in developing countries, has greatly facilitated collaborative efforts among citizens. These efforts have opened doors for the public to become collectors of geographic information, known as Volunteered Geographic Information (VGI) (Goodchild, 2007). VGI is a type of geographic information where people (experienced or inexperienced), either as individuals or collaboratively, voluntarily collect, organize and disseminate geographic information in Web-based environments (Tulloch, 2008).

VGI has the potential to address challenges of LAS in developing countries by providing timely, affordable, up-to-date, flexible, and fit for purpose (FFP) land information to support current systems. The FFP concept is supported and advanced by international agencies such as the World Bank, United Nations, Global Land Tool Network (GLTN) and International Federation of Surveyors (FIG). VGI can further improve the awareness of local communities about land management issues, increase their security of tenure, and facilitate inclusive planning and administration of land and its resources.

VGI can support basic tasks like map production and updating (Moreri *et al.*, 2015), but the involvement of volunteers, who in most cases are untrained or non-experts in handling

geographic information, implies that VGI can be of varying quality. Moreover, VGI initiatives like OSM and Wikimapia can suffer from serious weaknesses, such as lack of metadata about contributed datasets to inform potential re-users of the parameters employed for quality assurance measures (Goodchild and Li, 2012). VGI quality assessment is not often conducted in most projects, due to a lack of central coordination and absence of strict data collection guidelines (Haklay *et al.*, 2010; Corcoran and Mooney, 2013).

These challenges are further increased by the lack of usable, systematic, and comprehensive VGI quality assurance measures integral to geospatial data collection (Haklay *et al.*, 2008). Thus, VGI is characterised by unstructured, heterogeneous, unreliable data which makes data integration for value-added purposes difficult to effect. Moreover, these VGI quality challenges make authorities, including land administrators, reluctant to incorporate the contributed datasets into their official databases. A Trust and Reputation Modelling (TRM) methodology is proposed in this thesis to establish a 'proxy' quality and credibility measure of VGI without the typical reference to ground truth which characterises most quality assessments. TRM utilizes the 'power of the crowd' principle (Haklay *et al.*, 2010) to establish the level of trust of VGI and characterise the credibility of volunteers. The 'power of the crowd' principle has demonstrated success in non-spatial data collaborative initiatives like Wikipedia and open source software design. The rationale behind the principle is that inaccuracies in contributions are likely to be identified and corrected by many participants, thus reducing the overall errors. As this principle has not been explored extensively in VGI, this study has examined the potential of intrinsic measures of VGI quality based on TRM, and applied them to data handling in LAS, particularly where authoritative datasets for ground truthing are limited.

In the past, traditional land administration processes in most developing countries, Botswana included, were consensus-based (Collins and Mitchell, 2017). For example, whenever land adjudication took place, community members were required to be present to identify their land rights, while land surveyors mapped and demarcated the identified land parcel boundaries. When communities have a collective say, there exists a common sense of ownership and responsibility for stewardship. However, consensus-based decisions do have challenges. They can suffer from a lack of accountability from community members, especially if it is a large group without common goals, clearly implemented processes and active facilitators. A lack of clear decision-making processes can promote mistrust among community members. Additionally, community developments can suffer, and disputes occur when a consensus cannot be reached. Desirable features for good governance as outlined by FAO (2007) include: a)

enabling citizens to participate fully in governance through consensus-building and engaging them without curbing their freedom of expression, b) designing responsive systems that citizens want and need, and c) delivering quality services in the most effective and efficient way. Unfortunately, these features are currently lacking in LAS in developing countries.

Within the open source community, the assumption that as the number of contributors increases so does the quality, is known as 'Linus' Law' (Raymond, 2001). Haklay *et al.* (2010) proved that this rule applies when assessing the positional accuracy of spatial features in VGI. The research presented in this thesis proposes the application of this rule in determining the attribute and positional accuracy of VGI using TRM for land administration. As multiple participants work in the same geographic area, often capturing the same data, there are opportunities for errors made by others to be identified and fixed, consequently improving the quality of the contributed datasets without the need for formal quality assurance measures. Linus Law is assessed quantitatively and differs for each TRM parameter. The number of contributors required to establish VGI accuracy and credibility is elaborated in Section 4.3.4. For example, a minimum of 13 contributors are required to establish the thematic accuracy of a contributed dataset (Haklay *et al.*, 2014). To assist with data capture, a Web map application was developed with ArcGIS Application Programming Interface (API) for JavaScript and Configurable Map Viewer (CMV) to act as a testbed for volunteers to contribute land information of their local community which could later be assessed by experts using TRM methodology. The application has been designed such that it mimics official database schemas to enable a seamless data integration at a later stage in the administration of land.

The output of this research is a conceptual framework for an FFP land administration based on VGI. The objective is to demonstrate the role that VGI can play in adding value and flexibility to official LAS in developing countries. Part of the context is an acknowledgement by the global community that securing land tenure for citizens in developing countries implies that less conventional forms of land tenure, and its recording, should be recognized and given better forms of security and protection (Payne, 2001; UN-Habitat, 2012; Zevenbergen *et al.*, 2013). Examples of less conventional methods of recording land rights include the use of participatory approaches like VGI which can contribute to an FFP system with low cost and positive time efficiencies. The conceptual framework outlines how a participatory and FFP LAS should appear, including highlighting the important legal, social, institutional and technical aspects for a successful implementation. Previous studies have lacked conceptual framework underpinnings as they only concentrated on the benefits, opportunities, challenges and potential

risks of implementing a participatory LAS. The proposed framework presented here provides a better understanding of the initiative by identifying wider aspects involved and how they can be leveraged to provide a solid foundation that supports the adoption of VGI in official systems.

The process and extent to which VGI can be adopted in official systems remain a challenge which this study has investigated in a national context. Therefore, the conceptual framework further outlines techniques and measures of how VGI can be implemented in the administration of customary land, in this case in Botswana. Customary land makes up most of the country's surface area (71%). Currently, Land Boards (land administration authorities) lack proper registers of allocated customary land parcels (Malope and Phirinyane, 2016; Khama and Seleka, 2017). As a result, many allocated land parcels lack evidence that establishes tenure, while available land registries have outdated information (which eventually leads to an ineffective LAS).

1.2 Aim of research

This research aims to investigate the role that VGI can play in adding value and flexibility to existing formal land administration systems in developing countries.

1.2.1 Research questions

Several specific research questions are addressed in this research:

1. What is the current nature of land administration systems in developing countries?

2. How have VGI initiatives been implemented for land activities in developed and developing countries, and how can they be adapted for broader land issues like policy formulations, planning, and decision-making purposes in developing countries like Botswana?

3. What kind of land information do people want to record in a dynamic and collaborative environment, and what technical tools do they want to use to record this information?

4. What are the technical options available to develop a VGI Web map application and what are the implications of utilizing a particular tool?

5. What options are available to assess the credibility of contributed datasets in a VGI Web map application?

6. What options are available to design a conceptual participatory framework that addresses data quality issues and conflicting contributed datasets from different sources, such that they produce meaningful results?

The outlined research questions were motivated by the concern that developing countries have failed to take advantage of technological developments like VGI technologies, which have the potential to improve current procedures in LAS in developing countries. As such, this research has identified challenges as motivating factors that can help developing countries adopt and incorporate VGI technologies into their organizational workflows to improve LAS. The most important research questions include numbers 1, 3, 4, and 5 above.

The first research question stresses the need to understand the nature and current processes of LAS in developing countries. Colonial systems, as articulated in Section 2.1.1 are not flexible to adapt to traditional systems because of different spatial concepts involved: the former is focused on individual titled rights, while the latter is communal-based with varying undocumented social tenure relationships. These challenges are highlighted in Section 2.3 where shortcomings in the design, implementation and delivery of LAS are identified and categorized and an overall typology and list of problems of Sub-Saharan countries presented.

The third research question identifies land information of importance to the public and the tools they want to use to record it. It is very important for the buy-in and eventual utilization of the initiative, as outlined in Section 4.1.2. Furthermore, it highlights important land information that the initiative can focus on, such that it can be positioned to meet the needs of local communities. The fourth research question investigates technical options available to develop a VGI Web map application and the implications of utilizing such a tool. It is elaborated in Section 5.1.2. Despite the challenges raised in Section 3.3, of developing countries having poor mobile phone and Internet coverage, particularly in rural areas, recent statistics in Botswana have indicated that there has been great improvement in the latter (Statistics Botswana, 2017): On average 72.6% of inhabitants have Internet access, which outlines the significance of the technology and its consideration in this research as a viable tool to use in engaging the public in land related matters of the study area.

The significance of the fifth research question is that it argues that previous participatory initiatives in both developed and developing countries, as investigated in Chapter 3, have not sufficiently addressed the issue of assessing VGI quality and credibility of volunteers such that confidence can be placed against the contributed datasets. Therefore, potential reusers of the data may be sceptical to utilise the datasets to improve records in official systems or informed decision-making purposes. Moreover, Section 3.3 highlights that established data quality and credibility measures of VGI have been major challenges of implementing participatory initiatives, which this research challenge aims to address.

1.2.2 Objectives

For the research to meet its aim, there are a number of objectives mapped directly from the research questions that have been identified, and are to be specifically addressed as follows:

1. To undertake a review of LAS in developing countries to identify shortcomings in the design, implementation and delivery of LAS.

2. To conduct research on volunteered geographic information initiatives in developed and developing countries, dealing with land issues and investigating how the initiatives can be adapted in broader land issues like policy formulations, planning, and decision making in the context of Botswana land administration.

3. To conduct research in the study area to identify land information of significance to the local community and to examine how such information can be contributed and used to improve official LAS.

4. To develop a VGI Web map application based on ArcGIS Server using ArcGIS Application Programming Interface (API) and Configurable Map Viewer (CMV) to provide a platform that the public can use to contribute land information of their local community.

5. To develop a rating system to assess the quality of contributed datasets by the public and credibility of contributors, such that trust and confidence can be recorded in the datasets.

6. To design a conceptual framework for a Fit for Purpose Land Administration System based on Volunteered Geographic Information, and apply it in a case study in Botswana.

1.3 Structure of the thesis

Besides this introductory chapter, this thesis has seven more chapters addressing the aim and objectives, as stated in Section 1.2. Chapter 2 reviews relevant literature in the field of land administration in Sub Saharan Africa and the cadastral system of Botswana as an engine for LAS. Chapter 3 reviews relevant literature on VGI initiatives, defining key concepts and discussing previous initiatives, conducted particularly in developing countries, outlining their successes and challenges to establish how a participatory initiative can be implemented in the context of Botswana land administration. Chapter 4 presents a methodology for implementing an FFP land administration based on VGI. Chapter 5 outlines data collection activities conducted in the study area and discusses VGI application development processes. Furthermore, it presents a detailed methodology of this research, which focuses on establishing mechanisms in which public contributions can be assessed for quality and reliability, to increase the confidence of potential consumers and chances of incorporation in official systems. An analysis and discussion of results obtained from the data collection activity and their significance in improving official databases will be conducted in Chapter 6. Chapter 7 proposes a conceptual framework that introduces four main aspects necessary for VGI consideration in official systems and outlines how it can be incorporated into official systems in Botswana for value-added purposes. Finally, Chapter 8 presents a general discussion, recommendations and conclusion, highlighting key findings of the research and their contributions to the role that VGI can play in adding value and flexibility to LAS in developing countries.

Chapter 2. Review of land administration systems in Sub Saharan Africa and the cadastral system of Botswana

This chapter conducts a review of LAS in developing countries to identify shortcomings in their design, implementation and delivery. The objective is to examine and categorize shortcomings and issues that LAS in developing countries encounter, and present an overall typology and list of LAS problems of Sub-Saharan African countries. Moreover, it will investigate the cadastral system of Botswana as an engine for LAS in rural areas, administered by District Land Boards. To better understand how customary land is administered in the country, a review of policies, legal and regulatory frameworks, and institutional arrangements implemented by the country will be examined.

2.1 Land administration in Sub Saharan Africa

LAS are implemented with the anticipation that principles of equity, non-discrimination, efficiency, transparency (e.g. improving fairness of LAS by establishing open processes and procedures), productivity and sustainability (e.g. integrating land administration and other environmental resources to meet the needs of communities for continual reuse), among others, may be upheld in a local community. Many developing countries in Africa recognize that modernizing their cadastral systems can facilitate better land administration (Tembo and Simela, 2004). A cadastre is a system of registration of land rights that concerns properties within a certain district, based on a survey of their boundaries (Henssen, 1995). It is different from a LAS which defines a process by which land policies and laws are administered to manage ownership and secure tenure for citizens. Countries like Uganda, Kenya, Ghana, South Africa, and Botswana, are examples of nations that have adopted modern LAS.

The consensus is that a lack of modern cadastral systems contributes to land administration problems in developing countries, especially in Africa. A modern system in this context refers to initiatives framed on principles of sustainability, transparency, stability (e.g. establishing reliable LAS for local communities), security (e.g. protection against forced evictions), efficiency (e.g. completing Land Board transactions within a short period of time with less effort using modern technologies) and effectiveness (e.g establishing modern systems to facilitate the production of desired results). However, African countries continue to have traditional LAS that are not effective, efficient nor transparent. Africa, especially Sub-Saharan

countries have poor LAS because they lack functional systems to document land to provide legally recognized tools like a certificate of ownership and title deeds, which can facilitate investments in land by local communities. Moreover, limited maintenance budgets prevalent in developing countries make it difficult for organizations to conduct regular systematic updates of geographic information. Unsolved land tenure and land administration issues can result in economic and political disasters, as demonstrated by the Zimbabwe land reform in the year 2000 (Pienaar, 2009). A lack of strategies of how modernization initiatives can be implemented has been a persistent denominator.

2.1.1 Land tenure systems in Sub Saharan Africa

Land tenure describes the interests that the public, in general, holds over a piece of land. Many developing countries in Africa during the 20th century were under colonial rule, whose systems continue to have a major impact on how LAS are run. Their residual influences are still evident in post-colonial countries, as in state land and freehold land tenure systems practised in Botswana, Kenya and South Africa. According to Williamson (2000), colonial systems are not flexible to adapt to traditional systems because of the different spatial concepts involved: the former is focused on individual titled rights, while the latter is communal-based with varying, undocumented social tenure relationships.

Legal structures put in place by colonial powers, as articulated by Fourie (1998), have not been sufficiently adapted to accommodate local or indigenous norms. Such instances have led to countries embracing middle class or inappropriate standards often accompanied by a lack of capacity in regards to technical, planning, management and administration of land (Fourie, 1998). Developing countries have a range of tenure systems which include state, freehold, and customary land. The focus of this study will be on customary land tenure system (Section 2.4). Research (Kyomuhendo, 2007; Appiah, 2013; Ravnborg *et al.*, 2013) shows that customary land tenure has not been successfully incorporated into colonial systems yet it is applied over the majority of land areas of most Sub-Saharan African nations and affects the largest proportion of the population. It is characterised by poverty, insufficient documentation and tenure insecurity.

2.2 Characteristics of land administration systems in Africa

Implementations of LAS vary from one country to another because of differences in cultural practices and colonial histories. The factors that drive or affect the choice of strategies adopted are many and varied, hence the need for each country to have its own strategy. Nonetheless, strategies can be developed where many separate, well-understood, proven and generally accepted principles and concepts are utilized (Williamson, 2001). The generally accepted principles of land administration include good governance in both the corporate and public sector particularly concerning policy, planning, decision-making, administration and management (FAO, 2007). Good governance further requires land authorities to be accountable, transparent and provide the public with timely, accessible and accurate information. In short, valuable lessons can be learned from other countries with established systems and specific strategies developed for the country of interest. Such strategies could focus on the relationships that mankind has with land and its resources. For example, focus in urban areas could be on active land markets and informal squatter settlements, while in rural areas, it could be on customary land, social tenures, land subject to indigenous rights, and prime agricultural lands. Another consideration could be the acknowledgement that relationships to land evolve because of external forces like urbanization and sustainable development activities.

The following sub-sections are overviews of land administration efforts in some developing countries in Africa: Uganda, Ghana, Kenya, South Africa and Botswana. These countries have recently undertaken innovative land administration exercises and conducted participatory interventions that could be learned from. Botswana unlike other countries stated, was a British protectorate, not a colony, meaning that it had its own state but controlled by a larger country being Britain. This arrangement allowed it to have control of its land and resources through the stewardship of tribal chiefs until the formation of Land Boards post-independence. However, it has failed to be a true representative of a country with a functional LAS compared to other developing countries in Sub Saharan Africa. Despite having a large land mass (581,730 km^2), a small population of only 2 million inhabitants, and regarded as a middle-income economy (Statistics Botswana, 2017), the country still has land administration challenges that emanate from a lack of proper management and documentation of land due to limited capacities and insufficient infrastructures. To fully understand the core processes of how a LAS of a country works, there is a need to study how it has been modelled and reformed (Williamson *et al.*, 2010). Therefore, brief overviews of land reforms from the colonial era will be conducted for

each country investigated, to provide key elements regarding the organizational structures and processes of existing LAS in each country.

However, most land tenure in Africa is outside the conventional registration system (Augustinus, 2003), and focus on new land laws has been on new forms of title and tenure. Nonetheless, it is believed that research on conventional systems can further shed light on land rights outside these systems. The assessments of the five outlined countries will be on their compositions and the current public participatory activities of each country. A comparison of LAS in these countries is not meant to set one system off against another but to extract principal elements and to identify important parts where lessons can be drawn and applied in another country.

2.2.1 Land administration in Uganda

Uganda has three land tenure systems: a) freehold, b) leasehold and c) customary land. These systems have been attributed as the major root causes of land problems in Uganda, as they favoured European settlers and chiefs more than local citizens (Kyomuhendo, 2007). According to the author, large tracts of land were allocated or reserved for settlers and chiefs, while local citizens were made squatters in their own country. Such an arrangement, over the years, created social unrest in the country, which led to major land reforms that negatively affected LAS (Green, 2006; Bomuhangi *et al.*, 2011). To address these challenges, the country is in the process of investigating ways of harmonizing the various tenure systems to enable the standardization of land administration in the country (Ravnborg *et al.*, 2013).

Customary land tenure in Uganda occupies about 62% of the country and is inhabited by approximately 68% (8 million) of the population (Bruce, 2014). However, only 18% of land in the country is registered (World Bank, 2012). This limited extent of formal tenure, together with a lack of credible LAS, constrains land-based transactions. Land transactions in Uganda are further hampered by insecurity and characterised by unclear property rights, disputes and conflicts (World Bank, 2012). It has been reported by Ravnborg *et al.* (2013) that ambiguities and discretionary land rights administration have contributed to severe land rights insecurities and land grabbing. Uganda has long and costly land administration processes, which are not affordable to the rural poor. Therefore, current processes do not favour the rural poor who make up most of the population.

Despite the challenges discussed, formal land registration has been promoted through land reforms in Uganda. Just like other developing countries, the general belief is that they can guarantee tenure security and enhance investment in the land. Nonetheless, research in the past (Kyomuhendo, 2007; Deininger and Ali, 2008; Ravnborg *et al.*, 2013), has indicated that land reforms have not served the rural poor. Moreover, they have failed to actively engage local communities in consultations for informed decision making in land related matters (Deininger and Ali, 2008). In the political arena, some political leaders who own large masses of land are reluctant to support land reforms that aim at taxing their personal interests. This greatly disadvantages local communities, as land reforms aimed at bettering their lives are either rejected or sabotaged to take longer to be implemented. However, Augustinus (2003) argues that for instances where there are no documentary evidence to prove ownership, group cohesiveness can be used to secure the tenure of residents as practised in Uganda.

Public participatory initiatives in Uganda

The government of Uganda in 1995, decentralized land registration to local governments to ensure that local communities participate and democratically take part in decision making (Kyomuhendo, 2007). The decentralization process was also meant to make land registration activities quicker and cheaper, as well as easier to recognise and abide by local land rights norms. An attempt to introduce a participatory initiative in Uganda received varying degrees of success and challenges because of implementation problems (UN-Habitat, 2012). A pilot participatory project using a Social Tenure Domain Model (STDM) was conducted in Mbale, Uganda in 2012 by Cities Alliance and the International Federation of Surveyors (FIG). STDM is an initiative by UN-Habitat and FIG designed to provide an alternative and affordable land information tool to document social tenure relationships that citizens have with the land, to strengthen tenure security, empower poor communities, and improve their livelihoods. A detailed description and further application areas of the STDM are outlined in Section 3.2.2.

The main objective of the project was to pilot test the STDM and to document processes and capacity building requirements about its use and application in addressing requirements of informal and customary land tenures. Mbale residents were trained on the mapping approach to perform participatory enumeration of recording demographic data of other community members. The expectation was that the initiative would establish a dialogue between local communities and authorities to improve tenure security, encourage inclusive planning and improve access to basic services and infrastructure within the community (Jha *et al.*, 2013;

Antonio *et al.*, 2014). The project used a satellite image to produce a settlement map of houses, land parcels, roads, water points, etc. using an on-screen digitizing method. The mapping activity was conducted by citizens with guidance from authorities. The spatial data collected was later linked to descriptive information about occupancy and other supporting documents (scanned images, text and photos), to produce occupancy certificates for residents.

The data collected further provided a platform for communities to engage local authorities on issues like inclusive planning, request for access to basic services, negotiations of possible development activities and tenure security improvement (Jha *et al.*, 2013). The success of the initiative was attributed to the successful partnerships built between relevant organizations involved and the readiness of the government and other stakeholders to embrace it: which, enhanced its acceptability by leaders and the general community. According to Antonio *et al.* (2014), this community mapping project provided transparency, increased cooperation and built trust among community members to produce reliable and trustworthy data.

2.2.2 Land administration in Ghana

Ghana's land tenure system, comprises customary land, which occupies 78% of the country, the state owns 20% and the remaining 2% is owned by the state and customary authorities as partnerships known as vested lands (e.g. mineral-rich areas and watercourses) (Steudler *et al.*, 2010). Land related activities in Ghana are governed by two laws: a) the Lands Act for land tenure, administration, management, surveying and mapping, and b) the Land Use Planning Act responsible for all land use related activities. Despite the laws outlined, land tenure systems have had many constraints, which include: a) land ownership conflicts among individuals, land owning groups and the state, b) reliance on outdated legislation, and d) a lack of a coordinated geographic information system (Appiah, 2013). Other land administration challenges cited by Abdulai (2006) include a lack of consultation, coordination and cooperation among land development agencies, which impacted negatively on service delivery. Poor implementation of the land law regarding title registration has been reported by Sittie (2006) as one of the aspects that led to the ineffectiveness and inefficiency of the land registration system of Ghana.

Ghana practices two forms of land registration systems: the deeds and title registration systems. The deeds registration system was practised in the colonial era for registering all land parcels in the country. Deeds registrations were characterised with certain weaknesses since they were descriptive in nature and land parcels were not surveyed and demarcated (Appiah, 2013). Some of the challenges associated with the deeds registration system included: a) inaccurate plans

which often created conflicts among landowners, and b) inability of the system to detect multiple registrations, thus encouraging fraudulent practices by officials (Sittie, 2006; Mitchell *et al.*, 2008).

Title registration was introduced in 1986 to address the challenges of the deeds registration system (Sittie, 2006). It provides accurate cadastral maps to reduce fraud, multiple registrations and land litigations. Furthermore, it facilitates the publication and adjudication of conflicts. Title registrations are not justifiable by argument and can only be cancelled by the court of law, thus providing security of tenure to local communities. A Land Title Registered Law was formulated to govern the registration of all interests in customary and common law (Mitchell *et al.*, 2008). However, it failed to minimize litigation as initially envisioned, and weaknesses of the deed system remained unsolved (Sittie, 2006). For example, current procedures allow an individual to have a deed and title for the same piece of land. This leads to insecurity and uncertainty to land registration since it encourages corruption practices: it gives a landowner the opportunity to fraudulently sell their land parcel to two unsuspecting buyers using the deed in one transaction and the title in the other.

Public participatory initiatives in Ghana

Current land administration, management and conflict resolution activities in rural areas of Ghana are conducted by Customary Land Secretariats (CLS), which comprise local people led by traditional leaders (Byamugisha, 2013). The initiative was meant to encourage locally based forums to manage and resolve land disputes. However, the success of CLS has been hampered by lack of interest from the local community, corrupt practices by leaders, and weak capacity, which resulted in its subsequent failure (Byamugisha, 2013). A lack of clarity in purpose and scope of functions of Ghana's land authority has led to a loss of confidence by the general public on the ability of the government to protect their land rights (Sittie, 2006). This insecurity and uncertainty has forced some community members to engage illegal private security officers known as "land guards" to protect their land rights (Abdulai, 2006). The use of land guards is participatory in nature, since it helps fill in gaps of the state's inability to secure property rights in the absence of effective alternatives in the country. The role of land guards is to physically guard and secure land parcels of owners from unlawful access and occupancy. Nonetheless, the government has declared their engagement illegal, since they can be violent and intimidating (Obeng-Odoom, 2014). Despite the declaration, Obeng-Odoom (2014) maintains that people continue to utilise their services because they have a significant amount of utility to them.

Fortunately, land registration laws in Ghana allow the use of general boundaries, which provides an opportunity for participatory mapping activities (Ghana Land Act, 1986). A study conducted by Asiama *et al.* (2017) used a participatory initiative in the Nanton region of Ghana in 2016, to map and document farmlands in the area, where all the land is held under customary tenure. The land registration in the area is a deeds system which does not consider the survey or mapping of land parcel boundaries when registering land, but rather, descriptive data.

Asiama *et al.* (2017) examined how participatory land administration could fit into customary land administration to support responsible land consolidation. Two data collection methods were compared: a) a mobile phone app to collect boundary and attributes information of land parcels, and b) a printed orthophoto for farmers to trace land parcel boundaries of their farms with red markers. It was concluded that the mobile application was more appropriate for capturing farm boundaries since it was easy to use and required little training compared to the satellite imagery process (Asiama *et al.*, 2017). Even though the study did not undertake the actual land consolidation with the data collected, it concluded that the participatory initiative enabled the capture of all customary land rights and other relevant information necessary for land consolidation.

2.2.3 Land administration in Kenya

Before colonial rule, land in Kenya was owned communally: it belonged to the community as a collective and was controlled by traditional leaders. However, this changed when the colonial government introduced title deeds and individual ownership of land. According to Siriba and Mwenda (2013), individual ownership arrangements decreased agricultural production over the years since prime lands were reserved for the white minority. This reduction was due to the majority population being unable to produce large amounts of agricultural produce to meet the needs of the country. Kenya now has four land tenure systems: a) private/freehold – 40.4% of land area, b) public/government – 6.4%, c) customary – 53.1%, and d) non-formal de facto – 0.2% tenure systems (Olima and Obala, 1998). Private land is held by individuals, private companies and co-operative societies. Public land is like state land in other countries and comprises urban areas, game reserves, national parks, and protected areas, while customary land is held by local authorities on behalf of citizens. Non-formal defacto tenure refers to land occupied by squatters: where land is acquired, occupied and used without the permission from its owner, whether the government or private individual. Customary tenure holds about 75% of the country's population, and only 35% have formally registered land rights (World Bank,

2012). According to Kameri-Mbote (2005), a large proportion of the population in rural areas has unregistered land rights and is characterised by poverty and insecurity of tenure.

Land administration in the country is characterised by expensive, undemocratic practices that are prone to abuse, and result in excessive delays and injustices (Siriba and Mwenda, 2013). Moreover, Wayumba (2013) stresses that current LAS are complex and have ineffective centralized bureaucratic administrative structures. Such instances further provide opportunities for malpractices and corruption. In realizing that a centralized system was not efficient, the government in 2012 commissioned a study by the Institute of Surveyors of Kenya (ISK) to develop a suitable model for land administration for the country (Siriba and Mwenda, 2013). Recommendations of the study were that the central government should: a) decentralize its processes to local governments to work closely with local communities, and b) transfer its decision making and implementation powers, functions, responsibilities and resources to local governments.

The underlying logic of decentralization is that local institutions can have better access to information to effectively allocate resources and respond to local needs and aspirations. However, unclear roles of local and traditional authorities, together with undefined future sustainability measures of the initiative have been a challenge to the country (Bruce, 2014). For example, the sustainability of LAS, among other factors, depends on the willingness of landowners to actively participate in updating the system with current information. This renders it relevant for use for many applications. Unfortunately, it has not been the case with current systems in Kenya, hence being outdated and irrelevant (Wayumba, 2013).

Public participatory initiatives in Kenya

Kenya recently introduced a Community Land Bill that recognizes and supports the registration of communal land rights (Community Land Act, 2015). The bill advocates the engagement of the public in documenting, mapping and developing an inventory of community land. It further stresses that the engagements shall be carried out in a transparent, cost-effective and participatory manner such that it creates awareness of community land rights.

Public participation to ensure that there is accurate and up-to-date content in the land register is evident in Kenya, particularly in informal settlements (slums) and customary land. In the past, the country engaged local communities to establish general boundaries of their land parcels by planting hedges with guidance from demarcation officers from the land authority:

this was known as the ‘general boundary system’ (Ondulo and Kalande, 2006). According to the authors, the system was implemented in 1959 to speed up land registration in customary land as indigenous people had not received any title since 1903 when the cadastral system was introduced. Once the hedges had grown sufficiently, aerial photographs of the area were produced to generate Preliminary Index Diagrams (PIDs) (Wayumba, 2013). PIDs are tracings of land parcels from aerial photographs, which serve as interim cadastral data for agricultural land. General boundaries considered accurate and acceptable by the District Survey Office were used to prepare land titles at the District Land Registrar Office (Wayumba, 2013).

Recently, a participatory FFP approach to land administration was conducted in Makueni County, in 2017 by the Dutch Cadastre, Institution of Surveyors in Kenya, the Kenyan Ministry of Lands and Physical Planning, and local governments (Ambani *et al.*, 2017). The objective of the activity was to register people-to-land relationships, where villagers were engaged to collect data in the field by walking perimeters of their land parcels with handheld GPS units. To boost community involvement, village elders and leaders were informed of the activity, which further increased the awareness and buy-in of all parties involved (Ambani *et al.*, 2017).

Currently, the country has an ongoing project to uphold customary land tenure and to formalize informal land administration arrangements by the Kenya Informal Settlement Improvement Project (KISIP) (Mangira, 2017). KISIP is a seven-year (2011-2018) community-based mapping project by Kenyan municipalities and the World Bank, which aims to upgrade slums in the country by improving tenure security of residents living there. As noted by Mangira (2017), KISIP has adopted STDM procedures to engage local communities and their representatives to collect data of their local area. Moreover, it engaged government agencies in mapping and adjudication processes, which accorded the data collected some degree of formality and legitimacy. Another participatory initiative was conducted in Kibera (one of the largest slums in the world) in 2009 to empower inhabitants of the slum in Nairobi, Kenya (Panek and Sobotova, 2015). The project engaged citizens to record data, news reports, and map information about their community, which was later used to illustrate the living conditions of residents in the area. Furthermore, the information was used to influence policy and development by advocating for their needs to the Kenyan government (Haklay *et al.*, 2014).

2.2.4 Land administration in South Africa

South Africa has had one of the extreme examples of land ownership inequality in Sub Saharan countries, which has been the major source of conflict in terms of race relations and economic

injustice (Byamugisha, 2014). The country's land tenure and administration systems have been subject to racial and gender discrimination, as well as exclusion of groups and communities during the apartheid era. Such instances criminalized land tenure and established very strict and severe anti-squatting measures for certain racial groups (Pienaar, 2009). Efforts to rectify the discriminatory systems were introduced by a 1991 Land reform, which abolished some of the racially based apartheid legislation, particularly land markets and agricultural holdings that favoured the white minority (Kitchin and Ovens, 2013). During the apartheid regime, many citizens in rural areas had only temporary permits to occupy land without secure land rights.

Communal (customary) land in South Africa consists of about 14% of the country and less than 10% of it, is formally registered (Kitchin and Ovens, 2013). Most of it is inhabited by poverty struck citizens with insecure land rights. According to Bosch (2003), more than two thirds (71%) of South Africa's land is commercial farms. Communal land is inhabited by 13 million black Africans while commercial farms comprise only 60 000 mainly white owners (Lahiff and Li, 2014). The remaining 15% of the country is urban land. Land conflicts in the country are prevalent in communal areas, usually because of tenure rights and illegal occupation of land.

Communal land tenure in South Africa suffers from uncertainty over rights caused by legal pluralisms (unique cultural identities and different social interests), and weak legal statuses (Lavigne, 1999). The country has multiple arbitration authorities at customary and state level which causes problems for land adjudication: locally determined rules at village level can be over-ruled by state laws in the court of law, resulting in contradictory findings and eventual conflict escalation. South Africa has a land tenure legislation called the 'Prevention of Illegal Eviction and Unlawful Occupation of Land Act of 1998' (PIE) (Adams and Palmer, 2007). The legislation was developed to recognise informal and communal systems caused by the apartheid regime. It protects informal land rights of tenants, squatters, lessees, destitute and individuals in rural communities with insecure land rights or had been disposed of by apartheid land measures.

Public participatory initiatives in South Africa

The South African government recognizes the importance of public input and participation in land administration (Kitchin and Ovens, 2013). It has established a Land Administration Committee (LAC) in rural areas to create and maintain tenure security in local communities. LACs consist of democratically elected members and a traditional council recognized by residents, to establish and maintain community land registers of all inhabitants (Pienaar, 2009).

Communal land cannot be disposed of by the LAC without informed and democratic decisions of the community. This shows that public input and consensus are recognized and practised in rural areas of the country. However, Kitchin and Ovens (2013) argue that meaningful public participation in comprehensive processes is rare in rural areas because of the scarcity of public reports and the absence of rural land development policies. For example, policies that govern the equitable distribution of land in a transparent and efficient manner based on the country's legal framework for land governance. In a nutshell, Land policies provide guidelines for effective and efficient utilization, administration and management of land and its resources.

In 2005, the Association for Rural Development (AFRD) conducted a participatory mapping project termed 'Piloting of Local Administration of Records – PILAR' in Ekurhuleni to secure tenure and improve the quality of life of the rural poor. It adopted a 'general boundary' participatory mapping approach using a large-scale aerial photograph (1:2000) to identify and document land rights in the area. The information received was adjudicated by the public for consensus building and later integrated with other spatial tools to update the local land register.

2.2.5 Overall lessons learnt

Land-based transactions in the countries investigated are constrained by a lack of credible LAS. Despite comprising the most population, the rural poor cannot afford the long and costly land administration processes common in the countries investigated. To address these challenges, formal land registration has been promoted through land reforms, with the anticipation that they could promote tenure security and enhance investment in land. However, poor implementation of land laws regarding title registration has been a common hindrance to these countries. Generally, there is the uncertainty of land rights in rural areas of the countries investigated caused by weak legal statutes and ineffective LAS. Existing land administration practices are characterised by expensive, undemocratic practices that are prone to abuse and result in excessive delays and injustices. Current LAS are complex and have ineffective centralized bureaucratic administrative structures which provide opportunities for malpractices and corruption. Hence, there have been previous attempts by Uganda, Ghana and Kenya to decentralise their LAS to address these challenges. Unclear roles of local and traditional authorities in administering land to local communities have been identified as some of the major problems of LAS in the countries studied. Other efforts include the harmonization of existing tenure systems to facilitate the standardization of land administration.

Attempts have been made by these countries to introduce participatory initiatives, yet most of them, Uganda, Ghana and Kenya in particular, received varying degrees of challenges emanating from lack of consultation, participation and consensus building in local communities about land related issues. Nonetheless, efforts were made recently by these countries to address issues of consultations and participation: land administration has been decentralised to local municipalities to ensure that local communities participate and democratically take part in decision-making activities. Pilot projects have been implemented in countries like Uganda and Kenya to document informal and customary tenures, where residents were trained to perform participatory enumeration of recording demographic data about other community members. According to Jha *et al.* (2013), the initiative in Uganda was a success since it built successful partnerships between the government, relevant stakeholders and the general community. Moreover, it brought transparency, increased cooperation and built trust among community members to produce reliable and trustworthy data (Antonio *et al.*, 2014).

2.2.6 Land administration in Botswana

Botswana has a well-organized land policy and supporting legislation (Adams and Palmer, 2007). However, its failure to recognise customary land uses like hunter-gatherers has led to a loss of land of indigenous people. For example, in 2002, there was a removal of Basarwa (Bushmen) from their ancestral land in the Central Kalahari Game Reserve to pave way for mining activities. Other land uses unrecognised by modern systems include informal settlements, cultural ceremonial sites, old burial sites, and grazing land for cattle headers. This has led to a loss of communal land rights of poor cattle owners to wealthy townspeople and foreigners for use as commercial farmlands. Unfortunately, Botswana has not yet developed alternative means of protecting land rights of the poor in both peri-urban and rural areas (Nkambwe and Totolo, 2005; Clover and Eriksen, 2009). Hence, there is a void that affects a range of key decisions regarding land administration in these areas.

Botswana's LAS has similarities to other states investigated. For example, customary land occupies 71% of the country, and about 10% of it, is recorded in official land records (Augustinus and da Passano, 2010). Just like in Uganda, Ghana, and Kenya, a large proportion of the country is undocumented and holdings cannot be used by the rural poor to improve the security of tenure and increase their investments in the land, despite it being the major source of welfare in rural areas. Land information is limited in many rural areas of Botswana, because of the expensive nature of land administration is in the country. Botswana does not have an

adequate provision for the capture of new and existing land rights, which has led to poor land administration and management (Nkwae, 2008). This is a challenge that prior initiatives like the Tribal Land Information Management Systems (TLIMS), were introduced to address.

TLIMS was designed to facilitate data sharing between Land Boards and other government departments for better administration and management of land and its resources. However, it proved cumbersome over the years, due to lack of expertise and capacity which led to its subsequent failure and abandonment in 2011 (Maphale and Phalaagae, 2012). A comprehensive overview of TLIMS will be conducted in Section 2.6.

Public participatory initiatives in Botswana

Botswana is regarded as a leader in innovative land administration in Southern Africa (Bruce, 2009). However, it is unable to actively engage its citizens in land administration issues. The country does not have any policies that guide public participation in land related activities. Therefore, the public is relegated to becoming spectators in their own local communities while most of the work is performed by technocrats in government departments and private agencies. The limited public participation activities that occur, are only done through consultations in relation to village planning activities in kgotla meetings. A kgotla is a public meeting area, community council or traditional law court, usually referred to as a customary court. It is headed by the village chief or ward headman, and decisions are consensus-based.

Public participation has the potential to increase local community awareness of land related matters and to better manage their land. However, Land Boards do not have enabling structures or platforms to actively engage the public in land administration matters (Nkwae, 2008). Nonetheless, in areas with limited records, they rely on the knowledge of community leaders and the public for information about land occupation and ownership. Despite being regarded as a leader in land administration in the region, Botswana still has challenges of properly administering land in rural areas as its systems are characterised by outdatedness, irrelevancy and corruption. Engaging local communities as evidenced in other countries like Uganda, Ghana and Kenya could reduce these challenges, promote transparency and security of tenure, which in turn could lead to a better land administration, and improvement in the security of tenure of citizens in rural areas, and an increase in the public's investment in the land they hold.

2.3 Typology of land administration challenges in developing countries

This section presents a typology of land administration challenges faced by developing countries in their efforts to recognize, map and document informal settlements and customary land. Furthermore, it highlights challenges encountered by the five countries investigated in establishing participatory initiatives aimed at improving the administration of tribal land to improve the security of tenure and welfare of citizens, especially the poor and underprivileged. These challenges are as follows:

1. Despite comprising the large proportion of land in the countries investigated (except South Africa), customary land is the most undocumented, yet inhabited by a large population. A lack of documentation exposes residents to social ills including poverty, discrimination, crime, homelessness and insecurity of tenure.
2. A lack of adaptation of social and customary tenure arrangements by colonial systems, led to many land conflicts, while land reforms established to address these challenges failed to provide the anticipated security of tenure for citizens in the countries investigated.
3. The failure of land reforms in countries like Uganda and Kenya have been attributed to the lack of consultations and engagement of local communities for buy-in, informed decision making and understanding of social tenures on the ground.
4. The reservation of prime agricultural land to European settlers, elites and leaders, while leaving infertile and unproductive fields to local farmers has contributed immensely to poor agricultural production and subsequent poverty, as seen in most developing countries, like Kenya and Botswana.
5. Despite conventional LAS being developed with sound intentions, limited capacities and insufficient infrastructures at national and municipal levels can lead to their subsequent failure, as evidenced with TLIMS in Botswana.
6. A lack of scope and unclear definition of functions in a LAS can lead to a loss of confidence by the public on the ability of the government to protect their land rights. As a result, residents resort to illegal activities like the use of land guards in Ghana to protect their land rights or the increase in informal settlements as in Kenya.
7. The long and costly processes of registering land in developing countries are a major hindrance for citizens to secure their tenure through registering their land.
8. Complex and highly centralized, bureaucratic LAS, excessive delays and injustices provide opportunities for malpractices and corruption.

9. Reliance on paper-based systems due to the failures of complex computerized systems can lead to duplication of efforts, lack of data integration, multiple allocations, and inefficiencies in LAS as evidenced in Botswana.
10. The weak legal and regulatory institutions associated with communal land, like the multiple arbitration authority levels in South Africa can cause problems for land adjudications and escalate conflicts when resolutions cannot be achieved within a sufficient amount of time.
11. Even though many developing countries have decentralized their LA activities, Cousins (2009) argues that this is inefficient on its own, since it does not resolve the issue of authority and representation at the community level.
12. Consensus-based decision making is common in community mapping initiatives. However, it suffers from a lack of accountability, which can affect community development and incite disputes when citizens cannot have a general agreement.
13. Community mapping can bring out latent conflicts (De Gessa, 2008), hence sufficient dispute mediation measures are necessary for all stages of planning, execution and implementation.
14. The high cost of surveying communal land is prohibitive and its effectiveness as a basis for functional decentralized LAS for the capital-poor residents remains debatable (Rugege, 2005). Therefore, affordable techniques for delineating and measuring land parcel boundaries for land administration and registration purposes are a necessity for developing countries.

This section presented a review of LAS of five countries in Sub Saharan Africa, which provided an understanding of their land reforms and how they continue to influence current procedures of administering land to secure tenure for citizens. For example, legal systems put in place by colonial powers have not sufficiently accommodated and adapted indigenous norms, resulting in the side-lining of customary land despite its vastness and the larger population it supports. Thus, customary land is characterised by poverty, insufficient documentation, conflicts and insecurity of tenure.

To address these challenges, developing countries like Uganda and Kenya established participatory mapping initiatives that recognize social tenures and customary land to improve the security of tenure for citizens, particularly in rural areas. Successes of these initiatives have been attributed to the policies implemented by the countries to recognize the importance of

public participation in documenting informal and customary land rights. In contrast, the lack of policies that guide public participation in land activities in Botswana and South Africa make it difficult for local communities to actively participate in land administration activities of their area.

Participatory initiatives should be viewed as grass-roots activities that aim to empower local communities for better land access and tenure security. The shortcomings and issues affecting LAS in the countries investigated provided an understanding of efforts made by the countries to recognize, map and document informal and customary land to improve the security of tenure of residents, particularly in rural areas. All the investigated countries recognise the importance of active public participation in land related matters, as a means of facilitating good land governance, transparency and accountability. For example, Ghana, Uganda and Kenya have implemented policies that facilitate it, while other countries like Botswana and South Africa are in the process of formulating them. The following section investigates the cadastral system of Botswana in depth as the case study for this research to understand its legal, institutional, policy, and technical frameworks for handling geospatial data which is a major component of a functional LAS.

2.4 The cadastral system of Botswana as an engine for LAS

This section conducts a review of the cadastral system of Botswana as an engine for LAS in rural areas, which is administered by District Land Boards. An analysis of land reforms will be conducted on previous land tenure systems in the country, starting from pre-independence, during independence and after independence, to better understand how customary land was administered in the past. Throughout the reforms, customary land has proved to be the most challenging, yet comprising the most land mass and larger population. Moreover, it is under-resourced and its inhabitants are characterised by lack of tenure security and social ills.

Botswana lies in the Southern part of Africa, bounded by four countries: South Africa, Namibia, Zambia and Zimbabwe. It has a population of approximately 2 million as per the population census of 2011 and has a surface area of 581,736 square kilometres. The country is a former British protectorate (1885-1965) and gained its independence in 1966. It practices a multi-party system of democracy and holds regular elections every five years. Botswana's main source of revenue is diamonds, followed by tourism and beef export. The cadastral system of Botswana lacks an overall regulatory framework for the administration of tribal land, which includes

registration, archiving and retrieval of land information (Kalabamu, 2014). Before independence, the country was one of the poorest in Africa, and upon gaining independence, it started diamond mining operations which propelled it to a more stable economy. It is regarded as one of the richest and politically stable countries in Africa (Nkwae and Dumba, 2010; Isaacs and Manatsha, 2016). To understand the reform process in land administration of a country, it is necessary to outline a brief background that informs the main land tenure and land management practices (Malatsi and Finnstrom, 2011) (Figure 2-1). Therefore, the next sub-sections will conduct brief overviews of land administration reforms in Botswana.

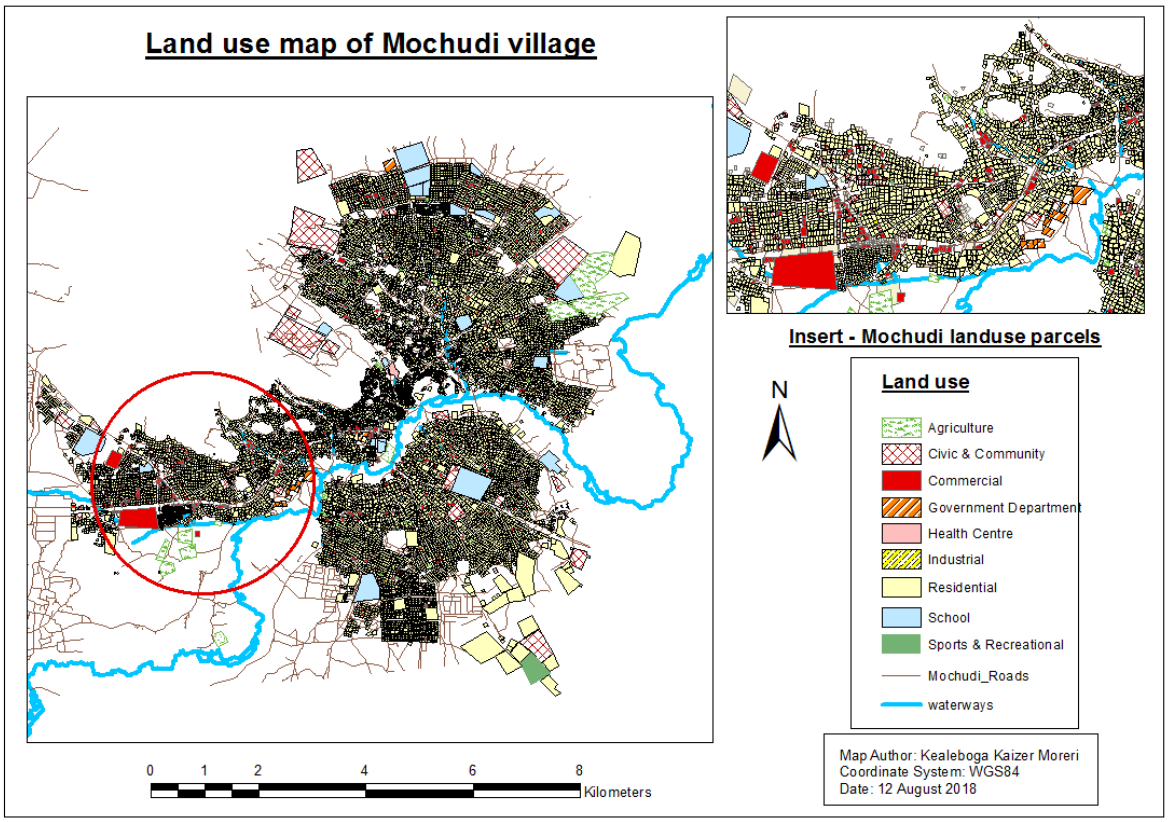


Figure 2-1. Land use map of Mochudi village

2.4.1 Land administration before the protectorate years

Prior to the country being granted a protectorate in 1885, land in Botswana was owned by various tribes in the country and village chiefs were its custodians. The chiefs administered land within their jurisdiction, who would then cede administration portions to ward herdsmen, who subsequently allocated to family heads for equal distribution among family members. Land allottees were not awarded any documentation as proof of ownership but were required to memorize physical features in and around the land parcel like trees, rocks or river boundaries to establish the extents of their land rights. During this period, all the land in the country was customary, inheritable, perpetual and could not be sold since it belonged to the tribe. To secure tenure, allottees were required to utilize the land and continue belonging to the community. When a family no longer required the allocated land, it reverted to the tribe. These initiatives encouraged active participation and created a sense of belonging within the society, especially in activities that required a collective effort. Un-allocated land remained under the ownership of the tribe and used by community members to harvest resources like firewood, wild fruits and as pasture land.

2.4.2 Land administration during the protectorate years

During the colonization period, chiefs continued managing the land as they had before. However, the colonial government renamed customary land to Native reserves and converted certain portions of it to Freehold and Crown lands. Freehold land was reserved for European settlers mainly for agricultural use (cattle ranches), whilst Crown land was reserved for the development of urban areas. Thus, the colonial government introduced three land tenure systems: Freehold land, Crown lands, and Native reserves. Land tenure systems determine the rules and conditions that people can use land and its resources, with regards to rights, responsibilities and restrictions (RRR). The colonial government further provided security of tenure to white settlers in Freehold land and citizens in Crown lands through proper surveys and documentation of land rights, whilst Native reserves were excluded (Malatsi and Finnstrom, 2011). The colonial government introduced an official system of land surveys (and some regulation thereof) and official documentation (except for Native reserves) that was carried forward to later LAS.

2.4.3 Land administration after Independence

After independence, the new government renamed Native reserves to customary land, Crown lands became state land, and Freehold land remained the same (Figure 2-2). Customary land now makes up 71% of the whole country, state land is 26% and freehold land is 3% (Malope and Phirinyane, 2016) (Figure 2-3). According to Nkambwe (2003), compiling land records and developing administration systems for these tenure systems has been challenging for the government of Botswana. For example, the traditional LAS cannot accommodate the social, informal and communal nature of customary land tenure.

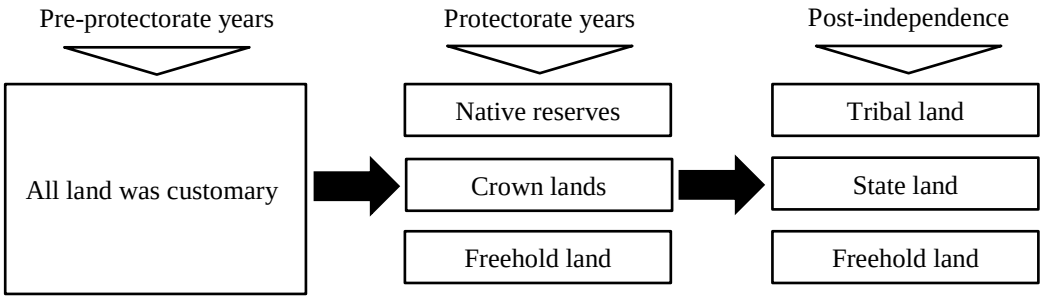


Figure 2-2. Changes in land tenure systems in Botswana (Malatsi and Finnstrom, 2011).

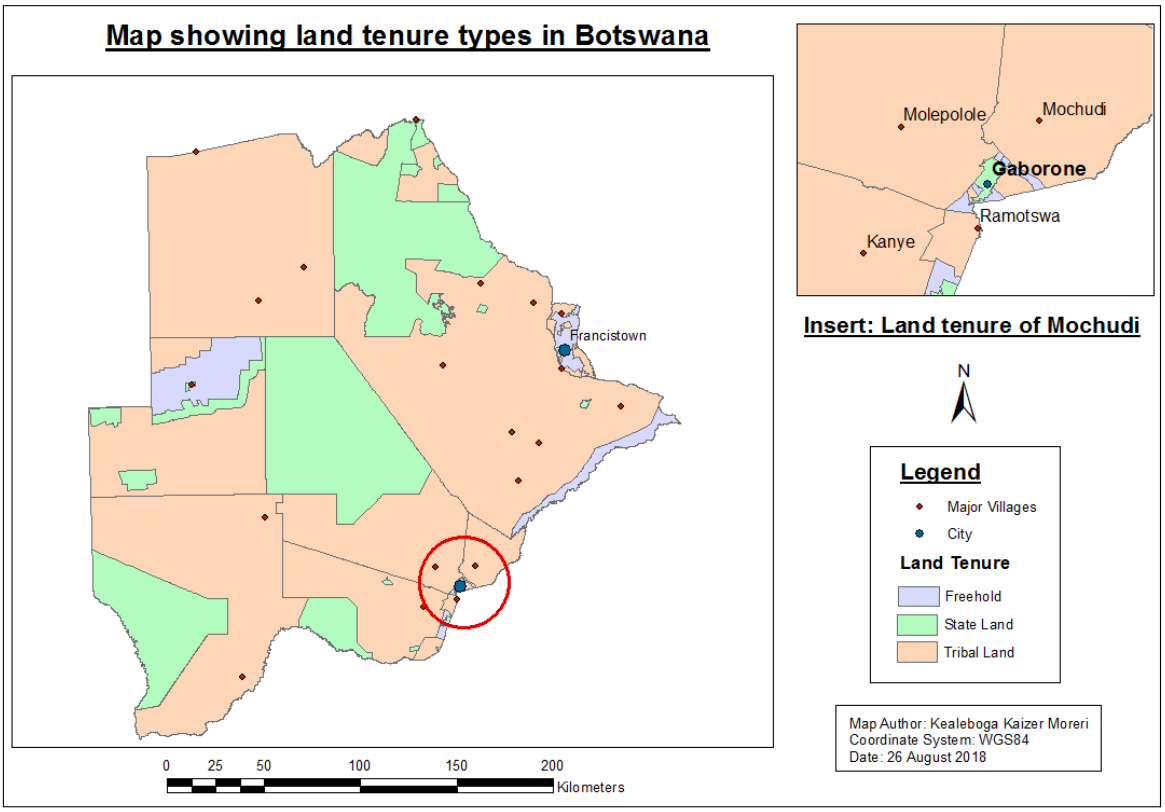


Figure 2-3. Map showing land tenure types in Botswana

The brief overviews conducted in this section have provided an understanding of how land was administered pre-and post-independence periods, as well as challenges encountered by the country in its efforts to effectively administer and manage land and its resources. The emphasis of this study is on customary land since it makes a large proportion of the country and is inhabited by a large population characterised by tenure insecurity because of insufficient land rights.

2.5 Land information laws and policies of Botswana

Botswana's land laws and policies guide the administration and governance of all land tenures in the country. A law sets out standards, principles and procedures that must be followed, while a policy outlines goals that the government hopes to achieve and the methods and strategies it will use to achieve them (Nkwae, 2006). If a law is not followed, the perpetrators can be prosecuted in court. Land laws that deal with customary land include: Tribal Land Act of 1968, Town and Country Planning Act, Deeds Registry Act, and Land Survey Act. The Tribal Land Act is the main land law which regulates Land Board structures and procedures for administering and managing tribal land (Nkambwe and Totolo, 2005; Ntumy, 2014). The Town and Country Planning Act makes provisions for the orderly and progressive development of land in both urban and rural areas (Republic of Botswana, 1980). While, the Deeds Registry Act facilitates the registration of land titles and registrable rights like customary grants which have been converted to a common law leasehold (Republic of Botswana, 1970). Lastly, the Land Survey Act provides for the survey of land in the country and defines land measure units for matters incidental to the land survey (Republic of Botswana, 1990).

To better address land administration challenges in rural areas, the land laws are supported by 6 policies that include (Nkwae, 2006; IRMT, 2008; Bornegrim and Collin, 2010): a) Rural Development Policy – formulated in 1973 to promote and facilitate rapid rural development through initiatives like the introduction of land use planning in land administration, farm fencing for individuals and the conservation of natural resources, b) National Policy on Land Tenure – resulted from a commission appointed by the president in 1983 to advocate the inclusion and involvement of local community-based institutions in the administration and management of land and natural resources (Republic of Botswana, 2002), c) Local Government Structure Policy – endorsed in 2004 to establish the independence of Land Boards and build their capacity to implement policies at local level, d) National Settlement Policy – designed to

control the spread of settlements (clustered community areas, smaller than a village) through proper land use planning, such that agricultural land can be preserved and natural resources conserved, e) Tribal Grazing Land Policy – established to improve the management of rangelands and to commercialize cattle ranching (Frimpong, 1995), and f) Botswana Land Policy of 2015 – designed to support processes of land tenure regularization and to promote the harmonization of land laws to facilitate a Land Administration, Procedures and Capacity Building System (LAPCAS) (Malope and Phirinyane, 2016). In short, the land policies were established to provide guidance towards the sustainable and equitable use of land and its resources within the country.

Land Boards were established in 1970 to perform the following functions on tribal land: a) land allocation, b) land registration, c) land use planning and monitoring, and d) land adjudication. The Tribal Land Act did not amend any customary laws, rather it transferred the role of the land authority from chiefs to Land Boards and introduced certificates of land rights as evidence for customary land grants (White, 2009). The primary objectives of the Tribal Land Act were: a) to provide a written law to be consulted in times of disputes, b) to improve livestock production through proper management of pasture land, and c) to provide people with saleable and bankable land rights (Mathuba, 1989; Kalabamu, 2014). Currently, the Act states that undeveloped customary land cannot be sold or transferred because it belongs to the state, rather developments within it like property can be sold or transferred to another citizen. Furthermore, customary land can be reclaimed by the government for any purposes without reference to the law, and acquisition compensation determined by the government (ECA, 2004). This negatively affects the security of tenure of landholders with customary land rights and acts as a discouragement for investments in land, especially for agricultural activities.

The main objectives of the Land Policy of 2015 include: a) protection and promotion of land rights of all landholders, b) establishment of an up-to-date, efficient, participatory, inclusive and accessible land information system, c) promotion of access, equity, efficiency, land rights security and the transparency of land administration and management, and d) responsiveness to emerging opportunities and dynamic planning and development of the country (Malope and Phirinyane, 2016). Furthermore, the policy recognises that changes in the legal framework can help address the socio-economic needs of all citizens. Thus, the government intends to develop a framework to evaluate and consolidate all land policies during the National Development Plan (NDP) 11 which covers a time period of April 2017 – March 2023 (Ministry of Finance, 2016). The NDP is an initiative by the government of Botswana that advocates for various policies and

strategies to promote growth and create employment opportunities. Its mandates include: a) the development of diversified sources of economic growth through initiatives like beneficiation, economic diversification drive and cluster development, b) utilization of domestic expenditure as a source of growth to promote inclusiveness and employment creation, and c) promoting an export-led growth strategy for the country despite the limited size of the economy. Within the NDP 11 period, the country plans to develop a land information system, under the LAPCAS programme to enable efficient land allocation, data sharing, exchange and dissemination across government agencies (Ministry of Finance, 2016). LAPCAS is a project between the Ministry of Lands and Housing in Botswana and the Swedish Mapping, Cadastres and Land Registration Authority to support the ministry in developing efficient and effective land administration to simplify procedures and correct information on land rights. The National Policy on Land Tenure, Land Policy of 2015 and the LAPCAS programme with their advocacy for the establishment of an inclusive, participatory and transparent LAS are essential for the implementation of VGI in official systems of Botswana.

2.6 Administration of tribal land in Botswana

Tribal Land in Botswana is administered by District Land Boards, which are regulated by the Tribal Land Act of 1968 (Cap 32:02) amended in 2004. (Republic of Botswana, 2004). They were established in 1970 to administer tribal land comprehensively with proper structures of management and governance. The introduction of Land Boards practically made chiefs bystanders in land related matters, especially allocation, and were only consulted in settling disputes of ownership on land allocated by them previously. To secure tenure for land rights allocated by Land Boards, citizens are awarded certificates of land rights for residential land (customary/tribal land grants) or common law leases for commercial land (common law grants) (Figure 2-2). The holder of a customary land grant has the right to use and develop the plot according to the allocated land use. Its tenure is inheritable and perpetual, but the government holds ownership of it (Kalabamu, 2000). In the past, tribal land was allocated without any documentation of the landholder nor of the plot itself, which meant that many residents held ‘legitimate’ occupation of land without any formal record from the Land Boards.

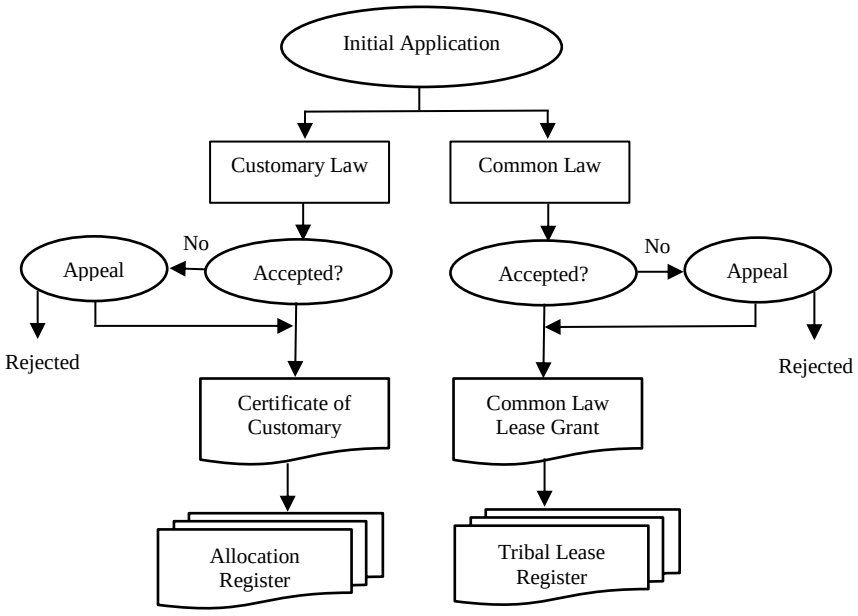


Figure 2-4. A simplified illustration of the land allocation process under customary tenure (Nkwae, 2008).

Common law grants can be granted for residential land, but these require the land parcel to be demarcated and surveyed to accompany the personal details of the allottees. These are granted on a 99-year renewable lease for residential and 50 years for commercial purposes to citizens. Non-citizens cannot be granted residential or commercial plots in tribal land as it is reserved for citizens but they can be allocated plots in state and freehold land. Land rights held under customary tenure cannot be used as collateral, thus plot owners are required to convert their land rights to leasehold to enable registration at the Deeds Registry Office. Leasehold means that a citizen has a lease agreement with the landowner (Land Board) to use the piece of land for many years, usually 99 years according to the RRR of the Land Board. Upon the elapse of the contract, the leaseholder can extend it for another term, which can further be transferred to another citizen with the consent of the Land Board. It is clear that Botswana has a complex and unique land tenure system in the region, which combines customary tenure with modern aspects of tenure (Adams *et al.*, 1999). This has led to poor implementations of LAS which affected the proper management and administration of tribal land. For example, Land Boards lack proper registers of allocated land parcels, which results in duplication of land rights allocations and lack of security of tenure for citizens (Nkwae and Dumba, 2010).

Land Boards also lack proper information on available land for allocation, which leads to long and complex administration and allocation processes. These challenges are some of the major concerns for the country's development and future in establishing the welfare of its citizens

through security of tenure. To address these challenges, land information systems were established by the government to facilitate an effective and efficient LAS, which include: a) Tribal Land Information Management System (TLIMS), and b) Land Administration, Procedures and Capacity Building System (LAPCAS). A scrutiny of these systems will be conducted to highlight their successes and challenges in securing tenure for citizens.

2.6.1 Tribal Land Information Management System (TLIMS)

TLIMS was established in 2002 by the Ministry of Lands and Housing to enable Land Boards to better process and manage tribal land records electronically. Some functions expected with TLIMS included capabilities to process the following: a) land use planning permits (Bornegrim and Collin, 2010), b) plot transfers and sub-divisions, c) sub-letting permits, d) land control and compliance activities (Kalabamu, 2014), e) compensation calculations, f) adjudication of land disputes, and g) capability to link attribute data with its spatial data component (Mooketsi and Leonard, 2013). It was further anticipated that the system would facilitate data sharing between Land Boards, other government departments and private agencies for better administration and management of land, which was never achieved (Isaacs and Manatsha, 2016).

A lack of proper networking of Land Boards and low Internet bandwidth made it difficult to transfer data during the countrywide implementation of TLIMS (IRMT, 2008). Another capacity challenge highlighted by Isaacs and Manatsha (2016) concerns Land Board staff who lacked the necessary skills to utilize the system to effectively process and store land records electronically. According to Mooketsi and Leonard (2013), there were project management issues surrounding planning, implementation and system documentation in relation to the pilot projects conducted in two selected Land Boards: Ngwato and Kweneng. The authors stressed that the system was built in haste since inadequate time was devoted to system development and user needs assessments, thus not meeting user needs. TLIMS did not perform some of the functions it was developed for, hence its minimal utilization and eventual abandonment (Maphale and Phalaagae, 2012). The failure of TLIMS led to the development of LAPCAS, with the anticipation was that it would address the challenges of TLIMS. For example, the various land policies highlighted in Section 2.5 practised in tribal land made it a challenge to effectively administer land using TLIMS (Malope and Phirinyane, 2016). Moreover, Botswana's complex land tenure system that combines both customary tenures with modern aspects of tenure has led to land administration being conducted in a piecemeal manner, which affected its efficiency and poor implementation of TLIMS.

2.6.2 Land Administration, Procedures and Capacity Building System (LAPCAS)

LAPCAS is an ongoing project by the government of Botswana in partnership with the Swedish International Development Agency, designed to improve and build capacity in land administration. LAPCAS aims to provide an efficient, effective and transparent land administration environment to aid the social and economic development of Botswana (Malatsi and Finnstrom, 2011). Initially, it was a five-year (2009-2014) partner-driven project between the Ministry of Lands and Housing (MLH) and Landmateriet, the Swedish Mapping, Cadastre and Land Registration Authority. After the five years, the project was rolled out to all Land Boards in the country, which was to be completed in December 2016. Currently, a review of the project's successes, challenges for conclusions and recommendations is being undertaken by the Ministry of Lands and Housing (Khama and Seleka, 2017).

The LAPCAS project intends to harmonize various land laws, possibly merging them into one land act to improve service delivery in the administration of tribal land. According to Malope and Phirinyane (2016), this harmonization can increase the efficiency of the Ministry of Lands and Housing by making it more responsive to customer needs. Unlike in the past where the country attempted to address customary land challenges in a piecemeal manner (Malatsi and Finnstrom, 2013), LAPCAS attempts to conduct a holistic approach to deal with land problems throughout the country. As noted by Khama and Seleka (2017) the government has shown its commitment to the project by funding almost 95% of it and developing a new policy (Botswana Land Policy of 2015) to support the initiative. However, the legislation has not been effected due to the consultative processes it must go through, which delays the agreed organizational structures recommended by LAPCAS. For example, LAPCAS has recommended the replacement of Land Boards with Land Authorities, to enable the administration of both tribal and state land tenure by a single organization where existent in a jurisdiction. The anticipation is that the latter could better address the needs of local communities by reducing their travel time and costs to major cities for assistance on state land related matters.

According to Khama and Seleka (2017), the project developed a process for systematic surveying, registration and adjudication of tribal land within the legal bounds of current laws. Nevertheless, this process met a few challenges which include the following: a) lack of interest of claimants to provide documentation to claim their land rights (Isaacs and Manatsha, 2016), b) occupants not concerned about the lack of certificates for the plots they occupy (Malope and

Phirinyane, 2016), c) the lack of a legal framework to compel community members to register their land rights, d) insufficient publicity resulting in lack of participation and buy-in from local communities (Isaacs and Manatsha, 2016), e) shortage of skilled personnel like surveyors, land use and adjudication officers, and f) delays in producing and issuing new certificates for already adjudicated plots (Ministry of Finance, 2016). These challenges resulted in a very slow registration process: out of a targeted 464,634 plots for the first quarter of 2015/2016, only 25,255 (8 percent) had been adjudicated, while 209,449 (45 percent) had been surveyed (Khama and Seleka, 2017). The surveying of plots was done free by the LAPCAS project to community members until December 2016. Currently, plot owners are required to pay a service charge of BWP630 ($63) to survey their plots for registration. As mentioned earlier, a review of the project is currently underway by the Ministry of Lands and Housing.

2.7 Legal frameworks for geospatial data acquisition and handling

Botswana does not have a legal framework that specifically addresses standard procedures for collecting, handling and disseminating geospatial data (Ryden, 2006). Nonetheless, it has Botswana Surveying and Mapping Standards (BSMS) which contain documented agreements of technical specifications, rules, guidelines, and quality assurance measures for the collection, manipulation and dissemination of geospatial datasets. Standards can help organizations utilize modern land information systems that involve Information and Communication Technologies (ICT) and Geographic Information Systems (GIS) as the driving forces for geospatial information management and maintenance (ASPRS, 2014). BSMS endorse the National Standards for Spatial Data Accuracy (NSSDA) procedure, published by the Federal Geographic Data Committee (FGDC) in 1998 (Ryden, 2006).

The NSSDA procedures informed the development of a Specification for Data Acquisition for Cadastral and Topographic Base Map for Village Mapping document in 2006 by the government to guide geospatial data collection activities at Department of Surveys and Mapping (DSM) and Land Boards (Ryden, 2006). The specification provides guidelines for large-scale mapping activities, geospatial data acquisition, handling and dissemination at the village level. Moreover, they provide an acceptance criterion that geospatial data must conform to, such that it can be considered acceptable for a specific use. For example, it specifies that cadastral base maps, land use and land cover features (like grassland, woodland and built-up areas) should be mapped from an orthophoto at a scale of 1:5000. This is the scale of the existing

orthophoto used by the country acquired in 2011 with a spatial resolution of 25 cm. Orthophotos for village mapping are acquired every five years (Mooketsi and Leonard, 2013). According to GeoManual (2014), an acceptable accuracy level for 2-dimensional onscreen digitizing activities from an orthophoto ranges from 1m to 4m, at a scale of 1:5000, to capture points, lines and polygons.

Currently, this orthophoto is used by Land Boards, government departments and private agencies for village mapping activities to produce cadastral and topographic maps. These mapping activities, done with on-screen digitizing method have an accuracy threshold of 40-100cm for digital orthophotos (GeoManual, 2014). The threshold is consistent with the American Society for Photogrammetry and Remote Sensing (ASPRS) accuracy standards for digital geospatial data (ASPRS, 2014). Table 2-1 shows horizontal accuracies for digital planimetric data and their associated thresholds for the current orthophoto in use as outlined by BSMS. According to the GeoManual (2014), the horizontal accuracy of contributed land parcels is computed by comparing planimetric coordinates of their well-defined points with coordinates from an independent source of higher accuracy.

Table 2-1. Horizontal Accuracy/Quality for Planimetric Data (1:5000) (GeoManual, 2014).

Map Scale	Approximate Source Imagery Ground Sample Distance (GSD)	Horizontal Data Accuracy Class	RMSEx or RMSEy (cm)	RMSEr (cm)	Horizontal Accuracy at the 95% Confidence Level (cm)
1:5000	40-100 cm	I	62.5	88.4	153.0
		II	125.0	176.8	306.0
		III	187.5	265.2	458.9

The horizontal accuracy thresholds (Classes I, II, III) provide map accuracy class ranges that contributed datasets can fall into based on the extent of their deviation from ground truth. The classes represent the following categories: Class I products represent high accuracy mapping-grade geospatial data; Class II products characterise standard grade mapping geospatial data; while Class III products can be used for lower accuracy and less user-demanding mapping applications. These classes inform the potential uses of contributed datasets in official systems.

Therefore, all the three classes may be considered for use in official systems based on their potential application areas as outlined in Table 2-2.

Even though these standards are primarily intended for planimetric data compiled from stereophotogrammetry, they are equally relevant to planimetric maps produced from digital orthophotos (ASPRS, 2014). The standards were developed such that accuracy of geospatial data could be reported at the 95% confidence interval as a function of the Root Mean Squared Error (RMSE) values of X, Y, and Z at ground scale (ASPRS, 2014). For a horizontal accuracy reporting of the location of a point, this means that if there is a radius of uncertainty, the true or theoretical position of the point will fall within the circle 95% of the time. Table 2-2 shows potential uses of datasets digitized from the 1:5000 scale orthophoto based on the BSMS standards:

Table 2-2. Potential uses of digitized datasets according to BSMS standard (GeoManual, 2014).

Horizontal Data Accuracy Class	Potential uses of digitized datasets in land administration
I	• policy formulations • development planning • decision making at the village level • land registration • cadastral mapping of sparsely populated areas
II	• standard mapping and GIS work • general boundary surveys • land registration • reporting of illegal activities • land rights recording of monumental sites • water points location determination
III	• reporting of illegal activities • land rights recording of monumental sites • water points location determination

One aspect of addressing the importance and utilization of spatial standards in cadastral and mapping systems lies in increasing the level of understanding of their relevance and significance to both consumers and producers (ESRI, 2003). Therefore, DSM continues to

interact with relevant stakeholders to ensure that the standards adopted in the country are appropriate and serve the needs of users.

2.7.1 Institutional arrangements for geospatial data handling at Land Boards

DSM supplies Land Boards with fundamental geospatial datasets to update them with current land information of their jurisdiction. It has licensing and data sharing agreements between its stakeholders, which are legally binding documents that prevent misuse and abuse of the datasets. Some of the mapping and surveying activities that exist in Land Boards include:

1. Production of high accuracy cadastral maps for title deed surveys, and lower accuracy land parcel maps for general mapping activities like land use and land cover maps,
2. Topographic mapping of the environment for base map production,
3. On-screen digitizing from orthophotos to produce vector data to be used in various activities like utility mapping, road constructions, land information management and the production of locality sketches for leasehold certificates.

Mapping activities through on-screen digitizing at Land Boards give room for VGI utilization in official systems provided there are well-defined quality and credibility measures to establish the accuracy and reliability of contributed datasets. DSM as a sole geospatial data custodian, encourages a Public Private Partnership (PPP) arrangement for the development, updating, management and maintenance of fundamental geospatial datasets, as a shared resource between the public and private organizations (GeoManual, 2014). Therefore, it is necessary to investigate participatory, inclusive and affordable initiatives that can facilitate effective PPPs for updating and production of land information capable of adding value to official systems.

2.7.2 Policies on public participation in land administration

The Town and Country Planning Act and the Tribal Land Act have legal provisions that recognize public participation in land related activities. The provisions state that planning at the village level requires public input and that land allocations should be publicly displayed for 21 days at the kgotla for transparency, public scrutiny, appeal and adjudication purposes. Furthermore, the Acts have clauses which stress that the public and other stakeholders should be engaged in the design of development plans which inform village expansion efforts over a 20-year period. According to Khama and Seleka (2017), the land policy of 2015 recognises cultural norms and institutions, and values the importance of stakeholder participation. It has set out a strategy in which the public can be engaged in land related issues, which include: a)

reviving village development committees to foster stakeholder participation, b) introducing communication and change management strategies headed by the Ministry of Lands and Housing to foster stakeholder participation, and c) establishing committees to conduct research on effective means of engaging the public in land related issues to improve the administration and management of land.

Currently, public participatory activities only take part through kgotla meetings, council meetings, public displays of cadastral layouts and maps requesting their input. Nonetheless, Nkwae (2006) argues that public officers at times confuse consultations with informing the public, thus the meetings end up as information sources, rather than consultative platforms for gathering public input and opinions.

This section presented a review of the cadastral system of Botswana as an engine for LAS in rural areas, which is administered by District Land Boards. A review of previous land reforms was conducted and it provided an understanding that throughout the reforms, customary land was the most challenging, yet comprising the most land mass and larger population. To better administer land, the country established land information systems to facilitate an effective and efficient LAS of customary land. The first system was TLIMS in 2002, which managed to reduce paper-based problems of filing and reconciliation of land records. However, its challenges eclipsed its successes which led to its eventual abandonment. Therefore in 2009, LAPCAS was introduced as the answer to TLIMS problems: to improve land administration and build the capacity of Land Boards to better manage and administer land in their jurisdictions. The project is ongoing and intends to harmonise various land laws, possibly merging it into one act to improve land delivery and administration services.

The government of Botswana has established laws and policies to guide the administration and governance of all land tenure systems. The main land law of customary tenure is the Tribal Land Act which regulates Land Board structures and procedures. Recently a new Land Policy (Botswana Land Policy of 2015) was formulated to facilitate LAPCAS procedures and implementations, to promote access, equity, efficiency, tenure security, active participation and transparency in land administration and management. Land Boards use less accurate handheld GPS devices to collect land parcel boundaries, which subsequently is used to prepare official Lease documents. This gives room for external data consideration in official systems provided there are well-defined quality and reliability measures of the contributed datasets to improve trust and confidence of potential users.

2.8 Summary

This chapter conducted a review of LAS in five countries in Sub Saharan Africa, particularly community mapping that uses spatial technologies and participatory measures to support and advance land rights agenda for rural communities. The successes and challenges of these initiatives to improve tenure security, build cohesion and advocacy for local communities in informal and customary lands were elaborated. Moreover, an overall typology and list of LAS problems affecting the countries investigated were presented, to provide an understanding of efforts made by the countries to recognize, map and document informal and customary land to improve the security of tenure of residents particularly in rural areas.

The formalization of informal and customary land is unavoidable in the current globalizing world. As elaborated in this chapter, traditional systems are incapable of addressing various tenure systems particularly those in rural areas. Such a challenge can be addressed by extending current registration systems to have components that handle informal and communal land tenure systems (Pienaar, 2009). For example, community mapping initiatives can be introduced to improve the security of tenure, provide capacity, awareness and sustainable means of documenting informal and customary land. However, such an extension can also increase their complexity, which then requires proper research on how it can be implemented for the benefit of local communities.

In Botswana, the policies that recognise public participation in land related activities are an indication that the government recognizes the importance of public participation and input in decision making. It is argued that with established, well-defined, researched and proven accuracy and reliability measures, datasets produced by the public can be used to update and improve the coverage of official systems and reporting land mismanagement practices within the community. Furthermore, a participatory initiative can improve the awareness and interest of the public about land administration and management of their local community.

As mentioned earlier, many customary tenures in Africa do not have documentary evidence to prove ownership, but use active occupation as the main evidence of ownership. Therefore, group cohesiveness of community members as practised in Uganda can help adjudicate rights of other members to secure tenure. The following chapter presents unconventional methods used particularly in developing countries to improve LAS and secure tenure for citizens in rural

areas, with the objective of investigating how they could be implemented in broader land administration processes of Botswana.

Chapter 3. Investigation of VGI initiatives in developed and developing countries

This chapter conducts a review of VGI initiatives in developed and developing countries. The objective is to appreciate their success and challenges as well as to identify those that may be suitable for implementation in the context of developing countries considering their limited capacities and resources. Different countries, depending on the state of their LAS may require different types of participatory initiatives to record land RRR. For example, developing countries with limited records on land rights may prioritize on the collection of ownership boundaries, occupation and land uses. In contrast, developed countries with well-established tenure systems may concentrate on environmental issues and areas not always integrated with the cadastre. According to Steudler (2014), no country with a multi-purpose cadastre has fully managed to implement a solution for holistic management of RRR of land and property. Therefore, it is necessary to identify and investigate new methods of collecting and managing land rights such that a multi-purpose LAS can be achieved.

3.1 Contemporary land administration initiatives in developed countries

Most developed countries have well-established LAS to secure land rights. However, Rahmatizadeh *et al.* (2016a) argue that many of these existing systems tend to formally register a limited number of RRR related to land and property, as they only focus on private, communal and public ownership boundaries. This 'narrow' land administration paradigm centred on the land tenure function neglects many other land RRR created through other legislations like environmental issues, are either not captured or not easily available (Bennett *et al.*, 2008; Steudler, 2014). Examples of environmental issues include collecting information about flood zones, forest fires, native vegetation, noise level mapping and monitoring, and national parks boundary mapping. Therefore, VGI can provide an opportunity for developed countries to enhance their current LAS to determine the spatial extent of other land rights not captured in current systems using citizen contributions. Moreover, it can facilitate the recording and better management of communal land not owned by individuals or group of people, through participatory means to protect it from theft and mismanagement activities like illegal mining, litter dumping and deforestation.

VGI in the past has been proposed as a timely and low-cost approach to fill the knowledge gap about land rights in LAS, in developed countries (Basiouka and Potshiou, 2012; Clouston, 2015; Rahmatizadeh *et al.*, 2016a). For example, Basiouka and Potshiou (2012), conducted a study to showcase the significance that VGI can have in the Greek cadastral system. The authors engaged community members in collecting raw measurements of their property boundaries which they assessed and concluded that it had no gross errors. In some instances, it was found to be more detailed than data collected by private agencies, particularly attribute data content (Basiouka and Potshiou, 2012). The conclusions of the study were that VGI initiatives could be integrated into a practical form to cadastral surveys. However, they have not yet been regulated in Greece.

Clouston (2015) investigated the potential use of VGI within authoritative databases for the New Zealand Cadastre. This research explored the applicability of VGI in official systems by using quantitative and qualitative data collection methods to gather perspectives of potential consumers, data providers and administrators. The findings of this study concluded that VGI indeed could improve data collection and maintenance processes in the country, but should be stored separately from official data for better management purposes. The New Zealand Cadastral strategy released in 2014 acknowledges that VGI has a potential role to play in the maintenance of the cadastre (Grant *et al.*, 2014). The main challenge is that VGI has not yet reached the level of recognition for incorporation into the fundamental cadastre. For example, the cadastral strategy states that only datasets lodged and certified by licensed cadastral surveyors are to be integrated into official systems (Grant *et al.*, 2014). This negates the possibility of VGI adding value to official systems in New Zealand soon. However, in 2014, New Zealand and Australia governments described a vision in a future-oriented national cadastre for 2034 to support the identification of all RRR related to land and property (Land Information New Zealand, 2014; ICSM, 2015).

In Canada, research has been conducted on the possibilities of incorporating VGI into authoritative databases like the Canadian Geospatial Infrastructure (CGDI) (Nkhwanana, 2009; Sabone, 2009; Rak, 2013). Nkhwanana (2009) defined roles that volunteers could play in making updates in authoritative databases and roles that administrators could play in verifying and accommodating verified updates in official databases. An accuracy compatibility evaluation of VGI with CGDI datasets was conducted by Sabone (2009). The results of the study were then used by the researcher to demonstrate an approach for integrating VGI with authoritative datasets which incorporated data validation and data sourcing. Research findings

by Rak (2013) identified that for VGI to be incorporated into CGDI databases, it must not only comply with accuracy standards, but legal rules and regulations regarding the datasets should be taken into consideration as well. A study by Ramos *et al.* (2013) investigated how VGI could be used as a source of information capable of improving official databases in Newfoundland, Canada. They presented a methodology for handling semantic heterogeneities when integrating VGI with authoritative datasets by using domain ontologies to map matching geographic information from different sources.

A study by Keenja *et al.* (2012) on the Dutch Cadastre provides an overview of issues to be focused on if crowdsourced land information is to be integrated with cadaster data. For example: a) who in the organization will support the contributed data by the public, b) the extent to which governments can be involved, c) how governments can enforce rules to protect the society, and d) the need to develop organizational strategies to deal with the flexibility of the changing technology. The authors stress the need for comprehensive studies on how crowdsourcing can be useful in supporting land information systems in developing countries, where there is a lack of land information systems or existing ones inefficient.

In Germany, Zielstra and Zipf (2010) conducted a comparative study of proprietary geodata from TeleAtlas (a commercial provider of geospatial information) and OSM datasets of five biggest cities (Berlin, Hamburg, Munich, Cologne, and Frankfurt). The comparisons were based on the completeness of road datasets from the two initiatives, which calculates the total length of roads in a predefined area between the two datasets. The study concluded that OSM data was inconsistent and that it was not yet a sufficient replacement for the proprietary TeleAtlas data for road networks if more consistent coverage was needed, particularly in rural areas. For urban areas, OSM was found to be a potential cost-efficient alternative to commercial datasets (Zielstra and Zipf, 2010).

A study conducted by Fairbairn and Al-Bakri (2013) on semantic similarity measures between VGI (OpenStreetMap data) and Ordnance Survey (OS) datasets in the United Kingdom, concluded that semantic similarity alone was not sufficient to solve the problem of semantic heterogeneity in VGI and that more research was needed on the matter. Whilst, researchers (Anand *et al.*, 2010; Haklay, 2010) analysed the quality of VGI from OpenStreetMap by comparing it with OS datasets. Haklay 2010, showed that OSM could be fairly accurate since it achieved an average accuracy of 6m of the position recorded by OS and with approximately 80% of overlap on motorway objects between the two datasets. Whilst, Anand *et al.* (2010)

investigated techniques and developed a prototype for integrating OSM road datasets with OS transport network datasets using map matching techniques. Even though their analysis showed good accuracy levels, they concluded that more work was needed in refining the process using additional constraints to enhance visualization and usability.

It is evident that developed countries recognize the importance of engaging local communities in participatory mapping activities like VGI to improve official systems. Despite their advanced LAS, many of these countries still use VGI for conservation and environmental activities where official cadastral coverage is limited. Therefore, VGI initiatives in developed countries are mainly used to address this limitation. As advanced by the Greek study, citizen contributions can have no gross errors and at times more detailed than data collected by private agencies particularly attribute data. Moreover, the New Zealand study, despite its conclusion that VGI should be stored separately from official data, argued that VGI could indeed improve data collection and maintenance processes in the country. Such discoveries and highlights have provided confidence that VGI could be of an acceptable quality to address land administration challenges in developing countries.

Studies conducted by Canadian and Dutch researchers have provided guidance and insights of key components to consider when integrating VGI with official systems like user roles of both volunteers and authorities, accuracy considerations, legal and regulations to consider for a successful implementation. The quality of OSM - a leader in VGI acquisition, has been compared against geospatial datasets in official systems and conclusions are that it can be accurate and more consistent in urban areas compared to rural areas. Therefore, to obtain statistically significant and representative results, insight from OSM studies were taken into consideration during the robust data collection activity of this research discussed in detail in Section 5.1.

3.2 Contemporary land administration initiatives in developing countries

VGI activities have been implemented in developing countries to improve tenure security and delivery of services in informal and customary settlements. Their participatory nature has improved awareness and confidence of the public in land administration activities. Examples of information collected from these activities being used to secure land tenure can be found in rural villages in many African nations including Nigeria, Kenya, Tanzania, Ethiopia, Rwanda and Zambia (Enemark *et al.*, 2014; Bennett and Alemie, 2015; Euwema, 2015; Odeniyi *et al.*,

2015; Siriba and Dalyot, 2017). Authorities in these countries have adopted these initiatives to modify land registration practices and improve the lives of citizens in rural villages, especially women and children, who in the past have been side-lined by traditional systems (Quan and Payne, 2008).

Many VGI initiatives have been carried out in developing countries by international organizations such as the United Nations, United States Agency for International Development (USAID), United Nations Food and Agricultural Organization (UN-FAO), World Bank, United Nations Human Settlements Programme (UN-Habitat), Global Land Tool Network (GLTN), and International Federation of Surveyors (FIG). These organizations have developed land administration standards, tools and applications to facilitate the implementation and adoption of affordable, inclusive, fast and participatory LAS in many developing countries. Moreover, they continue to conduct research and implement pilot projects in these countries, and others, to improve the security of tenure and service provision, mostly in rural areas. A discussion of each activity and its application areas follows in the next sub-sections. Lastly, a critical review of having these participatory initiatives led by international organizations will be conducted in Section 3.4.

3.2.1 The Land Administration Domain Model (LADM)

The Land Administration Domain Model (LADM) is an International Standardization Organization (ISO 19152:2012) standard, implemented in 2012 to standardize the design and development of LAS (Lemmen and van Oosterom, 2013). It was developed by FIG, to address challenges faced by many countries in developing their own LAS. LADM presents a conceptual model that organizes concepts and relationships related to RRR, ownership and their associated geometric representations (Pouliot *et al.*, 2013). Since LADM is a general standard for LAS, it should cover all its aspects. However, most rights and claims in developing countries are based on social tenures which often cannot be described relative to a single land parcel. This shortcoming has resulted in the development of a specialized specification of the standard to address different social tenures, termed the Social Tenure Domain Model (STDM) (Augustinus, 2010).

3.2.2 The Social Tenure Domain Model (STDM)

STDM was developed in 2006 by UN-Habitat and GLTN, to address a gap in conventional LAS - their inability to handle customary and informal land tenures in developing countries

(GLTN, 2015). It is a pro-poor, participatory, gender-responsive land information system (LIS) that aims to bridge the gap between formally registered land, ownership units, and those that are not registered or accounted for (Augustinus and Lemmen, 2011). STDM provides a standard for representing citizen-land relationships independent of strict, formal, legal and technical accuracies common in traditional LAS.

STDM has been used to document tenure issues in Ethiopia, Kenya, Uganda, Zambia, Colombia and Haiti (GLTN, 2015). The first prototype of STDM was tested as a pilot project in Ethiopia in 2008, to record different tenure relationships in rural areas not accounted for in official systems (Lemmen *et al.*, 2009). The outputs of the project included: a) documenting land rights of slum communities, b) boundary delineations of land parcels, and c) location and mapping of service facilities like health centres and schools in the area. In Kenya, STDM was applied in agricultural activities for poor rural farmers to map communal water points and grazing lands to protect them from encroachment and ensure controlled grazing (GLTN, 2015).

The participatory aspect of STDM helped farmers map their land parcel boundaries to resolve boundary conflicts. Challenges reported by Lemmen *et al.* (2009) on the implementation of STDM in Ethiopia included: a) the lack of trustworthiness of some participants who claimed extra areas when neighbours were absent, b) challenges of flexible boundaries of unfenced land parcels which moved with the seasons, and c) the prevalence of errors and redundancies in contributed data. These challenges were felt to reduce the authenticity and trustworthiness of information obtained from the initiative, which brought doubts about the overall acceptance of its results for official purposes.

3.2.3 Solutions for Open Source Land Administration (SOLA).

The Solutions for Open Source Land Administration (SOLA) Open Source Software was developed in June 2010 by UN-FAO. It was designed to support participatory activities in developing countries that could not afford the high costs of licensing commercial software products (McLaren, 2013). SOLA provides an open source, flexible and extensible LAS at a fraction of the cost of implementing proprietary-based systems (Pullar *et al.*, 2012). SOLA aims to improve LAS in developing countries by enhancing tenure security, service delivery and transparency in land administration governance. Its database design structure is based on LADM, thus benefitting from the international domain knowledge in land administration contained in the standard.

Recently SOLA was adopted by UN-FAO Land Tenure Team and implemented in rural areas of Nigeria, Uganda, Ghana, Lesotho and Cambodia to support FFP mapping concepts that facilitated the recording of land tenure rights through participatory means (Pullar *et al.*, 2012; Odeniyi *et al.*, 2015). In Nigeria, the initiative was used to grant certificates of occupancy of tenure in rural areas of Ondo State; whilst in Uganda, the system was accepted by authorities which led to investigations of how it could be integrated into the national LIS to improve security of tenure in rural areas (Pullar *et al.*, 2012).

3.2.4 Voluntary Guidelines on the Responsible Governance of Tenure (VGGT)

Voluntary Guidelines on the Responsible Governance of Tenure (VGGT), were developed by UN-FAO, in May 2012 to outline principles and practices that governments can refer to when making laws and administering land, fisheries and forest rights (Hall *et al.*, 2016). According to Pullar (2016), they were developed to advocate for transparent and participatory decision making avenues where non-discriminatory and gender-sensitive assistance is given to citizens to participate in processes that could affect their tenure rights. For example, the guidelines stress that governments should recognize and facilitate citizen participation in processes like land tenure governance, formulation and implementation of policy and law.

The guidelines provide a framework that countries can use when developing their own strategies, policies, legislation, programs and activities related to land tenure (Munro-Faure and Palmer, 2012). Recently, VGGT were adopted in 10 countries (Angola, Burundi, Ivory Coast, Ethiopia, Kenya, Malawi, Niger, Somalia, South Sudan and Swaziland) with support from the European Union to provide assistance in land policy and capacity development in land governance, and to later share experiences among member states (Hall *et al.*, 2016).

3.2.5 USAID's Mobile Application to Secure Tenure (MAST)

USAID's Mobile Application to Secure Tenure (MAST) project was implemented in Tanzania in 2014, engaging citizens to collect land rights information at village level using mobile technology. To increase tenure security in rural areas, the project engaged local communities to map, gather demographic information and record land claims and parcel boundaries of their local area. The information collected was later compiled and linked to government databases for the issuance of formal documentation: a certificate of customary rights of occupancy or similar document (Euwema, 2015). The project was designed to be FFP by adopting the legal

framework of the country and conforming to legally accepted positional accuracy levels of demarcation (5m) at village level (Euwema, 2015).

In a nutshell, the LADM provides a standard that addresses challenges faced by countries in developing their own LAS in terms of RRR. However, it does not include the social tenure relationship common in rural areas of developing countries. To address this challenge, an STDM was developed to handle both customary and informal land tenures. It provides a standard for representing the relationship that people have with their land, independent of strict, formal, legal and technical accuracies common in traditional LAS. Therefore, it has been used to document different tenure relationships in rural areas not accounted for in official systems. Nonetheless, the engagement of communities who are non-experts in handling geographic information can lead to errors and redundancies in the contributed data which can reduce the authenticity and trustworthiness of its products. The main advantage of SOLA is that it provides open source solutions to implementing flexible and extensible LAS which can be affordable to many developing countries. However, open source systems generally suffer from a lack of dedicated technical support, which many countries may struggle with for maintenance and troubleshooting purposes.

According to Munro-Faure and Palmer (2012), VGGTs can provide a framework that governments can refer to when making laws, strategies and legislations related to land tenure for improved governance of tenure. Nevertheless, they are developed by UN-FAO, an international NGO: this means that some western principles may be imposed on developing countries, which might not sufficiently address challenges on the ground. MAST provides an alternative to engaging local communities in collecting land rights information using mobile technology of their rural areas. The major weakness of this initiative is technological improvements in terms of Internet speed and access to handheld GPS devices or smartphones. For example, many rural areas in developing countries have poor or no Internet access, and this can negatively affect the scalability of the initiative to other regions, while handheld devices may not be affordable to the masses.

3.2.6 Fit for purpose land administration

The FFP concept for land administration was initiated by FIG and the World Bank in 2014. It is often referred to as the ‘external quality’ measure of geospatial data, has been commonly accepted in the geographic information quality community and corresponds to ISO definition of quality (Devillers *et al.*, 2010). The definition states that a product has good quality when it

can satisfy stated needs or complies with the requirements specified by a client. Rather than following more advanced technical standards, LAS should be designed such that they manage current land issues within a specific country or community (Enemark *et al.*, 2014). The FFP concept has three fundamental characteristics:

1. Focus on purpose – mainly on the result of meeting the needs of people and their relationship to the land, improving their security of tenure and adding value to current official systems,
2. Flexibility – flexible in terms of the demands for accuracy and shaping of legal and institutional frameworks to accommodate societal needs,
3. Incremental improvement – initially it should be designed to meet basic societal needs and allow incremental upgrading and improvement over time in response to emerging societal, legal and economic opportunities (Bennett and Alemie, 2015; Pullar, 2016).

These characteristics facilitate the development of a participatory, inclusive FFP LAS focused on building appropriate systems within a short period of time at an affordable cost (Bennett and Alemie, 2015). The FFP concept is supported by three complementary components (Figure 3-1): the spatial, the legal and the institutional frameworks (Enemark, 2015).

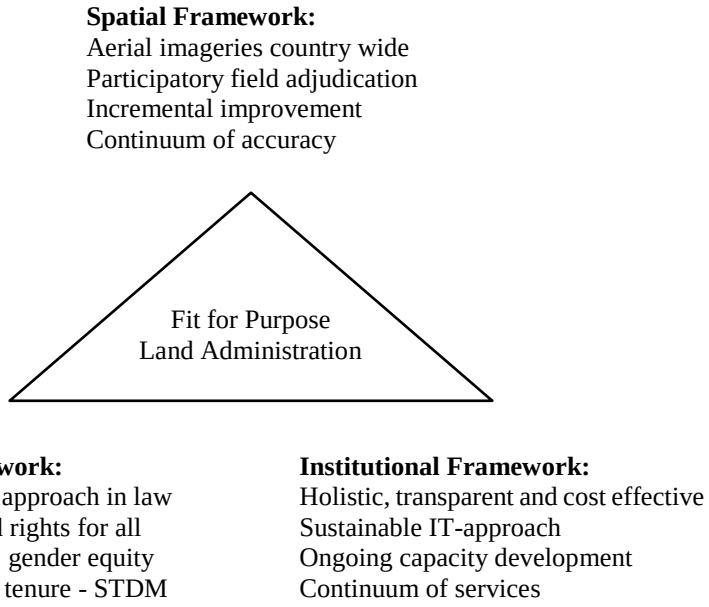


Figure 3-1. The fit for purpose concept (Enemark, 2015).

The spatial framework

The spatial framework advocates the recognition and use of non-conventional tools to map the general boundaries of land parcels and the recording and management of social tenures prevalent in developing countries. Furthermore, it stresses that the accuracy of land information should be interpreted relative to its purpose, rather than conforming to strict technical standards, which can be expensive to obtain and maintain. According to Siriba and Dalyot (2017), the general boundaries approach is sufficient for establishing security of tenure in land registration projects, as the important aspect is to identify a land parcel of interest in relation to neighbouring parcels. The spatial framework is made up of four key principles:

1. The use of aerial imageries rather than field surveys,
2. Mapping of general (visible) boundaries rather than fixed boundaries,
3. Accuracy relates to the purpose rather than technical standards
4. Demands for updating and opportunities for upgrading and ongoing improvement (Enemark *et al.*, 2015).

The legal framework

The legal framework promotes the adoption of a flexible approach to building LAS based on administrative rather than judicial lines, such that both legal and social tenures can be enshrined in the laws of a country. Existing legal frameworks in most developing countries do not serve the larger populations whose tenures are predominantly social rather than legal (UN-Habitat,

2012). Therefore, a continuum of land rights which considers all ranges of tenures within the society with different degrees of enforcement can be considered to offer stronger protection of land rights (UN-Habitat and GLTN, 2008). However, most formal systems in developing countries are from the colonial era, characterised by highly restrictive conventional field surveys and land registration methods based on legal rather than administrative processes (Siriba and Dalyot, 2015). This limits the introduction of flexible initiatives that can provide improvements necessary to improve the security of tenure for citizens in these countries. The VGGT guidelines introduced by UN-FAO (Munro-Faure and Palmer, 2012) can be used as a starting point to guide the development of the legal and regulatory framework.

Despite social tenures not defined in formal laws, they still have 'legitimacy' within the local community, as people still use them daily (Bennett and Alemie, 2015). Therefore, the FFP concept attempts to address these tenures within the continuum of rights approach. Enemark *et al.* (2015) argue that the legal and regulatory frameworks of developing countries need to be revised to support new, innovative, pro-poor recording methods that can accommodate non-conventional field surveying techniques for establishing land rights of local communities. The legal framework is based on the following key principles:

1. Designing a framework along administrative rather than judicial lines,
2. Enabling the recording of legal and social tenures,
3. Adopting a flexible approach to land recordation of various tenure types,
4. Designing gender-sensitive legal and regulatory frameworks (Enemark *et al.*, 2015).

The institutional framework

Land institutions in developing countries are fragmented and their land administration activities disintegrated. As a result, they are unable to deliver joint services or share land information to reduce duplication of effort. According to Munro-Faure and Palmer (2012), governments should adopt globally accepted principles and standards for responsible governance and administration of tenure, which can help determine whether their proposed initiatives constitute to acceptable practices.

An institutional framework that supports the FFP approach should further have: well-defined policy frameworks, inclusive institutional arrangements, organizational structures that aim to deploy resources locally, and is based on mutual partnerships with local communities (Zevenbergen *et al.*, 2013). However, many developing countries have fragmented land

institutions with overlapping duties and responsibilities, and inconsistencies are common. This fragmentation is a challenge in the proper administration of land and delivery of services to consumers. Institutional frameworks are guided by four principles which include:

1. Developing or adopting good land governance rather than bureaucratic barriers,
2. Establishing integrated institutional frameworks rather than sectorial silos,
3. Adopting flexible ICT approaches rather than high-end technological solutions,
4. Developing transparent and easily accessible land information systems and building trust with citizens (Enemark *et al.*, 2015).

It is necessary for institutions to be sustainable and have capabilities to deliver and maintain FFP solutions that can be scaled to national and regional levels.

There should be clear dependencies between the spatial, legal and institutional components to ensure that they are mutually reinforcing. For example, when legitimate rights are recognised, the legal component should be modified to legally enshrine the tenure type, while ICT solutions are adapted to support the overlapping rights and new relationships prevalent in social tenures (McLaren *et al.*, 2016). Moreover, data recording procedures in the spatial component should be modified to capture these relationships. To achieve FFP LAS and establish that the spatial, legal and institutional components are correct, implementing organisations should ensure that their initiatives have the following country-specific strategies (Munro-Faure and Palmer, 2012; Bennett and Alemie, 2015; McLaren *et al.*, 2016):

1. Identify and take advantage of key drivers for change like constitutional change, poverty reduction, social stability reduction, improved access to economic development and requirement to reduce land conflicts;
2. Obtain commitment and support from politicians to adopt the FFP approach;
3. Create a country specific FFP strategy and roadmap for land administration which includes cost, accuracy, scale and speed of delivery;
4. Advocate the use of aerial imageries to map general boundaries rather than field boundaries obtained from usually expensive and time-consuming field surveys.
5. Ensure financial sustainability like adopting GLTN's Framework for Costing and Financing Land Administration Services (CoFLAS) tool to support business planning exercises;

6. Start building capacity early. For example, developing strategies for recruiting and training land officers in terms of procurement, contract management, quality assurance, information management, ICT and human resource management is crucial for success.
7. Build scalable ICT solutions, like adopting a mixture of commercial, and Free and Open Source Software (FOSS) solutions to provide cost-effective alternatives. Over time and with confidence in FOSS, more commercial solutions can be replaced with FOSS solutions;
8. Focus on public consultation and awareness raising so that the public can be fully informed of their rights, obligations and what the rights mean to them;
9. Set performance targets and continually monitor progress to improve the initiative. Moreover, a regular external review of the initiative should be established to ensure that the targets are still appropriate and easy to comprehend.
10. Ensure equality. For example, establishing that there is no discrimination and that processes are systematic, in the sense that the output of the initiative is to secure land rights for everyone.
11. Learn quickly from mistakes, especially during scaling processes to a national level since mistakes will be made. It is important for implementers to acknowledge that errors will be made at the beginning, but if they are open to lessons learned and innovations based upon reliable management information systems, the program will evolve into a viable solution.

Establishing the outlined country-specific strategies need to be agreed upon by the country of interest and the implementing organisation. The FFP approach requires strong political support to succeed: nevertheless, this can lead to political bias, especially when politicians have their specific mandates to achieve within a set period. This top-level support can be beneficial to the initiative since it shows commitment from the government which then sets an agenda for the whole public service. However, politicians can also create barriers or delays when they do not support the initiative or see it as a threat to their political ambitions. As a result, politicians and decision-makers are key to the FFP approach success: it is vital they understand the social, environmental and economic benefits of it.

Applications of the FFP concept

The FFP concept has been applied recently in Rwanda, Ethiopia, Kenya and Namibia to provide land information and security of tenure to citizens in the respective countries. The whole country of Rwanda was successfully covered using the FFP concept within 5 years at a minimal cost of $6 USD per land parcel. In the formal LAS, it costs a fixed amount of Rwf 27,000 ($32.5 USD) to register land in Rwanda, even though about 65% of the population earns less than Rwf 50,000 ($60.2 USD) per month (Biraro *et al.*, 2015). These high registration fees make it a challenge for many citizens to register land in official LAS. Therefore, the FFP approach provided a cost-effective means of registering land of the whole country within a short period of 5 years.

In Ethiopia, a boundary delineation activity was conducted by the Ethiopian Mapping Agency (EMA), where a 40cm resolution aerial photograph was used as a base map for marking boundaries of land parcels. The information was later populated with ownership details and used to issue certificates of occupancy rights to local communities (Abza *et al.*, 2015). Therefore, the FFP approach facilitated a large scale rural certification and administration of more than 80% of households in four regional states of Amhara, Oromia, SNNP and Tigray, using participatory and cost-effective (about US$ 3.5 per household or less than US$ 1 per plot) within a short period of 5 years (Abza *et al.*, 2015). According to the authors, the initiative attained its primary objective of enhancing tenure security and reducing land related conflicts among farming households of the four states.

In Namibia, the concept was applied to fast-track the land registration process of citizens in rural areas (Bennett and Alemie, 2015). Here, aerial photographs were used to delineate land parcel boundaries within an absolute accuracy of 2 meters, and landholders were later requested to identify their land rights based on the digitized land parcels. According to Christensen (2017), this is an ongoing 4-year national project (2015-2018) and its evaluations and assessments are to be conducted upon its completion in 2018. In Kenya, the participatory initiative was implemented in the Kibera slum (one of largest informal settlements in the world), to create topographic and purpose-built maps for efficient delivery of health supplies, education, security, water, and sanitation (Donovan, 2012). The project taught local citizens how to use technologies like GPS to relatively quickly produce both digital and hardcopy maps of the informal settlement (Panek and Sobotova, 2015). The mapping and community media efforts created an effective way for Kiberans to turn information into a community resource, contest dominant norms, and get recognized by more powerful groups in formalized settings (Donovan,

2012). For example, the initiative facilitated community reporting services, which created a communications environment to use information as a component of broader social change (Panek and Sobotova, 2015).

VGI initiatives in developing countries prioritize on improving the currency of official systems, ownership boundaries, occupancy and security of tenure of citizens. International organizations have implemented participatory mapping and adjudication initiatives which consider the capacities and resources in these areas to provide platforms where citizens can actively participate in land related activities of the communities. The successes and challenges of these initiatives have been well documented which can be beneficial to organizations with intentions of starting similar initiatives in their local environments. The FFP concept stands out as the most comprehensive of the initiatives investigated because of its key principles, which are applicable in rural areas, whose leaders and administrators are mainly concerned with improving lives of local communities through their active involvement and participation.

The FFP concept will be adopted in this study since it is believed that it can address key bottlenecks of traditional LAS such as high accuracy and expensive land surveying techniques to record land rights. The concept is based on the principle that actual needs of the society should be identified prior to establishing a participatory initiative such that they can be addressed sufficiently with proper data collection tools and techniques. All these are ideals of an initiative that aims to address the challenges of LAS in developing countries by utilizing affordable technologies, inclusive and participatory means that consider local norms and processes of land administration. The FFP concept if successfully investigated and implemented, can succeed where traditional LAS failed, hence its adoption in this research.

Overall, developing countries have learned to embrace participatory initiatives like VGI to improve the administration of land records and tenure security of citizens, especially in rural areas. Moreover, they have learned that the affordability, inclusiveness, fast and participatory nature of VGI initiatives can provide means to document different tenure relationships not accounted for in official systems. Land parcel boundary conflicts between rural farmers are common in developing countries. Therefore, the participatory aspect of STDM has facilitated platforms for farmers to map their land parcel boundaries to resolve boundary conflicts. Initiatives like VGGT and MAST have provided an understanding of how countries can design and implement VGI initiatives that adopt the legal and regulatory frameworks of the country of interest.

3.3 Challenges of implementing VGI initiatives

International organizations that have implemented pilot VGI projects in the past have reported some key challenges that need to be addressed. These challenges focus on the authenticity of the information collected, the legitimacy of the data collection and handling exercise, repeatability and sustainability of the systems developed, and scaleability of the initiatives. In practical terms, the key challenges include: a) lack of transparency of governments and corporations in land transactions (Johnson and Sieber, 2013), b) poor mobile phone coverage and Internet access in rural areas (Batane, 2013), c) lack of established data quality and credibility measures of contributed datasets, d) lack of knowledge of how contributed datasets can be incorporated into official databases (Johnson and Sieber, 2013; Siriba and Dalyot, 2015), e) problem of silo systems where many participatory initiatives are created by different organizations for similar purposes, and f) lack of understanding and mechanisms of how the participatory activities can be made sustainable for future activities (Rahmatizadeh *et al.*, 2016b).

In Kenya, a lack of transparency has led to poor quality land information which resulted in a conflict between urbanisation, cultural preservation, and poor land governance (Koeva *et al.*, 2017). To address this challenge, international organisations like USAID developed participatory tools to record and raise awareness about customary land rights. In addition, the tools facilitated a better planning environment for the land information to be organised and maintained within the local community.

Enhanced network communications in terms of Internet and mobile phone coverage are essential for creating an inclusive knowledge-based society, partnerships and integrated solutions with local communities. Moreover, they are dynamic tools for stimulating growth in developing countries. Nevertheless, their lack thereof means that the poor and vulnerable people cannot be empowered by strengthening their capacity to receive and use knowledge for more informed decision-making. According to Guerriero (2015), about 2000 mobile Internet users in the year 2014 showed that 68% of Kenyans, 62% of Nigerians and 61% of South Africans concluded that mobile Internet ‘greatly improved’ their lives by providing better access to education, news, health and job-related information. Developing countries should invest in

improved network communications to enable citizens to participate in processes involving land administration, e-governance and e-voting.

Even though VGI is seen as geospatial data capable of improving LAS in developing countries like Kenya (Siriba and Dalyot, 2017) and Tanzania (Asiama *et al.*, 2017), it lacks established quality and credibility measures to ascertain its accuracy and reliability. These quality challenges may result in the reluctance of officials to incorporate VGI into their official systems to secure tenure for citizens in rural areas. Therefore, issues of how trust and confidence can be placed on VGI in such applications need further investigation, especially where ground truth is non-existent. According to Koeva *et al.* (2017), current processes and mechanisms in Rwanda do not actively facilitate data integration from participatory initiatives with the cadastral maps in official systems. A lack of cohesion between federal and regional levels in Ethiopia have led to implementation challenges because of unsettled legal frameworks, capacity and resourcing issues (Donovan, 2012). To address these challenges, attempts were made to concentrate on the judicial cadastre and aligning the initiative to the development agenda of the country.

The failure to regard ongoing projects by NGOs can lead to a problem of silo systems where many projects are created by different organizations for similar purposes. This challenge can further lead to duplication of effort, resource wastage, conflicting strategies, and confusion at the community level. For awareness raising and familiarisation with existing and ongoing community projects, organisations should engage local community leaders, network and communicate with other NGOs in the region. Other NGOs in the region could offer guidance to the implementers, subsequently improving chances of success of the initiative.

Community-based mapping is regarded as a best practice for locally-based sustainable planning (Panek and Sobotova, 2015). Sustainability in this instance refers to the ability of local inhabitants to continuously administer and manage the VGI initiative when western researchers and implementers leave the community. Therefore, community participation is crucial for the success and sustainability of the initiative at all levels of administration. However, participatory challenges can occur when the initiative is technologically demanding, as this would attract fewer members of the community to actively take part, hence lower the chance of sustainability. To address this challenge, VGI implementers should consider the capabilities and skills of community members to better align its technical demands with those of the participants for improved chances of acceptance and buy-in.

Institutional setups can also be barriers for adopting VGI projects in developing countries. For example, there may be a reluctance of decision makers and professionals to adopt a more flexible LAS because of resistance to change, or a reliance on colonial legacy systems. In many countries, decision makers are politically directed and when there is no political will, the possibilities of VGI acceptance in official systems are slim or non-existent. A lack of basic financial resources can also be a major constraint to adopting FFP LAS, as costs are initially high especially for preparatory implementation stages and training of coordinators and volunteers. Despite such shortcomings, participatory initiatives continue to be utilized by communities and organizations in many applications for informed decision making. For example, current projects have added value to a range of socio-political activities: a) vulnerable communities and disaster management (Ushahidi and Did You Feel It?), b) business services (Yelp), c) crime alert and prevention (WikiCrimes), and d) traffic and travel reports (TomTom Map Share and Waze). Such participatory activities, when directed to LAS, can improve current land administration processes in developing countries. In addition to the outlined challenges, there are further issues regarding the international organizations leading the participatory initiatives that need to be highlighted.

3.4 Issues of NGOs in Developing Countries

Participatory initiatives in developing countries are usually led by international organizations. However, there are several issues regarding this setup, that need to be highlighted. These include: a) imposition of westernised values and models which correspond to the western concept of development, market, and economic growth, b) failure to recognise different cultures and practices that exist in different regions for buy-in and successful implementation of the initiatives, c) lack of awareness-raising by implementers to the people affected of the meaning, value, potential benefits and anticipated outcomes of the projects, d) poor networking and communications mechanisms, and e) lack of foreign personnel to incorporate local managers and advisers as part of management for knowledge transfer purposes.

NGOs are highly dependent on donor aid from western countries, which require the adoption of western values and models (Kang'ethe and Manomano, 2014). However, imposing western models in developing countries limits their capability to sustainably take charge of the projects once the foreign funds and personnel are depleted. Furthermore, culture plays an important role in formulating development projects, policies and strategies. Nonetheless, many international

NGOs fail to recognise that initiatives based on the values, traditions and dynamic qualities of local communities can receive less resistance and acceptance from all stakeholders involved. Furthermore, they fail to take advantage of local distinctive characteristics into account: their conception and setting are usually 'foreign' to the populations concerned, hence seen as 'hostile' which later leads to their failure (Roberts, 2011). In contrast, Nechifor (1998) argues that NGOs like UNESCO emphasize the need to recognize the significance of the cultural dimension when developing projects, policies and strategies that aim to better address economic issues in developing countries.

Duplication of effort and conflicting strategies at the community level (as outlined in Section 3.3) are common among NGOs in developing countries because of poor networking and communications mechanisms (Kang'ethe and Manomano, 2014). Failure to regard ongoing community activities is a major cause of these challenges which leads to poverty, deprivation and under-development. Awareness raising and familiarization with ongoing activities could offer guidance to implementers and motivation to the populations involved. The lack of locals in management positions results in very few elements incorporated into the daily life of the population such that the project becomes part of their socio-cultural system, hence its eventual failure. In addition, Roberts (2011) stresses that the lack of integrating local decision-makers gives rise to incompatibility issues and a failure to find solutions appropriate to situations and needs of the countries concerned.

3.5 Summary

This chapter conducted a review of VGI initiatives in developed and developing countries. Most developed countries have well-structured and effective LAS, thus focus on participatory land administration activities are on environmental issues that are not documented in the official cadastre. As such, VGI provides an opportunity for these countries to enhance their current LAS to better manage environmental issues, to determine their spatial extent, and the likely impacts they may have on local communities. In contrast, developing countries have ineffective and outdated LAS with limited records of land rights. Therefore, they prioritise on the collection of ownership boundaries, occupation and land use information which can increase the security of tenure of citizens, especially in rural areas.

Emphasis was placed on contemporary initiatives developed by international agencies to improve land administration processes in developing countries, by utilizing participatory

means. The LADM, though not participatory, is important as the basis for other systems investigated. It embodies a relationship that citizens have with land parcels in a formal land administration setup. However, many developing countries are characterised by social tenures which LADM cannot address, hence the development of STDM. Pro-poor, participatory, affordable, and gender responsive land information systems have been developed by international agencies to address the inefficiency of conventional LAS in developing countries. Through their participatory nature, these systems have proved to be effective in improving the currency of land records, securing tenure, decreasing land conflicts, and increasing awareness of land related activities by local communities. Therefore, institutions can be encouraged to use VGGT to engage local communities as well as implement and incorporate STDM or SOLA solutions in their local environments for an FFP LAS.

Generally, the need for accuracy is lower in rural areas compared to urban areas. Hence, the FFP concept is ideal for VGI initiatives in rural areas as per the case study of this research. It is advanced here as the central tenet to establish a VGI initiative capable of adding value to LAS in developing countries. However, issues of how it can be successfully integrated with official systems remain unsolved. The outlined challenges highlight some of the core issues that need to be addressed to achieve and maintain an effective and efficient participatory system. The following chapter proposes an FFP LAS based on VGI that aims to address these challenges.

Chapter 4. Building fit for purpose land administration systems based on VGI

This chapter presents a methodology for implementing an FFP land administration based on VGI that aligns with the FFP principles discussed in Section 3.2. It then conducts a review of the TRM initiative in collaborative environments to establish the quality and credibility of consumers in online systems.

LAS should be designed such that they are secure, scaleable, sustainable and enable flexible responses to societal challenges and economic improvement within an area of interest (Williamson *et al.*, 2010). However, current systems in many developing countries are not scaleable and cannot accommodate social tenures common among the majority population. It is necessary to bring informal, customary, communal and other social tenures into the formal system through the scaling up of policies, regulations and investments in flexible LAS to protect the rights of most citizens in developing countries. A flexible LAS defines how the RRR in informal and customary land can be established and managed, considering existing statutory arrangements in a country.

The Global Sustainable Development Agenda (GSDA) aims to develop solutions for global land issues to alleviate poverty, social inclusion, stability, investments and economic development and the protection and management of natural resources (Nhamo, 2017). The GSDA, among other sections, consists of 17 Sustainable Development Goals (SDGs) of which those related to the FFP initiative include: a) ending poverty in all its forms everywhere, in this instance, through security of tenure, b) ending hunger, achieving food security, improving nutrition and sustainable agriculture, c) achieving gender equality through active engagement and empowerment of all genders, d) building resilient infrastructures, promoting inclusive and sustainable development and fostering innovation, and e) making cities and human settlements inclusive, safe, resilient and sustainable. According to Enemark (2015), land matters have been embedded in the SDGs which form a blueprint for a sustainable future supported and agreed to by all world leaders. The FFP concept is presented as an accelerator and facilitator for implementing these global standards in developing countries (Enemark, 2015). It is jointly endorsed by FIG and the World Bank. The FFP concept introduces a flexible and pragmatic approach rather than conforming to rigid, standards-based regulations with strict demands for spatial accuracy and unsustainable systems dependent on donor funding. The concept can

further be applied in countries without complete cadastral coverage and land registration, especially where the maintenance of land information has failed like in Botswana.

4.1 Implementing a fit for purpose land administration system based on VGI

Insights from previous studies (Enemark *et al.*, 2014; Rice *et al.*, 2014; Bennett and Alemie, 2015), have led this study to conclude that to understand how the FFP concept can be applied in VGI initiatives for land administration, there is a need to examine the following:

1. Scrutinize policy and regulatory frameworks that guide the handling and dissemination of land information (Rak, 2013),
2. Investigate current geospatial data standards in use and flowlines between other stakeholders (Enemark *et al.*, 2014; Bennett and Alemie, 2015),
3. Design strategies for engaging local communities in land administration and gathering opinions about existing systems (Goodchild, 2007; Coleman *et al.*, 2009; Budhathoki, 2010),
4. Develop an application for the public to examine current data samples contained in official systems and design mechanisms for them to contribute their own data,
5. Design data quality assurance and assessment measures of contributed datasets (Flanagin and Metzger, 2008; Bishr and Kuhn, 2013),
6. Using results from geospatial data standards in use by stakeholders, test and analyse if contributed data can abide by the legal and institutional requirements of LAS of the study area.

The parameters outlined above adapt the three components of Figure 3-1 (spatial, legal, and institutional) to enable VGI to be used as an operational element for establishing an FFP LAS for developing countries. For example, formulating strategies to engage local communities in land administration enforces the key principle of participatory field adjudication in the spatial framework. Scrutinizing policies and regulatory frameworks for land information handling and dissemination can help implementers enshrine the FFP approach into the laws of the country of interest. Lastly, investigating geospatial data standards and flowlines in use between stakeholders is crucial for developing a participatory initiative with inclusive institutional arrangements and organisational structures. The parameters can further be used to verify a country's readiness for the FFP approach to land administration (Enemark *et al.*, 2015; Lemmen *et al.*, 2016). The process of recording and registering land rights based on VGI for FFP land

administration is illustrated in Figure 4-1 and the connection between the parameters are outlined below:

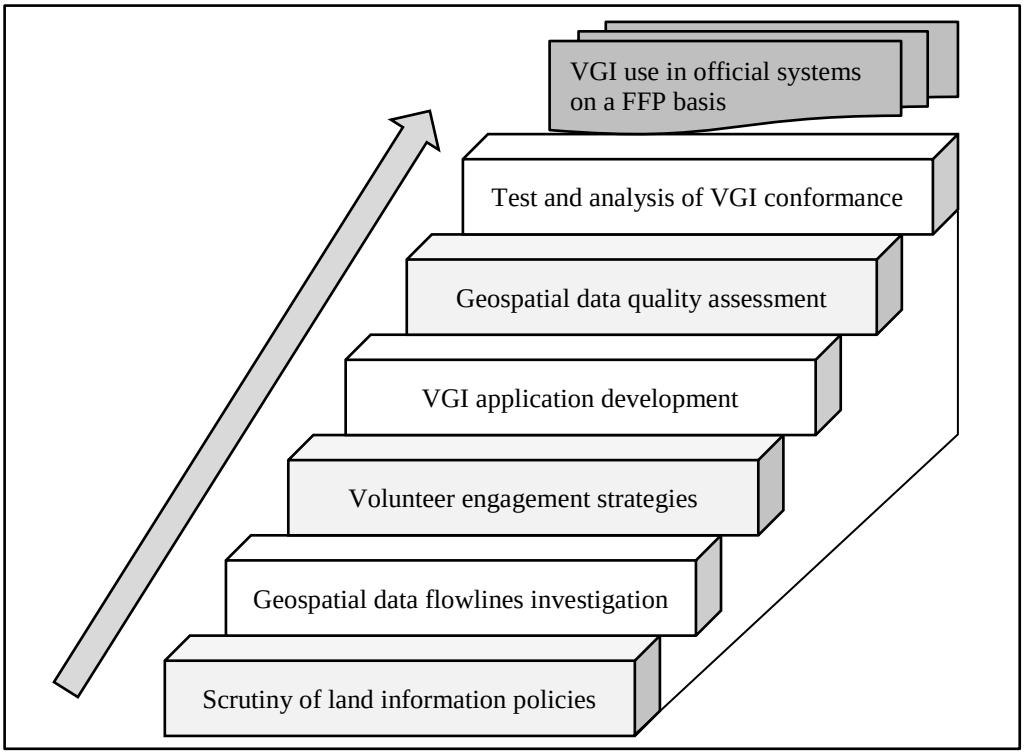


Figure 4-1. Implementing an FFP LAS based on VGI.

Figure 4-1 outlines parameters that should be taken into consideration for an FFP LAS based on VGI. It does not imply a linear waterfall approach, as each phase can be completed independently from others because they are no overlaps in the phases. All stages in Figure 4-1 are equally important to the success of the VGI initiative. However, there may be barriers in conducting some of the stages outlined, which include: a) The reluctance of land administration officials to corporate with VGI implementers to provide information about current geospatial data flowlines in government systems, b) Lack of documentation about current land information policies to guide the development of a successful country-specific initiative, and c) reluctance of volunteers to participate in the VGI initiative due to a lack of acceptance and buy-in. These potential barriers should be taken into consideration by implementers if an effective and efficient initiative is anticipated. The stepwise approach of Figure 4-1 is a simple illustration that stresses that to achieve VGI capable of use in official systems on an FFP basis, it is necessary to consider the outlined parameters.

The failure of traditional systems has been attributed to the lack of consideration and recognition of customary and social tenures prevalent in rural areas of developing countries (Adams and Palmer, 2007). Therefore, these parameters aim to address this challenge by investigating how current systems operate such that VGI can be positioned complementary to them for value-added purposes. Consumer buy-in is essential when developing a participatory initiative that aims to improve the lives of local communities. Thus, a parameter that focuses on the aspect of establishing effective ways of engaging local communities and officials is essential, so that the significance and potential value of the initiative can be realized. Engaging local communities and officials can further guide the development of an initiative that facilitates the contribution of known land information by citizens of their local area.

However, most members of the public are non-experts in geographic information handling, manipulation, and dissemination. As a result, potential consumers may question the quality and reliability of their contributions. This requires investigations on how the quality of public contributions can be assessed and measured for trustworthiness. Eventually, this contributed information should be tested and analysed for conformance into official systems if it is to be used to improve them. These parameters have been elaborated in the sub-sections that follow.

4.1.1 Investigating policies and regulatory frameworks for land information management

Investigating the legal frameworks of a country can inform the extent of its flexibility regarding recognizing and safeguarding the security of tenure for communities in rural areas. As noted by Enemark *et al.* (2015), an effective LAS requires a legal and regulatory framework that supports an adaptable tenure system that has a compliant land recording system. Therefore, governments in developing countries should adopt frameworks that accommodate the flexibility needed for an FFP LAS which can be developed up front or developed incrementally. For example, the Namibian government in 2012, implemented a Flexible Land Tenure Law to facilitate the introduction of new forms of legal evidence to incorporate social tenures into formal systems (Republic of Namibia, 2012).

Legal and regulatory frameworks generally contain comprehensive land laws and legislations that govern the conduct of administering land and control the operations of land registration and cadastral management. Unfortunately, many developing countries lack these frameworks to implement FFP concepts to improve the administration of land in their jurisdictions especially rural land characterised by the insecurity of tenure and social ills (UN-Habitat, 2012). Furthermore, the highly political nature of land in these countries leads to disengagement of

citizens since most decisions are made by political leaders neglecting consultation and engagement avenues traditionally used by community leaders. Existing legal and regulatory frameworks are usually barriers to implementing flexible approaches to administering land rights because of often unnecessary legal interventions by lawyers and notaries (Siriba and Dalyot, 2017).

The first step to adopting VGI initiatives for FFP land administration would involve the legal recognition of legitimate occupancy of unregistered land in customary areas in formal systems, with options of eventually upgrading them to a legal status as practiced in Namibia, Uganda and Mozambique (Christensen, 2004; Antonio *et al.*, 2014; Balas *et al.*, 2017). Traditional authorities initially involved in allocating customary land rights should be engaged in this process to legitimize the allocations to official institutions as practised in Botswana. Unfortunately, there is no outright legal recognition of legitimate occupancy of unregistered land in customary land in Botswana. Nonetheless, the new Land Policy of 2015 of the country currently under consultative review aims to address this challenge through the LAPCAS program outlined in Section 2.6.2. It is necessary to understand legislative and regulatory frameworks that control mapping activities in a study area, to inform the establishment of a VGI initiative in terms of positioning and what purpose it could serve to add value to official systems (Rak, 2013).

4.1.2 Understanding geospatial data flowlines between stakeholders

Understanding geospatial data flowlines between stakeholders can inform accepted practices existent within the local community, such that the VGI initiative, including system design processes, can adapt to national and local conditions. Building the initiative on existing local processes can further enhance its buy-in and acceptance by the state and local communities. Semi-structured interviews can be conducted with key personnel from the land authority and the main data custodian to provide information on current geospatial data arrangements, licensing agreements, standards and flowlines in official systems (Lemmen *et al.*, 2016). The information collected could later be used to determine the potential use and practicality of VGI in official systems.

The importance of engaging local authorities like Land Boards in the initiative is that they can provide guidance and support to organizations performing the participatory activity of recording land rights. For example, they can advise on effective ways and channels of interacting with local leaders and community members. They can further highlight strategies

for verifying and validating the information collected from the public such that accurate and reliable results are obtained. Additionally, understanding existing geospatial data flowlines between stakeholders can inform the technical development of a participatory initiative to best align to database schemas in official systems, for interoperability purposes and easier incorporation at a later stage.

For a participatory initiative to be FFP and to improve chances of its adoption in official systems, it should recognise and conform to accepted practices existent within a local community. In this case, it will not be viewed by officials and community members as an initiative that undermines or is a threat to existing systems and practices. Rather, it will be regarded as an initiative that aims to improve and add value to them for the benefit of all stakeholders.

4.1.3 Geospatial data collection and user engagement strategies

When building the spatial framework, the choice of surveying or mapping methodology should be determined by the minimum standard that fits the purpose for a specific area context (Basiouka and Potshiou, 2012). Even though the FFP concept recommends the use of aerial imageries (Enemark *et al.*, 2015), other areas without visible boundaries due to trees or clouds would require field surveys either with GPS enabled mobile phones or conventional survey methods. The effectiveness of aerial imageries in collecting boundary information was tested in Ethiopia and Rwanda and further showed that citizens have good spatial cognizance (Bennett and Alemie, 2015; Hilhorst and Meunier, 2015). Moreover, evidence has proved that aerial imageries are three to five times cheaper than conventional field surveys, and require less time and capacity (McLaren, 2013).

A participatory mapping activity focuses on the provision of skills and expertise for community members to create maps that represent the knowledge of their surroundings and the ability to document their relationships to land. Furthermore, it can be used as an awareness raising and empowerment activity, where citizens are enlightened of the significance of their participation and the potential benefits of the mapping activity. Prior to its commencement, a comprehensive user needs assessment is necessary to avoid pitfalls encountered by the participatory initiative of Bahir Dar city in Ethiopia (Bennett and Alemie, 2015). According to the authors, the failure of the project was attributed to the following: a) undermining the longer-term aspects of the initiative, like instituting sustainable updating procedures, b) not developing proper archival databases for sufficient storage and retrieval of contributed land information, and c) failure to

establish buy-in from an increasingly skeptical citizen population. The adoption of these aspects can support the characteristics of a flexible land administration which include upgradeability, inclusivity and participation. Moreover, they can provide an assessment and evaluation of conditions within the community, to guide the development of a participatory initiative that best addresses societal needs (UN-Habitat, 2012).

4.1.4 Volunteered geographic information application development

A participatory mapping activity requires a tool that enables the collection of geospatial data and adjudication of already collected datasets by local communities. Technological advancements have facilitated the collection of geospatial data using tools like GPS units, aerial photographs and remote sensing images, smartphones, tablets and Web mapping applications. The mapping process as outlined by Zevenbergen *et al.* (2013) can range from low-cost, low-resource, paper-based activities to more high-tech, high-input processes that involve GIS technologies yet require less technical skills to perform. A VGI application should be made simple to accommodate limitations in the telecommunications infrastructure, capacity and ICT skills of developing countries. Their complexity could incrementally be improved over time as demands increase and capacities improve. The FFP concept advocates a Minimum Viable Product (MVP) approach (Lemmen *et al.*, 2016) which focuses initially on the development of a set of tools to capture land rights, using available resources and conducting incremental adjustments over time to meet customer requirements.

VGI application development should be informed by an evidence gathering process from key stakeholders like officials at the land authority, lawyers, community leaders, community members (land parcel owners, aspiring owners, tenants, and other inhabitants) and other organizations involved in land related matters. These stakeholders can provide information on existing land administration processes, successes, challenges and requirements necessary for a flexible LAS by articulating key functions and technical tools required for the application. In addition, the application can be used to assess and evaluate the ability of residents to participate actively in the identification of their land parcels and overall registration process, necessary for its usability determination at a later stage.

Rather than re-inventing the wheel in application development, the STDM is recommended for an FFP land administration system (Enemark *et al.*, 2015; Lemmen *et al.*, 2016). According to Enemark *et al.* (2015), the STDM can facilitate the following: a) the modelling and managing of complex social tenure relationships that people have with land in rural areas, b) provision of

a standard for representing social tenure rights independent of the level of technical complexity, legality and formality in official systems, and c) incremental improvements of land administration activities to provide continuity as social and legal needs improve and in response to emerging economic opportunities of the local community. However, there may be instances where a participatory application like STDM cannot support the goals and requirements for specific areas. For such instances, Basiouka *et al.* (2015) recommend that organizations should build their own applications with well-defined security measures and functions that encourage public participation and address specific challenges of that area. The application can be designed such that it mimics official database schemas of the study area to enable a seamless data integration at a later stage in the administration of land.

For an application to be FFP, developers and implementers should consider the following: a) requirement of less technical skills to operate to accommodate limitations in developing countries, b) affordability, c) development from evidence obtained from key stakeholders involved in land administration, d) capabilities to record complex social tenure relationships existent in rural areas, and e) scalable enough to maintain effective performance after increased workloads either as larger datasets (storage capacity), or higher request rates (maximum number of transactions handled).

4.1.5 Development of VGI quality assurance measures

Currently, there are no standard measures to assess the quality and reliability of geospatial data contributed to VGI initiatives for land administration purposes, particularly when ground truth is non-existent. As such, land authorities may be sceptical to incorporate and utilize these datasets to supplement their land information systems. This challenge is further increased by the lack of coordinated approaches to collecting, disseminating and overall handling of geospatial data in VGI initiatives. It is necessary to investigate and develop holistic solutions that can enable potential consumers of VGI to measure its accuracy and trustworthiness.

The FFP concept states that the relative accuracy of land parcel boundaries is more important than precise measurements since the emphasis is on documenting the land rights and its connected social relationships to improve the security of tenure for residents. The term ‘fit for purpose’ is considered synonymous with quality and understood as the characteristics of a service that bears on its ability to meet stated or implied needs (Hoyle, 2009). In land administration, it suggests the capability of a LAS to meet the needs of the local community in terms of tenure, policy, legal, administrative, and capacity development systems, that are

aligned to it. As noted by Lemmen *et al.* (2016) administration and adjudication of land parcels should be a participatory process managed by locally trained land officers acting as trusted intermediaries, while officials like land surveyors manage the overall process of developing the legal, institutional and spatial frameworks of the initiative. This process of establishing the reliability of volunteer contributions through identification and adjudication is an important aspect for engaging community members to check and agree on the evidence provided by their peers, whose final decision is made by consensus.

In a VGI initiative, it is impossible to produce a dataset that meets the quality needs of all users. Consumers can have varying needs and uses for similar or different datasets. Nonetheless, for a VGI initiative that is FFP, measures of quality and reliability should be consensus-based, where the accuracy and trustworthiness of contributed datasets are regarded as correct if they are accepted by many residents. To bridge the gap between consumers' perceived quality and that of the producer, Grira *et al.* (2010) recommend the use of Web 2.0 technologies where consumers can express their opinions about a contributed entity. These include rating and evaluation applications, common in e-commerce and social websites, which allow consumers to subjectively judge and rate the accuracy and reliability of contributions made by their peers.

4.1.6 Testing and analysis of VGI conformance in official systems

The FFP concept is based on the use of affordable modern technologies to build a spatial framework like orthophotos that show how land is occupied and used in a settlement. In such instances, the scale and accuracy of the mapping activity may vary due to building and population density, topography and other requirements. However, these technologies have a significant role to play in raising the local profile of legitimate land rights holders and activating incremental changes in official systems. Zevenbergen *et al.* (2013) stress the need to have due-diligence processes that determine whether legitimate rights recorded by local communities can be considered sufficient to meet conditions that allow their integration into official systems.

Eventually, the recorded legitimate rights collected through a consultative and participatory process need to be protected by law. Enemark (2015) recommends an iterative revision of government legislations to recognize and accommodate FFP approaches, to support legitimate land rights. For areas where legal changes take long to implement, countries can: a) pass an overarching law providing legal status to legitimate rights holders, while detailed land laws can be updated at a later stage, b) schedule the recording of legitimate rights to be documented and legalized at a later stage in the program, c) issue provisional land certificates in areas where

citizens have legitimate rights, or d) incrementally improve the legal status of legitimate rights through bottom-up, pro-poor recordation initiatives (Lemmen *et al.*, 2016).

A co-management approach is recommended by Zevenbergen *et al.* (2013) which involves the community, particularly its leaders and trusted intermediaries, or Non-Governmental Organizations (NGOs) administering the front-end of the participatory system, while the state manages its back-end. According to the authors, this could make the system more affordable to the poor, by reducing large amounts of professional time usually involved in mapping and land registration. Nonetheless, such a system can be vulnerable to abuse by community leaders as experienced in Uganda, Kenya and Botswana, where it has been reported (Njuguna and Baya, 2001; Adams, 2003; Ravnborg *et al.*, 2013) that chiefs in the past allocated land unfairly to the elites and those they favoured. Therefore, proper checks and balances are necessary to ensure such attributes are avoided for legitimacy, integrity and acceptability purposes. These would enable the building of customary and informal social tenures into the official system over time.

4.1.7 Challenges of implementing an FFP LAS based on VGI

There are several challenges that can hinder the successful implementation of an FFP LAS based on VGI. By order of importance, they include the following: a) political constraints, b) colonial legacy, c) lack of basic financial resources, d) data quality and credibility issues, e) institutional and cultural differences, and f) lack of knowledge on potential benefits and opportunities of the initiative (Zevenbergen *et al.*, 2013; Siriba and Dalyot, 2017).

A rigid legal and regulatory framework, that does not allow flexible approaches to land administration can be a constraint to adopting participatory approaches like VGI. The legal framework states that the FFP approach should be enshrined into the laws of the country of interest. However, a lack of documented evidence on successful implementations of the initiative in developing countries may discourage officials to embrace the initiative and use it to secure tenure for residents in rural areas. Therefore, it is crucial for organisations involved in participatory initiatives to document and publish their experiences, successes and challenges in open platforms for comparison, buy-in and capacity building purposes.

The resistance from land professionals embedded in their professional codes, especially those with vested interests in their codes and legacy systems can constrain the adoption of flexible approaches in land administration. Rather than viewing participatory initiatives as a threat to official systems, land professionals should be open to alternative systems that can improve

existing land administration processes to improve the lives of residents. Participatory initiatives require basic financial resources which could be used for system development, training, capacity building, and implementation purposes. Nevertheless, financial constraints common in most developing countries can discourage decision makers to adopt initiatives like VGI. Therefore, it is essential to establish alternative and sustainable means of implementing the participatory initiative like engaging international NGOs who can source donor funding, provide expert knowledge, or adopt FOSS solutions.

The spatial framework advocates the recognition and use of non-conventional methods to record general boundaries of social tenures in developing countries. However, it may be regarded as promoting informality in informal settlements by officials, hence receive some resistance and lack of support from them. Even though the FFP concept supports the use of aerial imageries in geospatial data collection, these imageries can introduce errors to digitized datasets, especially when they lack basic elements of data quality like the date and time of acquisition (Goodchild, 2009). Since the majority of VGI datasets are captured at street scale, implications of a wrongly registered image could delineate objects in a different area when used with other features of the same location. A recommendation by Poore and Wolf (2013) is that any assessment of VGI should include information about its underlying basemap when creating a new feature. This information could later be used as metadata of the created features, which is crucial in the effective use of the datasets.

Data heterogeneity in VGI initiatives cannot be eliminated because of the culture and origin of collaborative systems. This has led to researchers (Goodchild, 2009; Heipke, 2010; Severinsen, 2015) to conclude that FFP or quality assessments of collaborative initiatives like VGI, must be considered at local level factors, as opposed to global levels. Hence, evaluations of accuracy and reliability of VGI should be considered relative to a range of datasets of an initiative at a given time and specific place (Severinsen, 2015).

The institutional framework stresses that participatory LAS should be holistic, transparent and cost-effective. However, transparency may be viewed by officials as exposing confidential land records to possible abuse by fraudsters, thus increasing land disputes within the local community. Therefore, it is necessary to capacitate them on what would constitute a public record for transparency purposes such that issues of abuse are greatly minimised or eliminated. The participatory field adjudication processes advanced by the spatial framework may not be feasible in communities that have internal cultural conflicts or differences. Therefore,

consultations with community leaders should be a priority, as they could provide guidance on how to overcome such shortcomings within their jurisdictions for the success of the initiative. Despite the outlined challenges, studies (Christensen, 2004; Basiouka and Potshiou, 2012; Bennett and Alemie, 2015) have proven that a flexible LAS can improve the security of tenure of citizens in customary settlements, and facilitate economic growth, social equity and environmental sustainability.

This section presented major parameters necessary for implementing an FFP LAS based on VGI. These parameters have been elaborated together with their potential successes and challenges to inform the consideration of VGI in official systems. Governments are urged to revise their legal and regulatory frameworks to adopt flexible, affordable, participatory and inclusive LAS to improve the lives of residents in informal and customary tenure systems as evidenced in Namibia and Uganda. The flexible, pragmatic, inclusive and participatory approach of VGI can be an operational component for facilitating an FFP LAS. To achieve this, lessons can be drawn from conventional systems, and professionals like lawyers, land authorities, local leaders and the public about the social tenure relationships existent in customary and informal areas. As noted by Grira *et al.* (2010) the public through a collaborative approach can be used to manage spatial data uncertainty that leads to a better quality comparable to traditional approaches.

A recommendation by Lemmen *et al.* (2016) is that the participatory application should be positioned to run parallel with official systems to support their databases with up-to-date land information or as a driver for change in official systems. Such a system does not defeat the objective of a single LAS. Rather, it provides mechanisms for the VGI system to address challenges not dealt by official systems without violating their overarching formal rules. Hence, they can enhance the efficiency of the relevant official systems. Moreover, the integration of the participatory system with official databases is a possibility which requires sufficient capacities like the safeguarding of official records from exploitation through proper security and authentication measures. In short, application development of a participatory initiative should focus on capabilities of modelling and managing complex social tenure relationships existent in developing countries. Even though the FFP concept states that accuracy relates to the purpose, and not concerned with traditional quality measures: it is necessary to develop parameters that potential consumers and officials can use to establish trust and confidence about utilizing the contributed datasets. The absence of metadata and quality metrics common with commercial geographic information has led to proposals of TRM as ‘proxies’ for data quality

in participatory mapping activities (Flanagin and Metzger, 2008; Bishr and Kuhn, 2013). These measures can further increase the adoption and use of VGI in official systems.

4.2 Volunteered geographic information quality determination using trust and reputation modelling

This section conducts a review of the TRM initiative in collaborative environments to establish the quality and credibility of consumers in online systems. A brief overview of challenges in VGI quality determination will be conducted and a comprehensive study of TRM systems in non-spatial and spatial projects will be done. The successes and challenges of these reputation systems will be investigated to understand how benefits can be derived from them as well as how they can be compromised. The anticipation is that these investigations can guide the development of a TRM model for VGI quality assessment in land administration. TRM relies on volunteers contributing data to a project and their peers subjectively assessing, rating and commenting on the accuracy of the contributions. As a result, scrutiny on the sufficient number of volunteers and assessors required to produce trustworthy and reliable datasets will be conducted.

4.2.1 Challenges of VGI quality determination

VGI can support basic tasks like map production and updating (Moreri *et al.*, 2015), but the involvement of volunteers, who in most cases are untrained or non-experts in handling geographic information, implies that VGI can be of varying quality. In VGI initiatives, people can collect geographic information without any guidance or instructions, leading to inconsistencies in the data collected. These challenges are further increased by the lack of systematic and comprehensive VGI quality assurance measures integral to geospatial data collection (Haklay *et al.*, 2008). Thus, VGI is characterised by unstructured, heterogeneous, unreliable data which makes data integration for value-added purposes difficult to effect. These VGI quality challenges make land authorities reluctant to incorporate the contributed datasets into their official databases.

A TRM methodology is proposed to establish a ‘proxy’ quality and credibility measure of VGI without the typical reference to ground truth which characterises most quality assessments. TRM utilizes the ‘power of the crowd’ principle (Haklay *et al.*, 2010) to establish the level of trust of VGI and characterise the credibility of volunteers. The ‘power of the crowd’ principle has proved successful in non-spatial collaborative initiatives like Wikipedia and open source

software design. The rationale behind the principle is that inaccuracies in contributions are likely to be identified and corrected by many participants, thus reducing the errors. As this principle has not been explored extensively in VGI, this study has examined the potential of intrinsic measures of VGI quality based on TRM, and applied them to data handling in LAS, particularly where authoritative datasets for ground truthing are limited. Within the open source community, the assumption that as the number of contributors increases so does the quality, is known as 'Linus' Law' (Raymond, 2001). Haklay *et al.* (2010), have demonstrated that this rule applies when assessing the positional accuracy of spatial features in VGI. This study proposes the application of this rule in determining the attribute and positional accuracy of VGI using TRM for land administration. In the context of VGI and TRM, it is suggested here that there are four data quality indicators which can contribute to the quantification of trust and reputation: (a) thematic accuracy, (b) semantic accuracy, (c) credibility assessment and (d) geometric accuracy measures. These data quality measures and their methodologies will be elaborated further in Section 5.2.4.

Consensus-based decision making (Collins and Mitchell, 2017) is widely practised in rural areas of Africa for purposes such as land adjudication. When communities have a collective say, there exists a common sense of ownership and responsibility for stewardship. However, consensus-based decisions do have challenges: they can suffer from a lack of accountability from community members, especially if it is a large group without common goals, clearly implemented processes and active facilitators. A lack of clear decision-making processes can promote mistrust among community members. Moreover, community development can suffer, and disputes occur when a consensus cannot be reached. Desirable features for good governance as outlined by FAO (2007) include: a) enabling citizens to participate fully in governance through consensus-building and engaging them without curbing their freedom of expression, b) designing responsive systems that citizens want and need, and c) delivering quality services in the most effective and efficient way. Unfortunately, these features are currently lacking in LAS in developing countries.

4.3 Trust and reputation modelling in non-spatial and spatial initiatives

TRM has been used in the past as a quality matrix for websites and Web services (Adler and de Alfaro, 2007; Bishr and Kuhn, 2007; Javanmardi *et al.*, 2010). Several studies have been conducted in the past to confirm the practical effect that reputation has on Web-based activity,

especially in building trust between online communities, as in e-commerce (e.g. eBay, Amazon) and for open, online encyclopedia (Wikipedia) websites. An investigation of the successes and challenges of these initiatives was conducted to inform the establishment of quality and credibility measures of contributed datasets in the context of land administration.

4.3.1 Trust and reputation modelling in non-spatial initiatives

Prior to their introduction in geospatial initiatives, trust and reputation models have been key factors in the successful adoption and utilization of e-commerce websites (Sabater and Sierra, 2005). The models have developed 'proxy' quality and credibility measures of goods and sellers respectively, for example, using reputation to reflect the trustworthiness of individuals in online marketplaces (Zacharia *et al.*, 1999; Mui, 2002). Online e-commerce websites, like eBay and Amazon, use reputation as a function of the cumulative positive, neutral and negative ratings for sellers and buyers regarding their transaction history (Resnick *et al.*, 2000; Bajari and Hortacsu, 2003).

Bajari and Hortacsu (2003) confirmed the empirical effect that reputation has on the Web, especially in building trust between buyers and sellers. One ongoing problem with online reputation systems is that they do not guard against the creation of pseudonyms: they can be prone to abuse and malicious attacks by individuals using false names, who can be mischievous yet unaffected by reputational consequences. Further challenges include imbalances between positive and negative feedback when quantifying reputation, lack of context dependence, and impact of reciprocity (e.g. mutual exchange of favour or revenge). Despite such challenges, reputation systems have seen tremendous growth in establishing the credibility and reliability of online sellers and the products they sell (Sonja *et al.*, 2009), especially when initially 'setting up'.

In social websites, a rating system is used to allow users to express their level of agreement or disagreement with other user's contributions. There are many scales of measuring the quality of features in such rating systems, including unary scales, binary scales, and common five-star rating scales. Unary scales are popular in social networking sites, like Facebook, involving users clicking on a 'Like' button to show appreciation of content contributed by other users. The unary scale provides a single response value which may be insufficient in the context of contributed VGI content, where several parameters might be included. For geospatial content, such parameters can include its currency, geometric (positional), semantic (attribute) accuracy

and completeness. These parameters would influence the final subjective judgment and award of a rating value for the geospatial entity.

Binary scales are popular with social news and video websites like YouTube, where users can express their like or dislike of a video by clicking the 'Thumbs Up' and 'Thumbs Down' icons respectively. Such a system, like the unary system, is also not ideal for VGI because it has a limited depiction of agreement or disagreement with a contributed entity. A five-star rating scale is commonly used in recommender systems for commercial retailer stores like Amazon and eBay. It is used to highlight the trustworthiness of online buyers and sellers in the e-commerce websites. However, Cowan (2013) argues that the approach only allows products to be judged on their popularity and not on their details. Nonetheless, Babbie (2007) argues that a five-star rating scale, when used as a data reduction tool, allows a summary of several indicators into a single numerical value that could be assigned to an entity (including geographic entity) as its final quality value.

To address the challenge of a quantitative system offering a one-dimensional rating, a qualitative component has been introduced by eBay in the form of commentary feedback. This provides more information to a potential customer, who tries to distinguish between two sellers with similar quantitative scores. In addition, it helps justify the quantitative scores given to a seller to provide more weight to the scores awarded (Kwan and Ramachandran, 2009).

Wikipedia uses a content-driven reputation system where authors are evaluated based on how their contribution fares on the website (Adler and de Alfaro, 2007). For example, when author A contributes an article to Wikipedia and author B revises it, she may choose to preserve some of author A's contributions, thus providing a vote of confidence in the contributions. Therefore, the reputation of author A will be increased based on the number of preserved contributions, as well as on the reputation of author B herself (Adler and de Alfaro, 2007). Furthermore, the reputation of an individual in Wikipedia increases if their contributions and edits are persistent. However, if their content is revised quickly, this could affect their reputation negatively. Such approaches compute assessments of data quality based on data provenance (data origin), which is eventually combined with user feedback (Artz and Gil, 2007). Wikipedia entries are associated with an Internet Protocol (IP) address and a user account. This removes the anonymity element and facilitates the tracking of all edits and contributions made to the platform. In addition, it helps users to search for trusted content, by using IP addresses, especially of known organizations, to make better-informed decisions.

TRM has played a major role in the growth of non-spatial initiatives, building trust between buyers and sellers in e-commerce websites. Moreover, TRM has been used to encourage honest online transactions by penalizing dishonest behaviour through loss of reputation. Despite challenges of abuse, malicious attacks, and dishonesty, these initiatives continue to evolve, by developing security mechanisms to curb against attacks. Such experiences could be applied to VGI initiatives which currently do not have established standard measures of assessing quality.

4.3.2 Trust and reputation modelling in spatial initiatives

In the spatial community, the concept of TRM has been applied to collaborative initiatives incorporating VGI approaches. Haklay *et al's* (2010) testing of Linus' Law to analyse data provenance in OSM data adopted the 'many eyes' principle. The analysis was mainly on the rollbacks and history of edits of contributed datasets which were then used to determine the quality and currency of the datasets, thus informing their FFP and reuse capabilities. In the context of spatial data systems, the FFP concept is not necessarily standards-based, like traditional mapping projects, but rather it is concerned with more pragmatic approaches by end users (Enemark *et al.*, 2014). For commercial and official geographic information, associated metadata and quality metrics are commonly presented to assist in determining FFP: but for datasets where such enhancements are unavailable, including VGI, trust and reputation models have been proposed as 'proxies' for data quality (Bishr and Kuhn, 2007; Kessler and de Groot, 2013).

Traditional data quality measures are generally lacking in VGI environments (Haklay *et al.*, 2010; Heipke, 2010; Osterman and Spinsanti, 2011) because there is no reference data especially in developing countries. Moreover, the dynamic nature of VGI renders traditional approaches inappropriate to establish the quality of VGI. This has motivated some in the geographic community to investigate alternative measures for assessing the quality of contributed datasets and the credibility of contributors in VGI environments. These community based collaborative models use trust matrices to assess the quality of contributed datasets in VGI platforms. For example, they involve volunteers contributing geographic information and their peers given the opportunity to subjectively judge and rate the quality of the contributed contents. Components which can be used to measure VGI quality include: a) attributes and semantic rigour (including folksonomies), b) positional accuracy, and c) volunteer reputation.

Related to each of these components, trust can be used as a measure of quality in a collaborative environment like VGI, adopted as a 'proxy' measure of geospatial information quality (Bishr

and Kuhn, 2007). A trust model developed by Bishr and Kuhn (2007) classified and filtered collaboratively contributed geographic information, relying on 'folksonomies' as a means of collecting metadata about user-generated content: a folksonomy is a collaboratively generated classification system, like an ontology, that enables users to categorize attributes they contribute or encounter on the Web (Golder and Huberman, 2006). Trust here is measured subjectively, where a trust-rated entity is considered of 'satisfactory' quality if it is regarded as useful and relevant to a larger group of consumers.

Assessing quality by positional accuracy of VGI has attracted more interest from the geographic information research community (Haklay *et al.*, 2010; Mooney *et al.*, 2010; Fairbairn and Al-Bakri, 2013). These studies have mainly compared contributed data with datasets in official databases. However, this approach suffers major drawbacks (D'Antonio *et al.*, 2014), since it requires access to professional datasets, often expensive and/or unavailable. Moreover, the quality assessment procedures developed are not universally valid, especially in those areas where ground truth datasets are inaccessible. To address these issues, D'Antonio *et al.* (2014) proposed a model that evaluates a volunteer's reputation and data trustworthiness deriving information from VGI data itself, rather than comparing it with external sources. The model developed identifies basic editing types where feature versions are evaluated against three characteristics: semantic attributes, geometric properties and qualitative spatial relations (e.g. disjoint, overlap, contains, cover). Using these characteristics, they concluded that data trustworthiness and reputation are a function of their direct and indirect editing effects over a period of time. That is, the more edits are performed on a contributed entity over a period of time, then more errors can be identified and corrected to improve its quality.

VGI is authored by heterogeneous sources and therefore there is a need to establish mechanisms to assess the credibility of contributors. Certain characteristics of a contributor can be used as 'proxy' measures of reliability and inherent quality of the datasets they produce (Flanagin and Metzger, 2008; Golbeck, 2008). The reputation of a volunteer can be based on several personal aspects that involve their qualifications, experience in handling spatial data, activity space (Goodchild, 2009), and their motivations to contribute to a VGI initiative (Flanagin and Metzger, 2008). It is argued that a contributor in geographic proximity to a source can produce more current local information compared to those further away from it (Goodchild, 2009).

Van Exel *et al.* (2010) suggest the use of three components for determining volunteer reputation: local knowledge, experience, and recognition: a) local knowledge helps consumers

identify missing or incorrect contributions relatively easily, b) the experience of a volunteer in contributing to a project is correlated to their overall interaction with the system over time and the quality of their contributions and c) recognition entails the awareness given to contributors by other consumers when a certain threshold is met.

For LAS, TRM could be used to build trust and confidence between residents as contributors of land information and officials from the land authority. Just like in non-spatial activities, it could be used to encourage honest transactions by penalizing dishonest behaviour through loss of reputation. Insights from spatial activities indicate that TRM in LAS could be used as 'proxies' for data quality and reliability determination of contributed datasets. For example, trust matrices can be used to assess the quality of the land information contributed by the public. A major limitation about the outlined benefits of VGI to LAS is that there are no established data quality and credibility measures of contributed datasets using TRM, particularly when ground truthing is non-existent. Moreover, VGI generally suffers from a lack of metadata about contributed datasets which could be used for quality assurance measures. As a result, potential reusers of the datasets may be sceptical to utilize them in official systems to update their land records.

Whether spatial or non-spatial, TRM systems are clearly embedded in the commercial arena, implicitly used in transactions and online data handling can be applied to a range of data, and have potential in volunteer data handling projects: despite this, they do have shortcomings that need to be highlighted particularly in a VGI context.

4.3.3 Challenges of trust and reputation systems

Reliable trust and reputation models have the potential to increase cooperation between contributors and consumers and thus improve the usability and overall performance of online applications (Mozhgan, 2012). Such models are built around feedback and human interaction, but before they can be accepted as a legitimate trust solution, it is necessary to understand how they may be compromised and how subsequent problems can be addressed. Challenges that weaken TRM when assessing the quality of online entities and the credibility of participants can be grouped into four categories: a) feedback generation, b) feedback distribution, c) feedback aggregation, and d) subjective feedback (Josang and Golbeck, 2009; Mozhgan, 2012).

Feedback generation involves users/consumers providing feedback to describe or rate their experiences in dealing with a system or entity. Online systems have developed rating systems

to collect participant feedback, but these can be abused or ignored due to: a) the inability of the system to provide incentives to motivate participants to provide feedback, b) bias by participants to provide positive feedback because of friendly actions, and c) cold start problems experienced by new volunteers. The latter occurs when new volunteers find it difficult to raise their reputation score due to the reluctance of other individuals to deal with low reputation volunteers. eBay and Amazon are examples of organizations that use a feedback generation system to provide quality and credibility measures of products and sellers respectively. Other challenges of feedback generation include the creation of pseudonyms, where participants create multiple profiles to initiate problematic behaviour like posting misleading information.

Feedback distribution involves collected feedback not being distributed comprehensively or appropriately to represent the entity being rated. For example, formerly, the reputation system of an eBay seller was based on a single measure which failed to distinguish whether the score provided by a buyer was awarded for the quality of products sold or the efficiency of the seller in delivering products on time.

Feedback aggregation occurs when the collected trust value of a participant is not representative of their past actions. For example, on eBay, a seller with 20 successful sales and 5 unsuccessful ones will have an equal rating with a seller with only 15 successful sales and no unsuccessful ones. This is a challenge which occurs because of inaccurate algorithms, like the value imbalance equation which weighs all feedback equally regardless of transaction value (Tavakolifard and Almeroth, 2012). According to Dellarocas (2002), a participant can take advantage of this property to build a good reputation by executing small value trades and use the reputation accumulated to cheat in a high-value transaction.

The fourth challenge is **subjective feedback** which is usually based on the personal taste and cultural background of a participant (Bishr and Mantelas, 2008). What is viewed as good by one person may be viewed as bad by another.

The challenges highlight the subjective nature of feedback and how online networks can be compromised. They can limit the effectiveness of these networks preventing their use and consideration in official systems. The challenges most important for VGI to LAS are feedback generation and feedback aggregation. Since VGI involves participatory activities, it is important to establish mechanisms to encourage volunteers to provide feedback about products contributed by their peers. Such feedback could later be beneficial in determining the quality and credibility of contributed datasets using TRM. VGI quality can be inferred from the trust

value based on the history of a participant's contribution. Therefore, accurate algorithms should be used to aggregate feedback based on transaction value for an accurate computation of reputation. Despite the weaker security guarantees served by TRM systems, they have been applied successfully in many peer-to-peer online systems to establish trust between consumers and sellers. To expand the scope of traditional security models, trust-based systems have emerged as solutions for citizens to accept risks and deal with uncertainty.

4.3.4 Considerations for Integrating VGI with official systems

Section 3.2.6 stresses that for a LAS to be FFP, implementers should build appropriate systems that focus on purpose, are flexible, can be incrementally improved, and developed within a short period of time, at an affordable cost. A parallel participatory application to that of the official system should be designed such that it mimics official database schemas to enable a seamless data integration at a later stage. According to Siriba and Dalyot (2017), such a design consideration makes the formalization process quicker, inexpensive and effective. Additionally, it allows concurrent data verifications of VGI against official datasets by authorities, thus requires minimum alignment in terms of schema transactions for data integration.

The sustainability of the participatory initiative depends on the buy-in of officials and citizens. Its success depends on the regular update, review and modification of land records and reporting of incidents as they occur within the local community by citizens. Developing countries should have a legal stance regarding the recognition and acceptance of external data in their official LAS. They should have legal documentation and specifications on how organisations can manage uncertainties and liabilities likely to be brought by external data. The formalization of VGI should focus on the value-added capabilities it can have on official systems and this could further be identified and the extent to which they could improve them outlined. Furthermore, innovative methodologies like TRM should be applied for quality assurance measures to demonstrate that VGI can be trusted for land administration purposes particularly in rural areas characterized by ineffective LAS. These can improve the trust and confidence of authorities towards datasets produced from the VGI application. The considerations outlined can position VGI to contribute to a better land administration by overcoming the lack of systematic cadastral coverage, currency, consistency and content in official LAS. In addition, they could address the inadequacy of services from official systems, thus improve community awareness, engagement and participation in land related matters.

4.3.5 Sample number considerations in establishing VGI quality

This study advances the 'wisdom of the crowd' principle (Raymond, 2001), to establish the 'proxy' quality of VGI and credibility of its creators, those engaged in collaborative knowledge building processes. No agreement has yet been reached on the sufficient number of participants needed to establish VGI quality, to have a representative sample of the data items collected, to achieve acceptable results, and to gauge participants' reliability. Furthermore, the number of samples required also depends on the entity being collected. For example, different numbers of samples are required to assess the quality of image classifications, vector drawings, or an observation of an animal. Successful collaborative mapping projects like OSM embody the collective intelligence philosophy to assemble user contributions into a 'patchwork' map (Spielman, 2014). Through established review processes, OSM aggregates participants' contributions into a single map for use by the spatial community at large. The trust and reputation concept as used in text-based initiatives, which relies on the number of contributors and volume of feedback to enforce quality is advanced here as the central tenet of a system to establish the overall quality of VGI. The basis of TRM is that the more participants engage in the initiative the better, as more bugs can easily be identified and fixed. Spielman (2014) confirmed that the more users and contributors a geospatial community has, the more likely it is to produce better quality products.

Mooney *et al.* (2010) stress that rural areas, unlike big cities which lend themselves to easy data gathering, require rigorous sampling by the inevitably smaller groups of volunteers to achieve representative and reliable spatial data for OSM. Foody *et al.* (2015) comment on the difficulty of identifying and favouring one contribution against the majority view provided by other contributors: an accurate label provided by one volunteer out of a million can be lost within the much larger sea of alternative categorization, as consensus-based initiatives always follow majority dominant views. There is a possibility that increasing the number of contributors may degrade rather than enhance the quality of contributed datasets: some studies (Snow *et al.*, 2008; Haklay *et al.*, 2010; Foody *et al.*, 2013) suggest there is a natural limit to the number of valid cases to reach the 'truth'. Foody *et al's* (2013) multiple, 'crowdsourced' investigation of the impact of sample size on attribute accuracy of VGI in land cover mapping engaged 65 volunteers on a classification activity of African forests. Only seven volunteers successfully classified at least 90% of the 299 cases requested: the other 58 volunteers were disregarded. Validation involved ground truthing of the VGI classification by three experts who determined that, as 'satisfactory' results were obtained, the small number of seven independent volunteers

was adequate for establishing the quality of VGI in a land cover mapping activity. Snow *et al.* (2008) confirmed that high accuracies can be achieved from a small number of contributors in a crowdsourcing activity. The statements above suggest that, even if many contributors can participate in the initiative, there is a probability that a high percentage of contributions is from a small number of volunteers. Therefore, their contributions should be regarded as sufficient for establishing VGI quality and credibility.

Haklay *et al.* (2010)emphasize that there are no observable correlations between the number of contributors and VGI quality (here, attribute accuracy), once they exceed 13. However, Goodchild and Li (2012), argue that Linus' Law is not as effective for geographic facts as it is for text-based projects such as Wikipedia. They argue that using many people alone is not sufficient to characterise trends in geospatial data error.

Positional accuracy can also be determined using the 'many eyes' principle: Haklay *et al.* (2010), consider that the presence of information from more people can actually lead to clutter, suggesting that the first five contributions made to a feature have the most influence (producing statistically significant positional accuracy correctness). Similarly, (Basiouka, 2010) concluded that there was no clear pattern of improved positional accuracy when the number of contributors increased above five when creating dynamic maps for navigational activities in OSM. The results obtained from her study were deemed 'sufficient' for assessing the positional accuracy of geospatial data. Spielman (2014) summarizes by arguing that collectively generated mapping from several participants, whilst not necessarily accurate, can produce credible maps that are beneficial to many users on an FFP basis.

Other factors to consider in addition to the number of contributors include: a) gender, b) age, c) highest education attained, d) land parcel ownership, and e) a number of years residing in the study area. Gender classifications and categorizations can help identify similarities, differences, patterns if any, in the way gender contributes or inspects geospatial datasets. The age of a participant often determines their knowledge and experience in a data collection activity (Phinney, 1992). Therefore, it is anticipated that contributors of different ages and genders can bring insightful information into the study in terms of identifying demographics from the information contributed. Demographic information enables cross-tabulation and comparison of subgroup results to examine variations between the groups (Phinney, 1992).

A person who has worked with maps before, or uses the Internet on a regular basis, especially mapping applications is likely to have confidence in engaging with Web map applications than

those unfamiliar with them. Therefore, collecting occupation information can help establish the reputation of the contributor. It can further help measure how well participants correctly identify familiar land parcels or interact with the Web map application to produce reliable datasets. The level of education that participants have attained can be used to measure their skills and competencies in confidently interacting with a VGI application to correctly or incorrectly identify and classify land information in it. According to (Smith, 1995) a participant with a Bachelor's degree, views things differently to one with a secondary or no schooling at all. Therefore, a participant with higher education can be expected to correctly classify a higher percentage of land parcels compared to the one with a little or no schooling at all. Education levels can be depicted with the following categories: a) Secondary school, b) Technical school, c) Tertiary certificate, d) Diploma, e) Bachelor's degree, f) Master's degree, g) Professional degree, h) Doctoral degree, i) No schooling completed.

In terms of land ownership, participants who own land parcels in the study area conduct land related activities on a regular basis. For example, they visit Land Boards regularly to pay for service levies, lease rentals and renewal of trading licenses (for those with commercial entities). As a result, their view of land related activities is different from those residing in the area as tenants or those who do not own land at all, which can have an impact in the overall quality and credibility of their contributions. Goodchild (2009), argues that activity space is a very important denominator in determining the familiarity of individuals with the broad topographic structure of the local area. An individual who has stayed longer periods in an area has comprehensive knowledge of the area compared to one with short term residency. Therefore, participants who have resided in the study area for longer periods of time can be expected to produce reliable land information because of their familiarity with that place

This section conducted a scrutiny of TRM measures in non-spatial and spatial initiatives to understand their applicability in the respective platforms, which provided an understanding of how it could be implemented in VGI environments. TRM has been a major growth factor for non-spatial initiatives in building trust between buyers and sellers in e-commerce websites. It has been used to encourage honest behaviour between consumers by penalizing dishonest behaviour through loss of reputation. TRM methodology works on the premise that as multiple participants work in the same geographic area, often capturing the same data, there are opportunities for errors made by others to be identified and fixed, consequently, improving the quality of the contributed datasets without the need for formal quality assurance measures.

Even though trust and reputation systems have the potential to increase cooperation between contributors, they do have shortcomings that revolve around feedback. An understanding of how these systems can be compromised is necessary to enable consumers to consider the risks and uncertainties involved and how they can be addressed. The 'wisdom of the crowd' principle (Raymond, 2001) is advanced in this study to establish 'proxy' quality of VGI and credibility of its creators. Successful collaborative mapping projects have used this philosophy to assemble user contributions and use them to determine the quality of their contributions. It is anticipated that it can further be employed in TRM such that trust and confidence can be placed on collaboratively contributed content.

4.4 Summary

This chapter has successfully managed to identify key parameters necessary for implementing an FFP LAS based on VGI. These parameters are mostly concerned with investigating policies and regulatory frameworks of the study area, engaging key stakeholders and developing enabling systems that can facilitate the collection, assessment and storage of geospatial data for consideration in official systems. Even though the FFP concept states that accuracy relates to the purpose, and not concerned with traditional quality measures, this study argues that it is necessary to develop parameters that potential consumers and officials can use to establish trust and confidence about utilizing the contributed datasets.

The dynamic nature of VGI renders traditional approaches inappropriate to establish the quality of VGI. To address these challenges, alternative collaborative models based on trust matrices have been proposed by the geographic community to assess VGI quality. These models involve volunteers contributing geographic information and their peers given the opportunity to subjectively judge and rate the quality of the contributed datasets. In these initiatives, trust is measured subjectively, where a trust-rated entity is considered of 'satisfactory' quality if it is regarded as useful and relevant by many consumers. The geographic community has further concluded that the reliability and inherent quality of contributed datasets can be implied from a volunteer's reputation based on their local knowledge, experience and recognition. The issues of building the FFP LAS based on VGI, revolve around the data collection activities conducted in the study area to be elaborated in the following chapter. Moreover, the chapter presents a case study for implementing the FFP system to improve current land administration processes at the Land Board.

Chapter 5. Case Study – Methodology for fit for purpose land administration system in Botswana

This chapter presents a methodology for implementing the FFP LAS based on VGI for Botswana using parameters outlined in Section 4.1. Initially, it outlines work carried out in the study area to investigate and collect information from key stakeholders about current processes of administering customary land and the significance of the applications developed to facilitate the activity. The information gathered from the data collection study further informed the development of the methodology presented here. Within the methodology, emphasis will be placed on a robust and novel approach to establish the quality of VGI and credibility of volunteers such that the contributed datasets may be considered in official LAS on a FFP basis.

A participatory land information system can provide affordable and timely FFP information about land and its resources (Bennett and Alemie, 2015). However, the establishment of such a system involves more than just technical solutions and administrative procedures: many social, economic and political aspects must be considered. Innovative approaches like VGI can help address the lack of accurate, reliable and FFP land information for LAS, but the integration of such sources relies on the quality and credibility of VGI. Verifying volunteer efforts can be difficult without reference to ground truth: a novel Trust and Reputation Modelling (TRM) methodology is proposed as a suitable technique to effect such VGI dataset validation. It relies on the view that the public can police themselves in establishing proxy measures of VGI quality thus facilitating the contributed datasets to be used on an FFP basis in LAS.

TRM can help people make informed decisions and judgements about the quality, reliability and relevance of information produced by other volunteers without reference to ground truth. It uses the 'wisdom of the crowd' principle and assumes that there are hidden objective truths which can be appropriated from many contributors and their consensus agreements. In this case, the introduction of TRM was motivated by a general lack of access to official datasets in LAS in developing countries and the lack of standard accuracy measures of VGI in land administration.

5.1 Data collection about land administration in the study area

The study area for this research is a village called Mochudi, located about 40 km north of the capital city of Botswana, Gaborone (Figure 5-1). It is one of the nation's larger villages of the

country with a population of 44,815 in 2011. Despite the abundance of land in Botswana, intense land scarcity is common in peri-urban areas like Mochudi where people and development are attracted by the perception of jobs and other economic prospects. These areas have suffered many years of planning neglect, which has led to poor LAS, characterised by lack of proper documentation of legitimate land rights and insecurity of tenure for residents, both urban dwellers and agrarian citizens. Mochudi was selected as a case study to demonstrate the potential application areas of VGI to address the LAS challenges prevalent in such a developing area and improve the security of tenure of residents through participatory means.

The village has a mixture of both traditional and modern land development patterns and variable land uses which include: residential, civic and community, commercial, industrial, and agriculture (commercial and subsistence farming) categories. The key stakeholders in this study are the national mapping agency - DSM, District Land Boards, local community leaders, and members of the public. DSM is the main geospatial data source for Land Boards, which are the administrators of customary land. Volunteers were engaged to represent a sample of the local community.

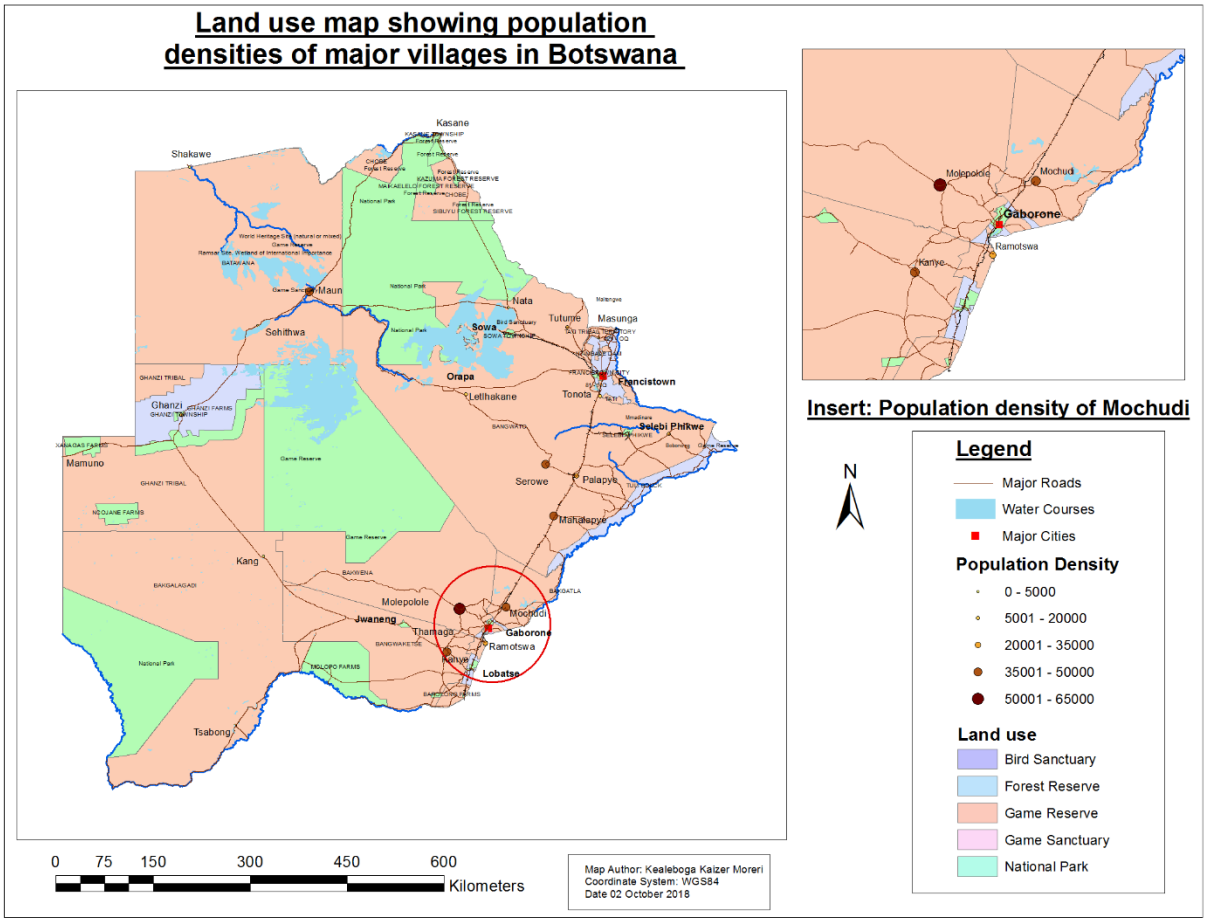


Figure 5-1. Land use map showing population densities of major villages in Botswana

The success of a VGI initiative depends on the ability to document the relationship that local communities have with the land and the ability to analyse the contributed land information for more informed decision making (Navratil and Frank, 2013). VGI can be a valuable geospatial data production initiative, provided that thorough investigations of efficient and effective data collection techniques are conducted (Rice *et al.*, 2014). The data collection activity was an iterative process conducted in three phases (Figure 5-2): a) phase 1 – preliminary data collection, b) phase 2 – development and testing of a VGI application which comprises of a Web map application and a rating system, and c) phase 3 – implementation of the VGI application in the study area. A total of 166 participants were engaged in the data collection activity over the three phases: phase 1 engaged 30 participants, whilst phase 2 engaged 31 participants, lastly, the implementation stage, phase 3 engaged 105 participants. Of the 166 participants, 122 were members of the public from the study area, while the 44 experts engaged were chosen from different institutions within the study area. Experts included land surveyors, land use and estate management officers, land adjudication offers, legal experts, IT personnel,

and records officers. To avoid contributor bias and influence on the results, each participant was engaged once in the study.

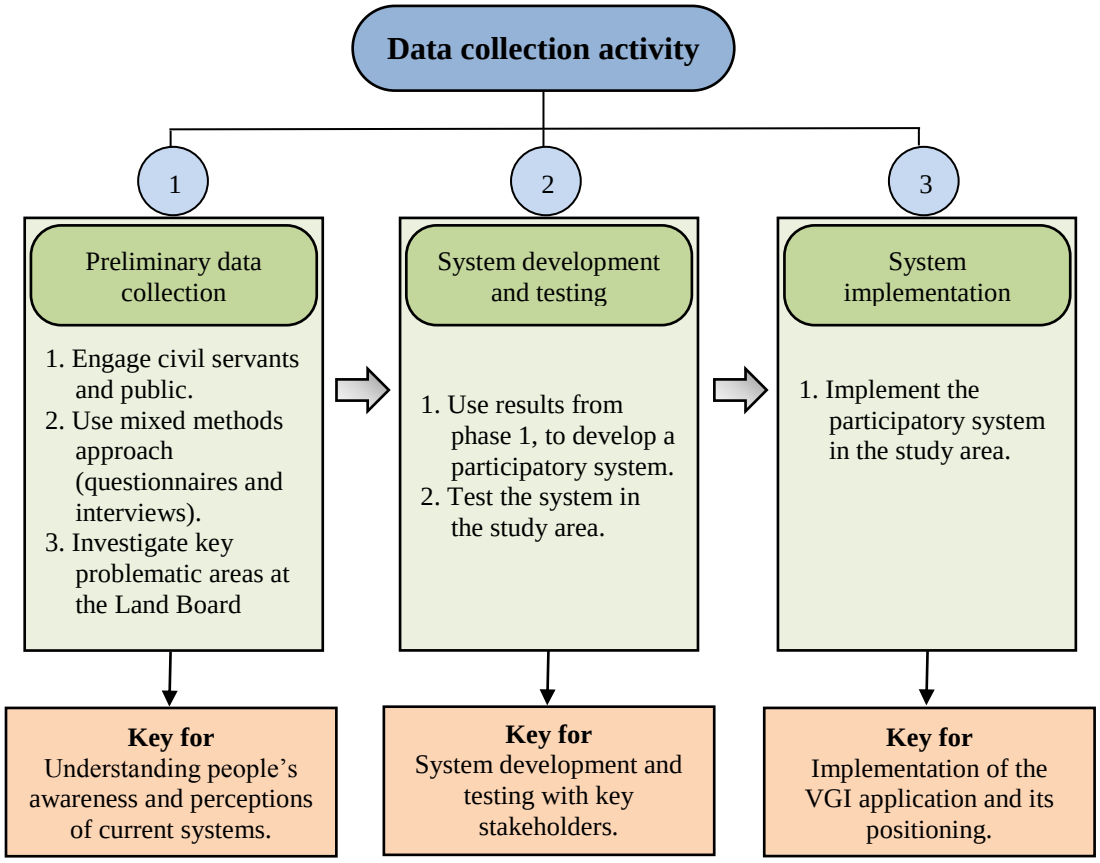


Figure 5-2. The data collection activity in the study area.

5.1.1 Phase 1 – preliminary data collection

To understand people's perceptions and the current LAS in the study area, a preliminary data collection activity was conducted in Botswana for a ten-day period during the spring of the southern hemisphere, in 2014. The objective of the study was to highlight the challenges and successes of existing LAS and to investigate how a participatory initiative like VGI could be positioned such that it adds value to them. Moreover, the concept of public participation in a Web mapping environment regarding land administration was introduced to gather people's attitudes and awareness of it. A mixed methods research methodology using questionnaires and structured interviews was conducted on civil servants involved in land administration and the public with interests in land related activities. The approach facilitated the collection of information from different angles to provide more evidence, validity and a better understanding of the research problem (Johnson and Onwuegbuzie, 2007; Freshwater, 2013). In addition, it provided strengths that offset the weaknesses of both approaches. The preliminary data

collection approach further included a comprehensive review and examination of problematic land transactions at the Land Board to provide justification for incorporating a participatory approach to improve them.

Preliminary data collection approach

The preliminary data collection activity involved the following processes:

1. Engagement of 30 participants, half being professionals in land administration (land surveyors, IT personnel, land officers and records managers) and the half typical stakeholders from the public (landowners, aspiring landowners, tenants, and other community members),
2. Issuance of questionnaires to participants from the civil service at Land Boards premises over a three day period with follow-up interviews conducted on the fourth day,
3. Issuance of questionnaires to the public at their place of residence over a two day period with follow-up interviews conducted on the third day,
4. Independent analysis of data collected from the two groups (authorities and public) using a mixed methods approach (Section 6.1),
5. Interpretation and publication of results obtained from the data analysis process (Section 6.1),
6. Investigating key problematic areas at the Land Board to provide justification for the VGI approach.

A total of 30 participants were engaged in this activity. According to Baker and Edwards (2012), this number provides an opportunity for a researcher to penetrate beyond a very small number of people without imposing hardships of data collection and in consideration of time constraints that researchers have. Furthermore, Mason (2010) in his review of PhD studies using qualitative research, cited that the mean sample size of the studies was 31: Of the 560 PhD studies investigated, 80% of the reports had a minimum of 15 participants for a qualitative study, irrespective of the methodologies used. For this activity, 15 participants were engaged from the civil service and 15 from the public. The target audience in the civil service included land officers, records managers, Information Technology (IT) personnel, land surveyors and other personnel involved in land administration. Participants from the public comprised of landowners, aspiring landowners, tenants and other residents of the local community. The anticipation was that the two distinct groups (civil service and public) could provide valuable

insights and findings from different perspectives, thus eliminating the likelihood of bias, probable if a single group was selected.

Participants from the civil service were consulted during working hours at the Land Board. They were given a questionnaire to answer in three days and on the fourth day, a follow-up interview conducted on each participant individually. The questionnaires acted as an initial base for discussion, while the interviews probed for more understanding. For the public, participants were only given two days to respond to the questionnaires at their respective homes, and interviews conducted afterwards. Participants were systematically selected from the local area with the help of a community leader and emphasis was placed on participants knowledgeable about the area, its land related activities, and those likely to answer the survey questions at ease. Furthermore, to broaden the range of perspectives, participants were not only chosen from one jurisdiction, rather, they were consciously varied from different jurisdictions.

To get the most from respondents, the interviewing and style of questions in questionnaires were varied, starting with more general conversational questions and gradually introducing probing specific questions. Starting with non-directive questions early in an interview can establish rapport with the respondent and provide insights into what is important to them before introducing sensitive issues (Salmons, 2014). Sample questions asked in the preliminary data collection stage include:

Questions to the public:

1. How do you currently interact with the land Board? In terms of the procedure to be followed when requesting for service. E.g. when applying for land, requesting services like transfer, extension etc.
2. What are your main concerns regarding the current state of land administration in the country?
3. What do you think the land board should do to better serve its clients? Services like timely responses to clients' queries and applications.

Questions to experts:

1. What mapping activities exist in Land Boards?

2. How does the Land Board ensure that landowners update their land records when significant activities like a change of ownership, a change of land use, and subdivision take place?
3. What percentage of land records in Mochudi would you say are up-to-date in terms of mapping?

Other considerations in designing the questionnaires to elicit information which could be tabulated and discussed include:

1. Writing an introductory statement that includes the questionnaire's purpose, an explanation of how the information obtained will be used, and a confidentiality assurance of all respondents,
2. The use of simple English language to ask questions that relate to the objectives of the study,
3. Avoidance of bias in questions by making them simple, clear, specific, less time consuming and devoid of jargon: this procedure reduces the unnecessary burden of interpretation on the interviewees,
4. Obtaining information about what people do, what they think, know, feel or want, by varying questions between knowledge, opinions, behaviours, and attributes,
5. Arranging of questions to 'flow' naturally, by grouping those about one subject together, and starting with general issues and then moving to those that are specific,
6. Using a mixture of both open-ended and close-ended questions to produce a variety of answers and responses: open-ended questions allow participants to respond in their own terms, which increases chances of obtaining truthful and insightful information (Adams and Cox, 2008; Mason, 2010),
7. Presenting questions for both target groups in the same order, so that responses could easily be aggregated and correlated with confidence.

Outline of the ethics approval procedure

In terms of ethics approval, the project was considered low risk by Newcastle University since it satisfies the University's ethical expectations and has been subjected to the appropriate level of ethical review. The ethical approval process helped shape approaches to key issues such as data protection, guarantees of confidentiality and anonymity in the following ways:

1. Sample data obtained from the Land Board was anonymised using pseudocodes for security reasons,
2. The researcher was honest and ethical with respect to conducting research work that included experimental design, generating and analysing data collected from the case study,
3. Plagiarism, deception, or fabrication of results were avoided by all means and credit given, where due, through proper citation and referencing,
4. In terms of data regulation, the researcher complied with the standards of research practice and legal requirements of the Department of Surveys and Mapping, and Land Boards in Botswana, which regulate land information in the study area,
5. To demonstrate proper research practice, clear and accurate records of all procedures were followed during the research process, including preliminary results and the final outcomes,
6. To demonstrate that the information obtained was accurate, authentic and verifiable, research records were retained and properly managed,
7. To ensure that participants contribute with ease and provide truthful responses, guarantees of confidentiality and anonymity were written in the cover letters of the questionnaires.

To obtain a verbal 'informed consent', the researcher conducted the following activities:

1. A verbal explanation of the study was given to potential participants which provided all relevant information, such as purpose, procedures, risks, potential benefits, and alternatives to participation: additionally, potential participants were given opportunities to ask questions,
2. The potential participant was provided with a written summary of the activity and given sufficient time to decide whether to participate in the research or not: sufficient time in this instance refers to five minutes which provided ample time for potential participants to evaluate the procedures, risks and potential benefits of the study,
3. After allowing the potential participant time to read the study information sheet, any additional questions raised were answered by the researcher for clarity prior to receiving the verbal agreement to participate in the research.

Gatekeepers, such as headmen (tribal and community leaders), provided an important communication link between the researcher and residents: they ensured that the latter

acknowledged the significance of the study; assured them that their participation was voluntary; and that they could withdraw from it at any time or choose not to participate at all.

Challenges encountered during the preliminary data collection stage

Some of the challenges encountered while collecting data include: a) the inability of civil servants to complete questionnaires within the agreed timeframe, b) failure by civil servants to honour scheduled meetings, and c) unwillingness of some members of the public to participate in the study citing a lack of interest since the current system did not serve their needs. Even though participants in the civil service were given three days to complete the questionnaires, there were instances where respondents did not observe this timeframe. As a result, several meetings were rescheduled to other timeframes suitable for the participants. Other instances involved the failure of participants to honour scheduled meetings and not communicating well on time. Such experiences were inconveniences logistically to the already planned schedule of the researcher.

The unwillingness of some members of the public to participate in the data collection activity means that there is a possibility that some crucial information may be missed, thus creating inconsistencies in the results obtained. Moreover, this could provide results that are not representative of the whole community, if some entire demographic group (e.g. village elders, youth, plot owners, or tenants) did not agree to participate in the data collection activity. Nonetheless, the tasks were completed successfully within the stipulated timeframe.

Investigation of key problematic processes at the Land Board

A review of land policies and regulations in the study area has revealed that external data is recognized in rural areas to support and improve contents and land administration processes in official systems (Republic of Botswana, 2015). Therefore, scrutiny of key land transactions at the Land Board was conducted to identify problematic areas in terms of delays in providing services to customers and how VGI could be positioned to address these challenges. Table 5-1 shows current Land Board procedures and timelines for common land transactions performed in the study area, which include: a) land transfers, b) lease registrations, c) change of land use, and d) water borehole applications.

Table 5-1. Common Land Board transactions and timelines.

Activity	Timeline
Land transfers	1 month
Lease registration	2 months
Change of land use	2 months
Allocation of a water borehole	3 months

Customary law prohibits the **transfer of land** to other citizens without habitable developments. Therefore, land transfer processes require technical officers to conduct site visits in the presence of plot owners to physically inspect and check for developments therein. A transfer request of an undeveloped plot is usually rejected and clients advised accordingly. **Lease registrations** require a locality sketch plan, which technical officers must produce by visiting the site, and surveying the plot in question and its neighbouring plots using a handheld GPS unit.

Change of land use requests require site visits by land use officers to verify if the use requested is in conformance to the zoning of the area of interest. For example, an industrially zoned area cannot be changed to commercial or residential or vice versa. For conservation purposes, **water borehole** locations are determined by a buffer distance of 5km: a borehole application cannot be approved if the location applied for, has a buffer distance that is less than 5km from existing nearby boreholes. This requires technical officers to visit the site and collect coordinates of the area applied for, with computations conducted at the Land Board offices.

Manual files of these key transactions were scrutinized for client requests received in a period of six months (January – June 2016). The scrutiny was based on the number of requests received, the time taken to complete the requests, and the names and designations of responsible officers for accountability and tracking purposes. Emphasis was placed on the timelines achieved for each activity and these were compared to those in Table 5-1, to identify and document delays at each stage. The number of files investigated and the average amount of time to process and complete the transactions are presented in Table 5-2.

Table 5-2. Land Board procedures and average delays to complete customer requests.

Activity	Timeline	Number of files in 6 months	Average duration to complete task and delay cause
Land transfers	1 month	118	83% (98) of records exceeded the 1-month period: delays caused by compliance checks and technical officers to prepare locality sketch plans.
Lease registration	2 months	105	75% (79) of records had site visits to survey parcel boundaries done more than 3 months after of customer application date.
Change of land use	2 months	75	69% (52) of records were completed beyond the allocated timeline, because of delays from the technical team to provide sketch plans.
Allocation of borehole	3 months	50	66% (33) of records have been rejected because of non-compliance to allowable distance buffer limits from other neighbouring boreholes (5km buffer).

Scrutinizing problematic areas has provided important insights that can help officials understand specific areas within their administrative processes where VGI can be applied to improve them, and these will be discussed in Section 7.5.

5.1.2 The significance of the preliminary data collection study

The preliminary data collection study has provided information on how a participatory initiative like VGI can be designed in terms of functionalities, security, capabilities and positioning such that it is relevant to both the public and official systems. This information was used to guide the development of a Web-based VGI application for the public to add land information of importance to them and to subjectively rate and comment on the accuracy and reliability of contributions made by their peers. For example, the public suggested functionalities and services they would like to have in the Web map application. To develop a system that best meets the needs of potential users, these suggestions were taken into consideration and incorporated into the Web map application design. The public further suggested that the application should be positioned such that it can support existing LAS and allow them to update land records and initiate land transactions at their convenience. Therefore, further system design parameters included adopting the database schemas of official systems to ease data integration at a later stage and enabling functionalities to facilitate online records updating and system request processes.

Concerns raised by the civil service about modifying existing systems include security issues, possible fears of system abuse, storage, data management, data quality assessment and assurance measures. These were all taken into consideration during system design. For example, proper and functioning user authentication systems were employed in the Web map application to protect and secure confidential land information. Moreover, authentication systems can help curb system abuse and fraudulent activities. Geospatial datasets, particularly orthophotos, require large storage facilities. As a result, adequate system storage that allows efficient retrieval, manipulation and dissemination of geospatial datasets contributed by the public was provided as outlined in Section 5.1.2.

The TRM methodology proposed in this study addresses the concern of data quality assessment and assurance measures advanced by civil servants. Developing countries are characterised by a lack of ground truth to establish the accuracy and reliability of contributed datasets, thus TRM can build trust and confidence of potential consumers to utilize the datasets (Bishr and Mantelas, 2008; Ali *et al.*, 2014)An in-depth explanation of how the participatory system was designed will be presented in Section 5.1.2. Overall, the explanatory design strategy of the mixed methods approach provided a better understanding of the research problem that could not be achieved with either approach alone. For example, questionnaires were used to address the research problem and to record participants' views about existing challenges in LAS, and suggestions on potential remedial factors. Structured interviews were then used to further explore information collected from the first data collection phase: key findings, outliers, and extreme cases from questionnaire responses were noted and pertinent questions created for the interview phase. The interviews in the preliminary stage were converted into numerical codes to be statistically analysed. Each sentence or phrase was assigned to a certain category. Additionally, text from each category was aggregated to allow a count of responses to create frequencies for better interpretation. The downfall of the coding technique is that it can result in the loss of depth of information from respondents (Light *et al.*, 2009). Nonetheless, it provided valuable information about participants' views and assessment of current systems, and desires for better inclusive LAS.

The survey findings from questionnaires were useful for the initial data collection phase. However, they did not present the motivations behind the participant's responses. Therefore, structured interviews were conducted with the anticipation that they would provide more insights into participants' questionnaire responses. For example, in instances where participants in questionnaires noted their disapproval, dissatisfaction or inconveniences caused by current

systems, interviews provided more information to the responses given, such as missed business opportunities resulting from long, closed, and expensive bureaucratic processes at Land Boards. Participant 3 in his response to a question about his views on the efficiency and effectiveness of current LAS, provided a negative response, which was common to 13 other participants (87%) from the public. The participant did not furnish any explanation of the response given in the questionnaire. Nonetheless, a further inquiry through an interview revealed that the participants had recently missed an agricultural business opportunity from financial institutions since they could not fund his proposal, citing a lack of land to execute the business. According to the participant, he had been on a waiting list for plot allocation since 2010 but had not been allocated the business plot because of 'unfair and corrupt' practises of Land Boards. Interviews further helped reveal participants' motivations and desires towards having a participatory initiative which could add value to current official systems.

5.1.3 Phase 2 – VGI application development and testing

The second phase of the data collection activity took place for a period of two months in the summer of the southern hemisphere, in 2015. The purpose of the activity was to test the functionality and usability of the Web map application and rating system developed from insights obtained in the preliminary data collection phase. The expectation was that the applications would enable the public to contribute land information of their local area and allow them to subjectively rate and comment on contributions made by their peers. Further scrutiny of standard procedures, legal and regulatory frameworks regarding geospatial data collection, handling and dissemination between DSM and Land Boards were conducted. To obtain this information, structured interviews were conducted with key stakeholders in the study area. The key stakeholders included: two principal land surveyors at DSM and Land Board, one at each organization; two land law lecturers at the University of Botswana (UB); and two community leaders in the study area.

The interviews with principal land surveyors provided information about current geospatial data flowlines between DSM and Land Board, licensing and institutional arrangements, and adopted standard measures within the two organizations. According to a Principal Land Surveyor (respondent 1) from DSM, the only geospatial information that has some legal framework is that of the cadastral domain. Cadastral surveys are governed by the Land Survey Act. Moreover, respondent 1 noted that in early 2000, there was a proposal to establish a geoinformation policy within the National Spatial Data Infrastructure (NSDI) framework, but it was never realised.

Despite the failure of the geoinformation policy, the country introduced new land policies to address proper management of land in Botswana. For example, State Land Act and Tribal Land Act were established in the mid 2000s by the government to govern the management of land in state and tribal land respectively. However, these Acts do not have any clauses that specifically address standard procedures for collecting, handling and disseminating geospatial information.

An interesting statement made by the land surveyor was that there is no law that guides public participation activities in land related matters of Botswana. According to the interviewee, this lack thereof relegates the public to become spectators in land related activities, while most of the work is performed by technocrats in government departments and private agencies. Public participation is only done through consultations in relation to village planning activities through Kgotla meetings. Respondent 1 further highlighted that DSM has functional licensing and data sharing agreements among its stakeholders, to encourage better management of geospatial data and prevent misuse or abuse of the datasets.

Respondent 2 was a Principal Land Surveyor at Kgatleng Land Board, who noted that geospatial data specifications set out at DSM are also implemented in Land Boards. For their mapping activities, Land Boards currently use the latest high accuracy orthophotos acquired in 2011 and supplied by DSM, at 25cm resolution. The acquisition date of an orthophoto is very important for the VGI application that can be used on an FFP basis. For example, a recently acquired orthophoto can provide the current pictorial view of the ground with new land developments. As a result, volunteers may easily identify objects on the ground for improved land use classifications and plot boundary delineations. Meanwhile, data maintenance activities that exist at Land Boards include 5-year systematic updates of cadastral and topographic datasets. These activities involve the engagement of the under-staffed surveyors and technical officers, with fewer resources. Respondent 2 stressed that these capacity challenges result in irregular updates and maintenance of mapping information, thus leaving many parts of the village and other jurisdictions with outdated datasets.

According to respondent 2, public participation through VGI initiatives could be vital to improving Land Board processes, particularly land registry and mapping activities. However, he questions the quality, integrity and credibility of datasets to be produced by non-experts in mapping activities. Other concerns by respondent 2 include the feasibility and practicality of the participatory initiative in securing land rights for informal areas. His fears emanated from

the view that it might encourage and endorse lawlessness through the sporadic emergence of squatter settlements.

To understand regulatory frameworks that facilitate access to land information in the country, two land law lecturers were also interviewed. Respondent 3, a land law lecturer at the University of Botswana stated that there were no policies or legal frameworks that guide the collection, handling and dissemination of geospatial data in the country. For example, the interviewee cited the Land Survey Act, which states that any survey of more than one hectare should be deposited and recorded at DSM. Nevertheless, this legal provision is hardly enforced by practitioners or institutions.

Regarding public participation in land related activities, respondent 4 argued that there were legal provisions in the Town and Country Planning (TCP) Act and Tribal Land Act that cater for such. An example given by the respondent is a clause in both Acts that states that all village planning activities require public input and adjudication through Kgotla meetings. Other provisions within the acts stress need for a public display of land allocation lists for a period of 21 days at the Kgotla for public scrutiny and acknowledgement. According to respondent 4 (another land law expert), public consultations are conducted as stated in the TCP Act, when new plans and developments are introduced in a local community. However, his concerns were that public officers often confuse consultations with informing the public, thus some meetings end up as information delivery, rather than consultative platforms for gathering public input and opinions. Overall, the interviewed land law experts provided understandings on the country's land policies, standards and legislative statutes that govern geospatial data collection, handling and dissemination. Furthermore, they provided information on legal issues regarding regulatory frameworks that facilitate access to land information in the country.

The interviews conducted with the community leaders provided information on how the current LAS engages local communities as well as its shortcomings from the public's perspective. For example, a Boseja Ward headman (respondent 5) addressed the researcher with disappointment that current LAS overlook community leaders and the public when conducting consultative meetings regarding village planning. This setup, according to the headman greatly reduces their involvement and participation in land related activities of their local area. Moreover, he stressed that as community leaders, they are aware that the public is eager to participate in land related activities of their community. The interviewee went on to blame the current customary laws of the country which, according to him have greatly reduced the powers of community leaders in

land matters and placed them with Land Boards. Despite concerns raised by the headman, responses from the Phaphane Ward headman (respondent 6) indicated that Land Boards do engage community leaders during land acquisitions for village expansion purposes. Respondent 6 highlighted that community leaders assist Land Boards acting as intermediaries with the public during land acquisition consultations: community members are culturally inclined to their leaders, which increases success rates of land acquisitions. Respondent 6 further stressed that if current policies were to be amended, they could actually provide more assistance to Land Boards to improve existing LAS. All the interviews conducted in the second phase of the data collection study were tape recorded with the permission of the interviewees, whilst the data collected was later analysed using a discourse analysis methodology.

The methodology allows the scrutiny of verbal and textual data for an effective consolidation of research findings. It facilitates the identification and study of underlying voices and ways in which people express themselves during interviews and conversations (Jermsittiparsert *et al.*, 2012). Such a methodology was very helpful when interviewing community leaders in the study area who are knowledgeable about land administration processes in the area but may lack proper writing skills. Thus, the tape recordings allowed participants to use communication mechanisms they were comfortable with to convey their knowledge and understanding of current land administration procedures and challenges. However, Mogashoa (2014) argues that discourse analysis does not have fixed meanings and that everything is always open to interpretation and negotiation. This according to the author, provides room for misinterpretation of results, since similarities and differences between concepts may cause confusion to researchers. Hence, there should be explanations of concepts and justifications of their use in every analysis (Mogashoa, 2014). Nonetheless, the insights provided by the information collected were very useful to this study as they informed the development of a functional VGI application that provided a platform for citizens to actively participate in land administration activities of their community. Moreover, they provided valuable information towards designing an innovative conceptual participatory framework that considers all relevant parameters (social, legal, institutional and technical) necessary to produce VGI capable of use in official systems on an FFP basis.

The flowline of participants contributing geospatial datasets to the VGI application and experts (trusted intermediaries) assessing and rating their accuracy and reliability is as follows (Figure 5-3):

1. The **Web map application** requires participants to register their personal details, username and password into an authentication system, to be stored in a relational database.
2. Authentication system then grants access to the participant to interact with the Web map application to independently assess a sample of official datasets, comment on them and contribute land information of the area.
3. The contributed datasets are then stored in an enterprise geodatabase.
4. ArcMap was used to exemplify how administrators retrieve and manipulate contributed datasets by the public.
5. ArcMap further allows administrators to design more Web services and publish them to ArcGIS Server.
6. The Web services are then consumed from ArcGIS Server by the Web map application which provides a front-end platform for experts to assess and rate contributed datasets by the public.
7. The **rating system** involves experts registering in the authentication system and their personal details, username and password stored in the relational database.
8. The authentication system then grants experts access to the Web map application for them to inspect public contributions.
9. After the inspections, experts would then subjectively rate and comment on the quality and reliability of contributions made by the public, using the rating system.
10. Expert ratings and comments will then be stored in a relational database to later inform potential consumers, about the quality and reliability of contributed datasets by the public.
11. A cross-reference database will facilitate the linking of source database (enterprise geodatabase) fields with those of the target (MySQL) database fields for cross-indexing.

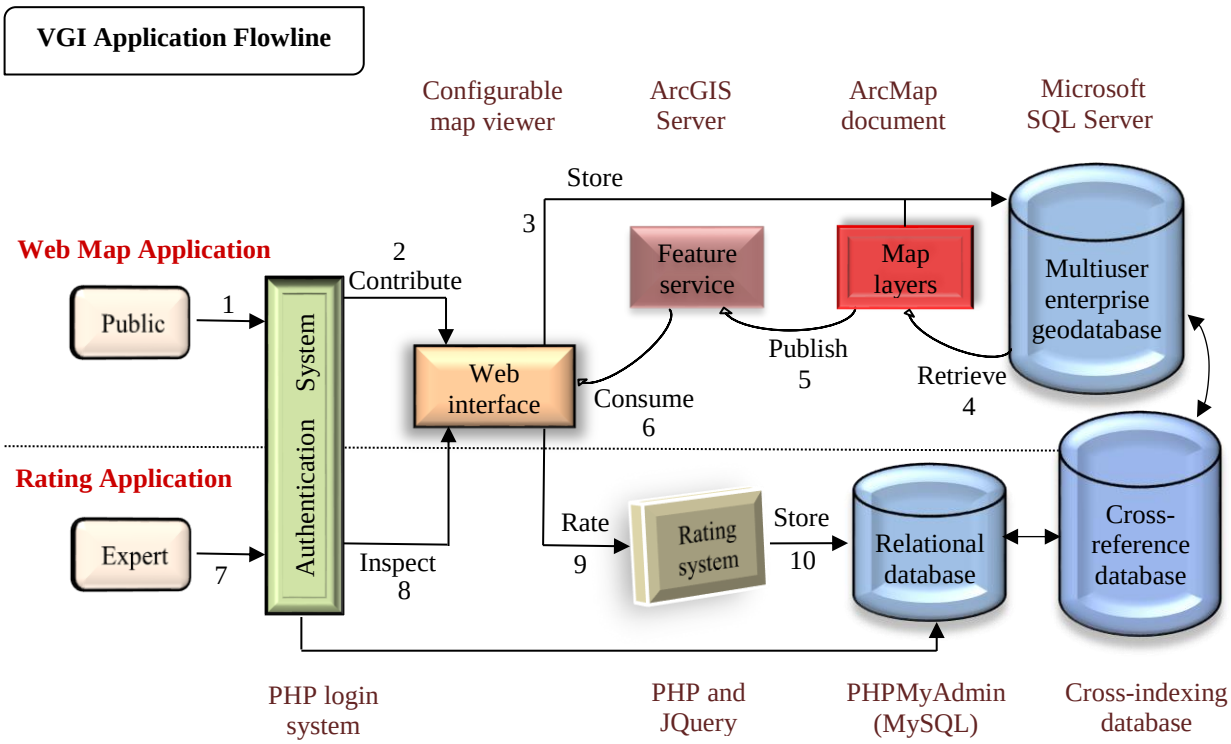


Figure 5-3. The VGI application flowline showing the necessary steps to be taken by the public to contribute geospatial datasets and how the trustworthiness and reliability of their contributions will be established.

Web map application development

The Web map application was developed using ArcGIS JavaScript Application Programming Interface (API). The objective of its development was to use it as a test bed for the public to examine a sample of existing geospatial data in official databases, to comment on, and later contribute land information of the study area. ArcGIS Desktop was used for geospatial data processing and map authoring, while ArcGIS Server was used for creating and managing GIS Web feature services. A Configurable Map Viewer (CMV) application was used as the front-end tool for visualizing and interacting with the published Web feature services in a Web interface. CMV is a community-supported open source mapping framework that works on the ESRI JavaScript API, ArcGIS Server and ArcGIS Online applications. CMV was hosted on a local Web server, known as XAMPP: a free and open source Web server package that works on various platforms to allow Web application developers to test their work on their local computers. To restrict access to the application and enable editor tracking of contributed datasets, an authentication system was developed with an HTML form and PHP which requires users to register or login prior to using the application. The form enabled participants to fill in their personal details, usernames and passwords which were saved in an SQL database.

Geospatial datasets collected from participants was stored in a multiuser enterprise geodatabase, Microsoft SQL Server 2014 Express Database. This database is provided free of charge by Microsoft, an international software company. However, the database has a limitation of storage space: it can only store a maximum of 10 gigabytes of data. Nonetheless, the sample dataset used and the data collected was less than two gigabytes, hence sufficient for this study. This free database version contains all the core functionalities found in the commercial system. As such, it does not have any limitations in that aspect. Alternative multiuser enterprise geodatabases include PostgreSQL, Oracle, and IBM Informix. The choice of the geodatabase was based on a system that provided an easier deployment environment and sufficient storage for the data to be collected. The Web map application (Figure 5-4) utilized geospatial datasets of the local community, currently used by the Land Board which include:

1. base maps of the area,
2. road and river network data,
3. land parcel data with general information like occupancy, land use, development status, etc.

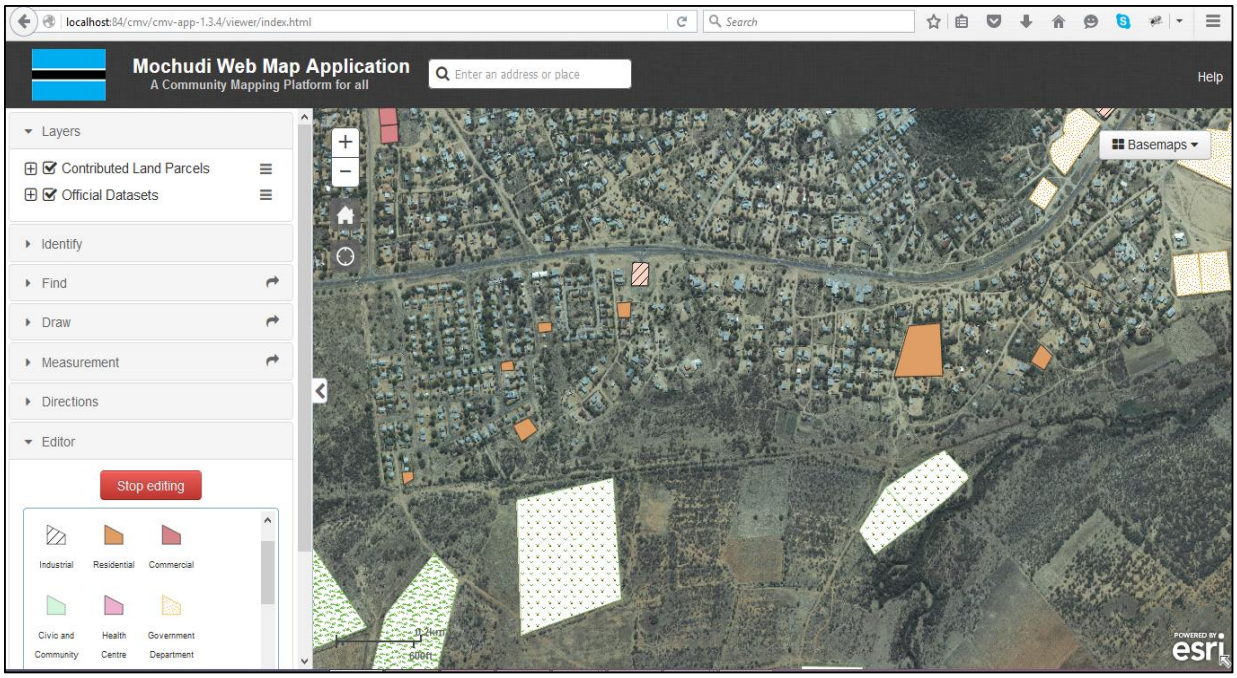


Figure 5-4. VGI web map application.

Key functionalities of the application were designed to be user-friendly to enhance participants' experiences. The collection of land parcel information was based on two online-based approaches: The first approach was the tagging process, where participants tagged a centroid of a land parcel in the 25cm high-resolution orthophoto, then provided attribute

information that described it in a pop-up window. The contents of the pop-up window were designed to mimic fields and schemas in official databases for ease of integration at a later stage. This is a quick and inexpensive method of collecting land information. However, Basiouka *et al.* (2015) argue that the approach is only beneficial where the official cadastral declaration is at the preliminary stages.

The second approach was the on-screen digitizing method, where participants declared their ownership and knowledge of land parcels in the orthophoto: by digitizing their boundaries and providing attribute information about them. According to Basiouka *et al.* (2015), this method is 'extremely successful' for identifying land parcel boundaries when high-resolution imagery is used (Figure 5-5). It ensures that land parcel boundaries are easily identified and documented by participants. GPS units may also be used as alternative instruments for collecting land parcel boundaries. However, signal discrepancies in rural areas may lead to failures in achieving sufficient accuracies. The anticipation was that the Web interface could attract volunteers to the VGI system and promote land administration concepts to the public. Experts were then engaged in inspecting, rating and commenting on contributed datasets by the public using a rating system developed in this study.

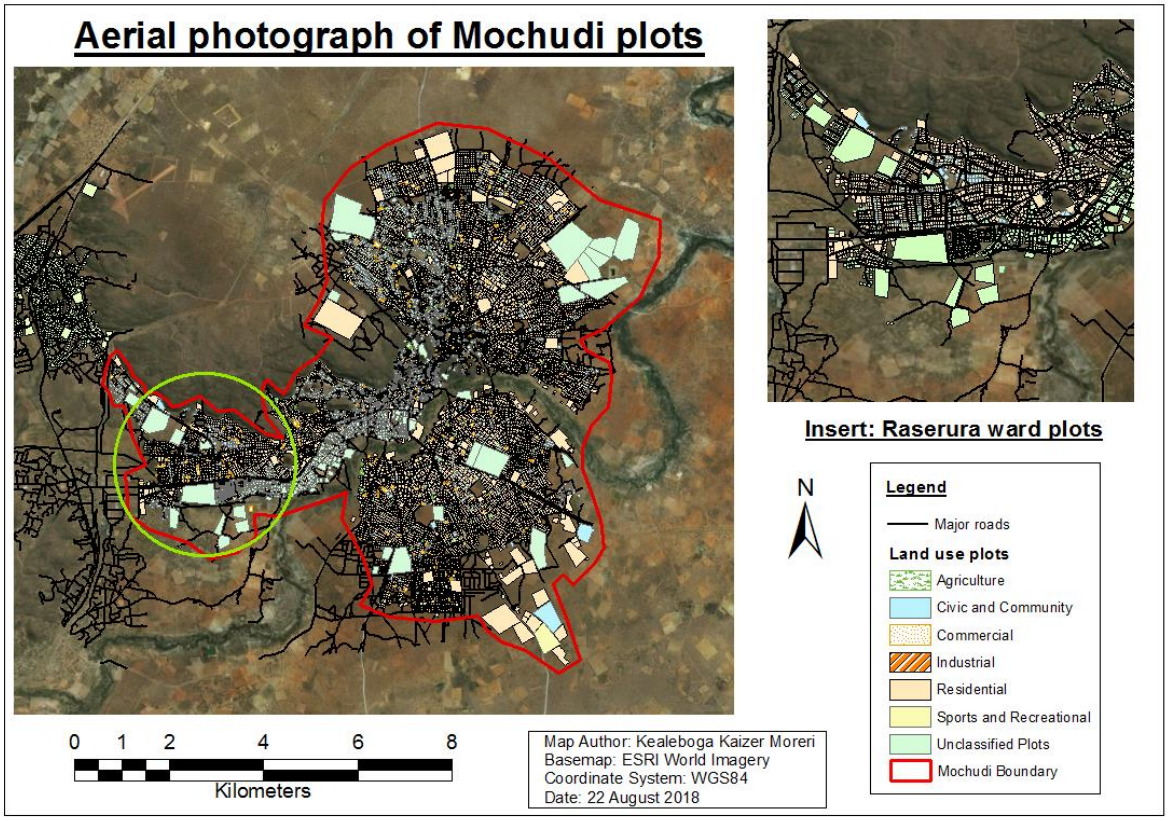


Figure 5-5. Aerial view of Mochudi land parcels

Rating system development and data storage

A key challenge of VGI lies in establishing the authenticity of information collected from a multitude of volunteers. Among other aspects, VGI quality assessment is not conducted in most projects due to a lack of central coordination and strict data collection guidelines (Haklay *et al.*, 2010; Corcoran and Mooney, 2013). However, just like in open source software networks, there is perceived value in what the general community can offer in VGI initiatives. Therefore, a rating system was developed to provide a platform where the quality of contributed datasets could be established collaboratively. It involves the public contributing information to the VGI application and their peers given the opportunity to subjectively judge and rate the information quality and reliability. The ratings and comments were based on the land parcel's currency in terms of development status and occupancy, and land use classification accuracy.

The rating system was developed with JQuery, PHP and MySQL to store information from inspections provided by experts, as well as aggregate a land parcel's individual ratings into a single value (Figure 5-6). JQuery is a JavaScript library that provides capabilities for developers to create dynamic Web map applications. A MySQL database was used to store all user inspections, comments and rating values obtained from the data collection activity. Land parcel

numbers were used as primary keys for easier storage and retrieval. The rating system was connected to the VGI Web map application through a hyperlink embedded in the pop-up window that describes geospatial data. As such, for a user to access the rating application, they would first view contents of a dataset, then click a 'Rate this feature' button, which would open the rating application in a separate Web page. JQuery functions have been created such that the land parcel identification number of a clicked parcel is automatically stored in the rating application. Such a functionality helps eliminate input errors likely to be brought by experts: thus, improves the consistency and validity of the rating application.

PHP is a recursive acronym for PHP: Hypertext Pre-processor, an open source general-purpose server-side scripting language used for developing interactive Web pages. It was used in the rating application to enable the storage of user inspections and rating values to the relational database. Moreover, PHP facilitated the aggregation of ratings into a single entity and provided the number of ratings received by that entity. Furthermore, it was used to enforce integrity rules by allowing an entity to be rated once by a single IP address. Such a function reduces abuse of the system, which increases its credibility. When an entity is rated, that value is added to the existing rating values and averaged to produce a final rating score.

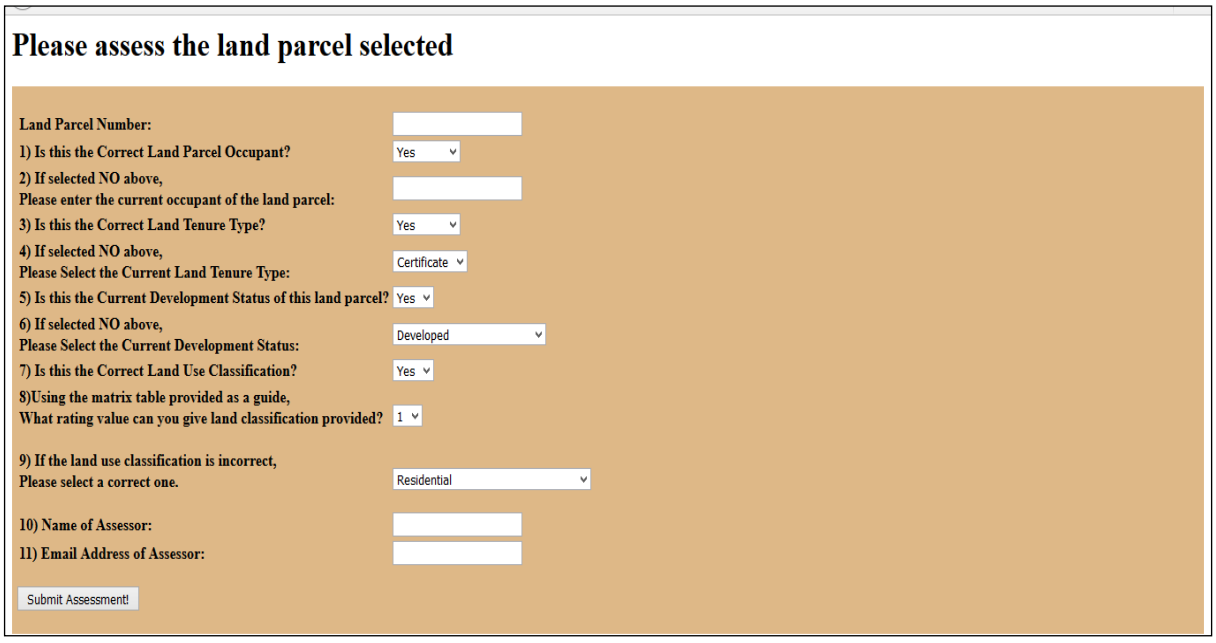


Figure 5-6. Land parcel rating system.

The lack of existing authoritative datasets in developing countries to compare with contributed datasets for quality assessment, make the rating application a viable tool for determining the trust and reliability of VGI. It enables consensus and statistical measures to be used in establishing the trust and confidence of potential consumers towards the utilization of VGI in

their environments. Bishr and Mantelas (2008) stress that functioning communities rely strongly on subjective trust between individuals.

Even though the VGI application has been designed with two separate databases, a cross-reference database was created in ArcCatalog, to create a link between them that facilitates cross-indexing. The cross-reference database is based on the source (enterprise geodatabase) and target (MySQL) database schemas specified by the researcher. It was based on a source workspace, in this case, the enterprise geodatabase, the primary point of comparison, while the target workspace was the MySQL database. Since both the source and target databases contained a primary key (plot number), and a common field (rating value) these enabled fields in the source schema to be populated with datasets from the target database. Therefore, the table in the source database would contain all information of common fields from the target database. As a result, the VGI application can answer key questions likely to be asked by potential users of contributed datasets, such as which land parcels have the highest trust rating? The significance of such a capability is that it helps establish the 'proxy' quality of contributed datasets such that potential users can have trust and confidence in utilising them.

Testing the VGI application in the study area

To test the VGI application, 25 participants were engaged: 17 were members of the public, while 8 were experts from the land authority. The 17 participants contributed a set of pre-defined geospatial datasets through a digitizing and annotation process. A brief explanation and demonstration of the functionalities of the application was conducted with each volunteer such that they could interact and perform the required tasks with ease. Volunteers vary greatly in their ability to accurately label and describe land parcels because of their motivations, enthusiasm and skill level (Coleman *et al.*, 2009; Basiouka and Potshiou, 2013). As such, variations in labels were anticipated.

The digitizing activity for each participant involved three known and three unknown land parcels in the study area. While the annotation process involved a tagging activity that involved a set of 20 pre-defined land parcels of different land uses (commercial, industrial, civic and community, and agriculture), five for each category. The objective of the digitizing process was to investigate if the participants could identify land parcels in the Web map application, and to test their ability to digitize land parcel boundaries and provide their corresponding attribute data. The attributes of interest in the digitized land parcels included: a) development status, b) land use, c) occupancy, and d) general comments. The annotation process was performed with

the objective of establishing how well participants could identify and describe the pre-defined land parcels within their community. Multiple tags of the same entity were received which were later used to determine the extent to which the public correctly classified land parcels and their reputations based on the content they contributed.

Junior staff personnel of the Land Board (land surveyors, land use and estate management officers, and land adjudication officers) were engaged as trusted intermediaries (experts) to assess and rate data contributed by the public. The rating application facilitated subjective measures of the quality and credibility of contributed datasets for conclusions to be drawn based on consensus agreement. The ratings were based on how well individuals identified and classified objects in the VGI application. Agreement measures were used to assess the reliability of data contributed by volunteers, quantifying accuracies of land parcel classification by public contributions relative to the experts' decisions. Based on the number of ratings an entity received, an average rating value was then computed to denote trust on that dataset. Demographic information of participants from the public was collected such that conclusions could later be made regarding the extent to which a certain group accurately classified land parcels and contributed reliable land information to the VGI application.

Usability evaluation of the VGI application

All participants who took part in the second phase of the data collection activity were requested to evaluate the usability of the VGI application upon completion of their tasks. An online questionnaire with 10 questions was designed in the SurveyMonkey[1] website, to provide a platform where participants could share their experiences of interacting with the application and suggest improvements thereof. Questionnaires in system development allow developers to provide fixed questions which directly discuss aspects of the system being investigated. Unlike traditional approaches that produced questionnaires on a sheet of paper, online systems store responses directly in relational databases, for easier manipulation, analysis and interpretation. Moreover, the Web environment enables a wider reach of respondents and flexibility as participants can answer questions at their convenience. To obtain a varied array of responses, the questionnaire consisted of a variety of questions that include (Dix *et al.*, 2004): a) open-ended questions – asking users opinions without restricting their responses, b) scalar questions – where users specify the degree to which a statement relating to the system is correct, and c)

[1] www.surveymonkey.com

multi-choice questions – which offer users an opportunity to provide a set of explicit and independent responses. The questionnaire consisted of usability questions that include:

1. Rating scales that measured how easy or challenging it was to:
    a. navigate through the application,
    b. inspect land parcels in the official record and rate its contents,
    c. digitize land parcels and provide their attribute information,
2. Rating scales that measured how poor or good the usability of the application was in terms of:
    a. visibility of satellite image when zoomed in for digitizing purposes,
    b. searching for map features,
    c. accessing help functions and guidance documents,
3. General questions about the application and its contents and whether participants:
    a. would use such an application to contribute land information of their community,
    b. could trust information from the application,
    c. thought the application could improve efficiency at Land Boards,
4. A commentary box that requested participants to:
    a. list the functions they liked in the application,
    b. outline the tasks that were more difficult to complete and why they were difficult,
    c. state the functions they would change in the application and provide reasons for it,
    d. suggest other functions for improving the VGI application.

According to 85% of the reviewers, some of the application's key strengths are its flexibility, clarity and offline capability. They observed that its offline capability could be beneficial in remote areas without internet coverage since work could be done in offline mode and later reconciled and updated when internet connectivity was obtained. Nonetheless, 58% of reviewers had concerns about the technical complexities of the application like its basic navigation functionalities. For example, the panning function, which on several occasions had a delayed effect when loading the orthophoto (during zoom-in and out activities) and the cursor icon when digitizing, which at times did not select a point clicked. Such challenges as stressed

by reviewers could frustrate users and result in the loss of interest in utilizing the application. Other concerns were noted and summarized as follows:

Public responses:

1. 78% of public reviewers asked for functionalities of the application to be increased to include: a) mapping activities such as buffer tools to help users locate active and inactive water points near their farms, b) area measures of land parcels and length measure tools to compute distances to areas of interest, and c) tools to determine soil and crop suitability based on location and environmental conditions of the area,
2. 72% of public reviewers requested for an import function that allows geospatial data from a variety of sources at different scales (e.g. GPS units and smartphones) to be incorporated into the VGI application. Such a concept as highlighted by McLaren (2010), ensures that an application adheres to the good practice principle of 'collecting or mapping once, and using many times',

Experts responses:

1. Some experts (67%) stressed the need to have a system with a faster download speed for maps. According to Dragicevic and Balram (2004), this can be achieved by the provision of asynchronous services which do not halt other services while waiting for the request to return. Therefore, a user can continue interacting with the application, while waiting for the request to be completed,
2. 91% of experts requested a help tool that focused on 'user perspectives and needs' rather than a developer's perspectives and instructions. For example, user-centred designs focus on multiple sources of knowledge to support creating systems based on user's abilities, capabilities and tasks involved, rather than on the technology of the devices used (Ritter *et al.*, 2014).

The constructive nature of reviews and comments received from participants strengthened the conceptual, technical and usability aspects of the VGI application. Moreover, the usability evaluation activity emphasised key areas that improved the robustness, acceptance, usefulness and effective implementation of the VGI application such that it was relevant to the community it served. The comments have further highlighted important aspects of system development to consider in terms of conformance to established standard procedures, institutional frameworks and official database schemas of the study area. Such considerations have the potential to increase the recognition of the application and eventual use of its products in official systems. Overall, stakeholder involvement in testing and gathering inputs about the usability of the

application have brought understandings and suggestions that include: a) identification of bugs and other undesirable aspects that were missed or overlooked by the researcher. For example, there were suggestions by respondents 16 and 19 (both community members) about the introduction of buffer and distance measure functions to enable consumers to compute proximity and distance measures between two or more points of interest; b) ideas on how the application could better be positioned, functionalities and possible information it should have such that it benefits all stakeholders; and c) authentication and security measures to consider in safeguarding contribution of sensitive land information by users. According to respondent 2 (Land Board, Principal Land Surveyor), a secure environment can improve trust and confidence of consumers to utilise the contributed datasets in either updating current official databases, for adjudication processes, or for more informed decision-making purposes.

Concerns raised by participants like the technical complexities of the application were taken into consideration and sufficiently addressed. For example, the snapping tolerance distance between land parcel vertexes was increased to enable the pointer to automatically snap to the existing vertex once the set radius is met. Such activity can improve the quality of digitized datasets as overlapping land parcels would be eliminated or greatly reduced. Therefore, prior to implementing the application in the third phase of the data collection study, all concerns raised by participants were sufficiently addressed. The objective of this study is to develop a FFP system and this was facilitated by developing the application further such that it meets user needs. The significance of the usability questionnaires is that they have revealed important issues to be taken into consideration regarding the improvement of the VGI application such that it can be strategically positioned to be functional to both spatial and non-spatial experts (public).

5.1.4 Phase 3 – VGI application implementation stage

The fundamental objective of the third phase was to engage the public in obtaining an unbiased representative sample VGI to demonstrate the practical handling and assessment of contributed datasets, such that they can be considered for use in official systems. A total of 105 participants took part in this activity: 90 were members of the public, whilst 15 represented experts (junior officers) from the Land Board. Public participants from the study area were selected with the help of local leaders using the following criteria: a) computer literacy, b) familiarity with the Internet and Web mapping applications, and c) demographic data, like age, gender, occupation, highest qualification attained and years of residence in the study area. Additionally, participants were evenly chosen from different locations within the study area. The number of participants

engaged in this phase (105) should allow for statistically representative results taking into consideration the activities to be performed and the approximate size of the study area (5km^2) (Barlett *et al.*, 2001; Ramasubramanian, 2010; Comber *et al.*, 2013). The participants took part in the activity for a period of 6 weeks during the southern hemisphere spring, in 2016. Each member of the public was requested to tag and classify 30 pre-defined land parcels and further digitize 12 land parcels of different land uses in the study area. Even though the data collection activity consisted of pre-defined land parcels, the emphasis was placed on well-known properties within the community to measure the extent to which participants could correctly identify and classify them. Furthermore, the pre-defined land parcels were introduced to facilitate database entry and comprehensive analysis of multiple records of similar objects to measure the quality of the contributions using the proposed TRM methodology. Experts were then engaged in inspecting, rating and commenting on the records contributed by the public. Moreover, they were requested to digitize the 12 land parcels digitized by the public, so that the geometric accuracy of public contributions could be determined against experts' contributions.

A total of 6 blocks were created for volunteers to identify and classify the 30 pre-defined land parcels of different land uses (industrial, commercial, residential, civic and community, parastatal/government department, and agriculture) in each block. A land use category had 5 different land parcels. Approximately, 15 participants were engaged in each block to tag and label the 30 land parcels contained in it, from the orthophoto provided in the VGI application. Therefore, each land parcel was tagged approximately 15 times by participants to obtain multiple records. All pre-defined land parcels in a block were highlighted with red push pins and participants asked to provide descriptive information about them. The total number of contributions using the tagging process were 15 volunteers * 30 land parcels * 6 blocks = 2700 records. The objective of the tagging process was to measure how well participants could identify and correctly classify land parcels in their local community. Furthermore, multiple records help assess the extent to which the land parcel classifications are reliable using the many eyes principle (Haklay *et al.*, 2010; Wang *et al.*, 2015).

The results obtained from the consensus agreement of experts about public contributions were then used to measure the 'proxy' quality of contributed datasets and credibility of the public (volunteers) using a novel TRM methodology to be discussed in Section 5.2. Usually, the positional accuracy of contributed datasets is determined by comparison against ground truth (Haklay, 2010; Goodchild and Li, 2012; Fairbairn and Al-Bakri, 2013). However, the lack of

geospatial datasets in official databases has prompted this study to conduct a Real Time Kinematic (RTK) survey, using a high accuracy GPS unit to mimic official datasets of the study area.

Real-time kinematic survey of the study area

The objective of the RTK survey was to establish ground truth to use in determining the positional accuracy of digitized datasets by the public, with a RMSE methodology (FGDC, 1998). RTK surveying is a relative positioning technique which measures the position of two GPS antennas relative to each other in real-time (Donahue *et al.*, 2013). The process involves setting up a static point with fixed coordinates, known as a base station to transmit raw observations to a rover unit in real-time. The rover would then compute its relative position using observations from the base. This type of surveying requires a reliable communication link between the receivers because the rover needs continuous observations from the base.

The study area ($5km^2$) has a short baseline with open sky areas and good satellite geometry: this enabled the acquisition of observations to several centimetres (3cm). According to Chekole (2014), RTK survey has proven to be a reliable and efficient method for determining precise relative baselines. However, it is limited to short baselines of approximately <10km because of distance related errors (atmosphere and satellite orbits) which have effects on the initialization and solution precision (Satalich and Ricketson, 1998; Ahmed, 2012). For example, RTK precision decreases as the baseline length increases. To verify the accuracy of the derived rover positions, known points in the area were measured and their coordinates compared to existing ones, which were within the acceptable cadastral survey limits of the study area (3cm horizontal RMSE, at 95% confidence interval). Positional accuracy measures can increase the trust and confidence of potential consumers of VGI, particularly when they are considered to conform to accepted local standards and accuracy thresholds by officials. Moreover, such conformance can address key problematic areas of official databases at the Land Board.

The data collection study has successfully engaged key stakeholders in the study area to provide an understanding of the perceptions of the public and those in the public service regarding the status of land administration in the study area. The consensus is that current systems are impractical, outdated, prone to abuse, lack policies and standards that can enable public participation in LAS. Even though, the legal system of Botswana recognises that non-experts can actively participate in improving LAS, particularly in rural areas. The country lacks

enabling systems to facilitate their active participation in land administration activities of their community, despite their desire and willingness to participate.

The development of the VGI application has demonstrated possibilities in the practical handling of VGI to provide a testbed for the proposed participatory system. The application enabled participants to identify, map and contribute information on land parcels in their local environment. However, to build trust and confidence of potential consumers including officials, it is necessary to develop mechanisms of establishing the accuracy and credibility of VGI. As a result, the rating system was developed, which positively demonstrated its effectiveness in inferring trust on contributed datasets using real-world geospatial datasets. The absence of geospatial datasets in the study area has motivated this study to conduct an RTK survey of a sample land parcels to mimic official datasets to determine the geometric accuracy of contributed datasets. It is anticipated that the scrutiny of problematic areas within land administration processes regarding key customer requests, can provide an understanding of possible areas where VGI can be used to reduce transaction time and improve service delivery at Land Boards.

5.2 VGI quality determination and credibility assessment of contributors using TRM

Geospatial data collected by the public may potentially contain many errors, thus, TRM is proposed as a method to establish the 'proxy' quality of VGI and credibility of volunteers. It is suggested here, in the context of VGI and TRM, that there are four data quality indicators which can contribute to the quantification of trust and reputation: a) thematic accuracy, b) semantic accuracy, c) credibility assessment, and d) geometric accuracy measures (Figure 5-7).

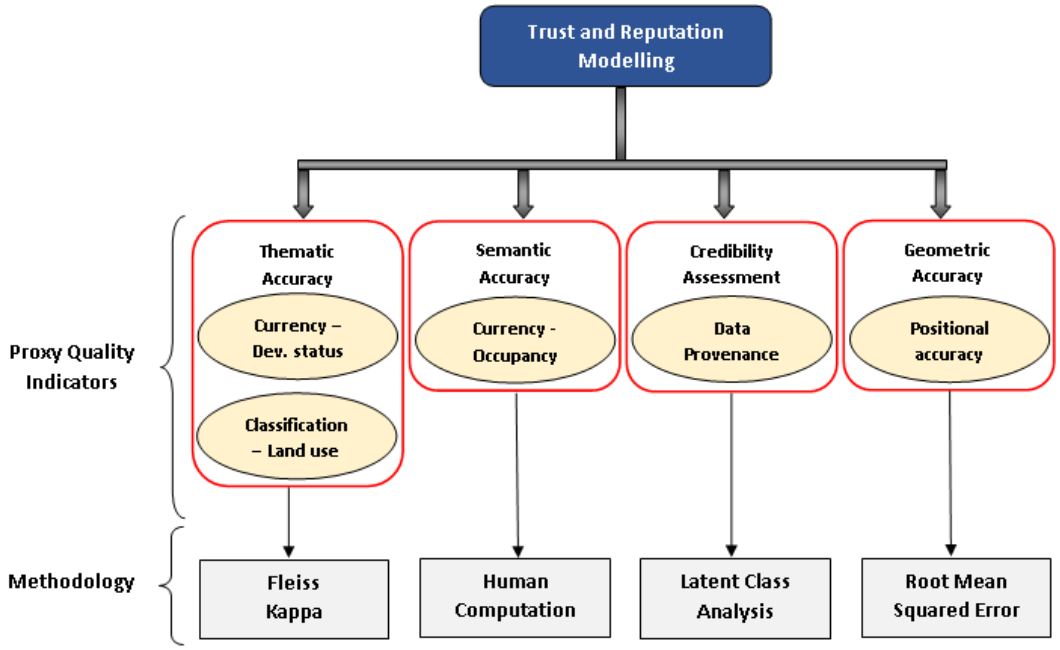


Figure 5-7. Trust and reputation modelling framework for determining proxy VGI quality and credibility.

Figure 5-8 shows the four data quality indicators identified, together with the land parcel parameters to be investigated by each indicator, and the methodologies to be used to establish the quality of VGI and credibility of volunteers. TRM can adopt the 'social', 'crowdsourcing' and 'geographic' approaches introduced by Goodchild and Li (2012), to establish robust quality measures of VGI. These three approaches have been adapted here to a more general TRM framework, such that comprehensive 'proxy' quality and credibility measures of VGI are obtained.

The **social** approach involves utilizing trusted individuals as gatekeepers to assess and monitor contributions by other volunteers. For example, TRM can use experts (trusted intermediaries) in local government to examine and assess volunteer contributions to establish the quality of their contributions. The **crowdsourcing** approach assumes that when more people work in the same area, they are likely to identify and correct errors in the data, thus increasing the quality of the datasets. For example, TRM stresses that the more participants agree to a contribution by a volunteer, largely through inaction of not editing it or provision of positive reviews about it, the more it can be regarded as reliable and of acceptable quality to other consumers. The **geographic** approach exploits knowledge from geography to detect unlikely or impossible configurations in the contributed datasets (Ballatore and Zipf, 2015). For example, there is a general geographic knowledge that land parcels cannot be in the middle of watercourses or road

networks. Quantifying VGI quality outlines its usefulness in terms of reliability, credibility, and potential for incorporation in official systems.

The four data quality indicators of VGI in TRM (Figure 5-8) address five specific parameters about contributed datasets: a) currency evaluation of a land parcel's development status, b) land use classification accuracy, c) identification and description of a land parcel's occupancy, d) data provenance, and e) positional accuracy determination. These parameters are fundamental to the establishment of effective land administration, especially for policy formulation and monitoring components of a LAS (Dale and McLaren, 1999; Ayten and Cay, 2014). Thematic accuracy of contributed datasets was determined by the first two parameters, semantic accuracy and volunteer credibility by the third and fourth parameters, and geometric accuracy by the final parameter.

5.2.1 Thematic accuracy measure

Thematic accuracy measure examines how well individuals identify and classify objects in the VGI application. The Fleiss Kappa index was used to assess the reliability of data contributed by volunteers, quantifying accuracies of land parcel classification by public contributions relative to the experts' decisions. Fleiss Kappa is a generalization of Scott's pi statistic, a statistical measure of inter-rater reliability (Banerjee *et al.*, 1999). Unlike Cohen's Kappa and Scott's pi, which work for two raters, Fleiss Kappa is applicable for many raters to process categorical ratings for a fixed number of items: it is the most widely used index of inter-rater agreement for variables with nominal categories (Randolph, 2005).

The advantage of using Kappa, compared to other statistical measures of agreement, is that it considers an agreement that would be expected by chance. Therefore, it is a more robust measure of agreement than simple percent agreement calculation (Sim and Wright, 2005). Nonetheless, a Kappa measure can often provide low values despite high levels of agreement between raters, because of chance correction computation. In addition, a single value of Kappa is difficult to interpret, especially when trying to diagnose the possible cause of a lack of agreement (Byrt *et al.*, 1993). It is recommended that a confidence interval be constructed around the obtained value of Kappa to reflect sampling error (Mashour *et al.*, 2010; Olofsson *et al.*, 2014), providing meaningful interpretations of the minimum and maximum possible values for Kappa: a small range between the lower and upper limit for Kappa depicts a precise and high likelihood of agreement, a large range more imprecision and less likelihood of agreement.

Fleiss Kappa is the most widely used index of inter-rater agreement for variables with nominal categories (Randolph, 2005). Fleiss Kappa (*K*) takes the form:

$$K = \frac{observer\ agreement - agreement\ by\ chance}{1 - agreement\ by\ chance} = \frac{P_o - P_e}{1 - P_e} \quad (1)$$

Where P_o is:

$$P_o = \frac{1}{Nn(n-1)} \left(\sum_{i=1}^{N} \sum_{j=1}^{k} n_{ij^2} - Nn\right) \quad (2)$$

And P_e is:

$$P_e = \sum_{j=1}^{k} \left(\frac{1}{Nn} \sum_{i=1}^{N} n_{ij}\right)^2 \quad (3)$$

Where *N* is the number of cases, *n* is the number of raters, and *k* is the number of categories. P_o indicates the extent to which the raters agree. P_e indicates the extent to which raters would be expected to agree by chance.

Despite its widespread use, Kappa is discouraged by some: Pontius and Millones (2011) argue that Kappa does not serve a useful role in accuracy measures or area estimations, and Olofsson *et al.* (2014) stress that the corrections of chance agreement produce measures not descriptive of the map accuracies to be encountered by a user. However, in the absence of ground truth, Kappa can be regarded as a reliable tool for 'proxy' accuracy assessment of VGI based on the wisdom of the crowd principle. If many people agree with participants' contributions, this provides valuable information on the reliability of the contributed data, and consensus agreement increases the confidence of potential users of VGI. Kappa, in these instances, is used as a confidence and reliability measure of volunteer contributions by raters, providing quantified agreement between two or more raters who make independent ratings about attributes of a land parcel contributed by volunteers.

Alternatively, Krippendorff's Alpha can be used to determine inter-rater reliability. It is commonly used in a content analysis to quantify the extent of agreement between two or more raters. However, it differs with other measures of inter-rater reliability because it calculates disagreement as opposed to agreement: It is measured by computing a ratio (observed disagreement/expected disagreement). According to Stemler and Tsai (2008), the major disadvantage of the methodology is its computationally complex nature because it involves resampling methods like the bootstrap. Nevertheless, Hayes and Krippendorff (2007) argue that the results of both Alpha and Kappa are statistically similar, hence the methodologies could be used interchangeably.

5.2.2 Semantic accuracy measure

The lack of ground truth in developing countries to help establish the quality and credibility of VGI has motivated the investigation of data provenance as an indicator of VGI quality. Data provenance can provide a valuable dimension when multiple records of the same entity are aggregated to define a final label and improve semantic accuracy. Metadata created in open labelling systems for collaborative projects like VGI can be examined with semantic accuracy measures to collect folksonomies. While a flexible collaborative approach of VGI allows for the rich description of geospatial objects to capture local meanings, it also creates semantic heterogeneities: there may be diverse and conflicting attributes used to describe the same object contributed by many users. Unlike thematic accuracy measure which concentrates on examining the extent to which individuals correctly identify and classify objects in the VGI application, semantic accuracy determination is concerned with the aggregation of multiple records of the same entity from different contributors to define its final label and improve semantic rigour.

Semantic heterogeneity was addressed here by Human Computation (HC) methods (Ballatore *et al.*, 2013; Celino, 2013; Ronzhin, 2015), a technique whereby some computational processes are 'outsourced' to humans. In HC, a computer asks a person or group of people to solve a problem, then collects, interprets and integrates their solutions: in VGI this can consolidate contributed datasets from a variety of sources (Law and von Ahn, 2011; Celino, 2013), and addresses the shortcomings of heterogeneous information collection and semantic accuracy challenges common in VGI. Here, HC is a technique that consolidates land parcel labels with similar lexical vocabulary contributed by different volunteers into a single label. A tag with the highest number of aggregated values will then be assigned as the final land parcel label for that entity. Therefore, HC uses the many eyes principle to suggest that an entity labelled similarly by many contributors can be regarded as its correct classification.

The structure of HC is made up of three steps (Figure 5-8): 1) Task definition, where contribution tasks and requirements are clarified to participants, 2) Task execution, where multiple participants are given similar tasks to contribute information, and 3) Task solution, where individual contributions are consolidated and harmonized into a central solution (Celino, 2013). HC addresses the semantic heterogeneity of VGI by consolidating similar contributions into single labels, thus improving quality. In this study, HC was implemented in three stages as shown in Fig 5-8: a) brief demonstrations of tasks and requirements were conducted by the researcher to participants such that they understand what was required of them when interacting

with the VGI application, b) to obtain multiple records, participants were then given similar tasks of identifying, classifying and digitizing land parcels of different lands uses in the study area, and c) one of the tasks included classification of occupancies of pre-defined land parcels where similar contributions were later aggregated into a single label.

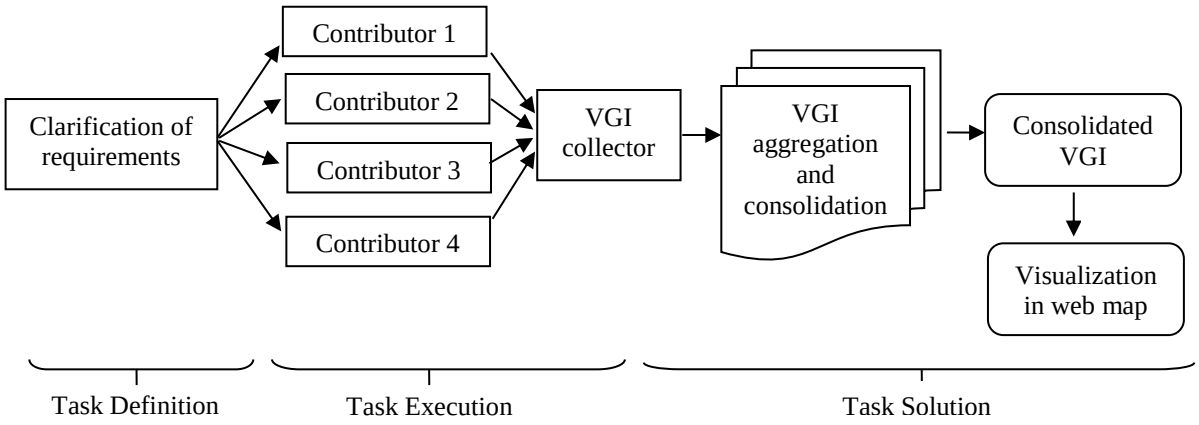


Figure 5-8. The Human Computation workflow for VGI collection and consolidation (adapted from, Celino (2013)).

Contributed datasets from volunteers were converted into a Resource Description Framework (RDF) – a World Wide Web Consortium (W3C) specification since 2004, such that it can be manipulated and integrated with other external data over the Web. RDF enables source data (Shapefiles) to be converted into a set of triples (subject, predicate and object) in the task solution stage for semantic accuracy determination. Here, the subject is the unique identifier (parcel number) of the contributed entity, the predicate is the attribute of the entity (e.g. land use), and the object represents its attribute name (e.g. commercial).

Semantic accuracy was computed using Datalift, an open platform for publishing and interlinking datasets on the Web. A semantic query language for databases, SPARQL, was used in Datalift to query, retrieve and manipulate data contributed by volunteers. SPARQL, a recursive acronym for SPARQL Protocol and Resource Description Framework Query Language, is a W3C specification (since 2008) used here to aggregate and consolidate VGI based on the tags contributors provide for the same land parcel. The merging process is facilitated by a Natural Language Processing (NLP) technique that uses a text mining algorithm known as Named Entity Disambiguation (NED) to automatically combine similar text snippets from multiple sources to form a summary (Manning and Schutze, 1999; Barzilay, 2003).

SPARQL uses an aggregation algorithm to consolidate VGI tags based on a simple agreement mechanism. Its functionality is such that, as soon as two contributions with similar text content

from two different volunteers are recorded, the algorithm is triggered and the contributions consolidated into a single occupancy label. Figure 5-9 shows a sample SPARQL query on the provenance data which conducts a count and concatenates all land parcel **occupancy classifications** ('Occupant_N') with similar lexical terms for a single output value.

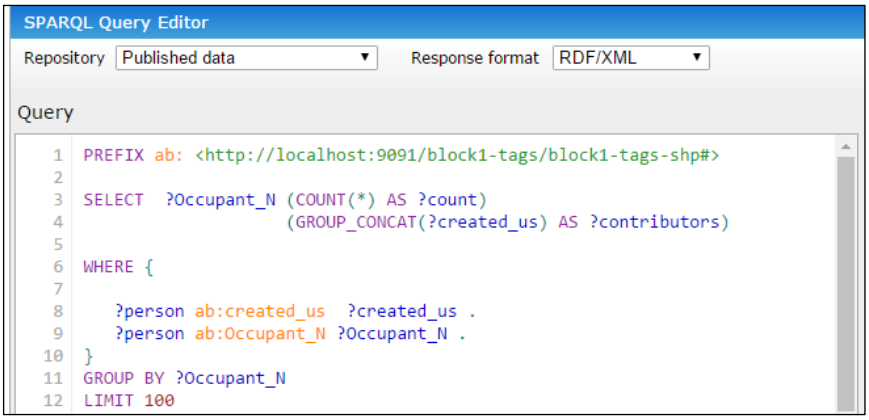


Figure 5-9. Sample SPARQL query on the provenance data.

Every time a new contribution is made, the algorithm compares it with previously stored labels to determine if consolidation must occur or not. The aggregated results are then displayed as the final label (in the case of a land parcel, this could describe 'occupancy', or 'land use') as HTML. The HC approach shows how VGI provenance can be leveraged in a data aggregation and consolidation activity to improve VGI quality based on similar words that volunteers use to describe land parcels in the study area. It then creates a hierarchy on the remaining land parcel labels.

Implementation of Human Computation in the study area

For the semantic accuracy measure, multiple labels from the tagging process were used as input data. This information was then converted into RDF and analysed using SPARQL. For example, 15 participants were requested to label the occupancy of a brick moulding plant in Pilane. The actual name of the plant is Pilane Brick Moulding. However, the norm in the area is that some community members, particularly older people. prefer to describe land parcel occupancies using the entity's owner name or describing the land use of the place as its actual name. Despite the different labels received, some participants labelled it correctly. Therefore, various tags were received of the same entity which include: a) Pilane Brick Moulding (8), b) Ga Thabo (Thabo's place) (3), b) Ko Diteneng (the place where bricks are made) (4).

The count and concatenation of all land parcel occupations with similar lexical terms for a single output value were facilitated by the SPARQL aggregation algorithm. The consolidated outputs can later be incorporated into the VGI application as the final occupancy labels of the land parcels. This increases the semantic accuracy of the land parcel's classification, as the occupancy label with the highest number of similar contributions is consolidated as its final classification label.

5.2.3 Volunteer credibility determination

No single measure exists for establishing the credibility of VGI volunteers: this is another challenge in assessing VGI quality and a hindrance for its consideration in authoritative systems. If the information is attributable to a known source by a consumer, it is likely to be trusted more, and have higher reliability and quality, than from the majority of VGI, mostly produced by unknown volunteers. According to Antoniou and Skopeliti (2015), the emphasis of VGI quality determination has been on the characterisation of contributed geospatial datasets, with less emphasis on volunteer credibility.

Statistical methods can be used to analyse and model the relationship between volunteers and their contributions. To establish the credibility of volunteers, a Latent Class Analysis (LCA) methodology is proposed. LCA is recognized as an effective methodology to analyse trends and qualities of multiple contributions from volunteers (Huang and Bandeen-Roche, 2004), and has been widely used to assess the accuracy of volunteers in land cover maps (Foody and Boyd, 2012; Foody *et al.*, 2013). It takes observed variables provided by volunteers to compute information on the unobserved (latent) variable, here representing volunteer reputation. Moreover, LCA can be used to evaluate diagnostic tests without reference to validation by ground truth. The contributions from volunteers were compared against consensus-based classification values of trusted intermediaries via cross-tabulation, to represent final land parcel tags used as input for volunteer reputation computation in Mplus Statistical Analysis software (Muthén, 2004; Jung and Wickrama, 2008). LCA requires that each observed entity be statistically independent of other variables. Foody *et al.* (2013) used latent class models to measure the accuracy of four volunteers in labelling tropical forests in a 'Globcover' map in West Africa, extracting information on the quality of contributed datasets to establish contributor accuracies in the map without reference to ground truth.

A standard latent class model can be constructed based on the probability of observing patterns of class allocations by a series of classifiers applied to a dataset (Foody, 2012). These class

allocations are known as observed variables (here, land parcel classifications), and are used to provide information on the unobserved variable (which equates to the volunteer reputation). Volunteer reputation has been established using Bayes theorem, which describes the probability of an event happening based on prior knowledge of conditions related to it (Vermunt and Magidson, 2003). For example, a person's ability to correctly identify and classify several land parcel parameters can be used to represent a reputation category to which they belong. Therefore, a volunteer's reputation derived from Bayes theorem was allocated to the class which displayed the highest posterior probability of class membership (Vermunt and Magidson, 2003; Foody, 2012).

In this study, LCA was used to estimate the reputation of volunteers based on their multiple classifications (land use, occupancy and development status) of different land parcels. To achieve this, experts can: a) be engaged in assessing and rating how well volunteers correctly classified land parcels in the study area, or b) undertake a tagging activity independently and their outputs aggregated to be used as a reference to determine how well volunteers correctly classified land parcel parameters. The latter was adopted in this study. Volunteers with good reputations are characterised by producing geospatial data of good quality. An advantage of LCA is that it can be used to characterise the accuracy of each contributor's labelling regardless of the number of contributions made (Foody *et al.*, 2015). One of the main issues with LCA is determining the number of classes and statistically assessing the fit of each class to the data to obtain representative results (Nylund *et al.*, 2007). A four-class model was selected to compute volunteer reputations: it means that there are four categories that volunteers can fall into based on the accuracy of their classifications. For example, a volunteer with the most correct classifications would belong to a very good reputation category, while the opposite would belong to a very bad reputation category.

Entropy in LCA is used to examine the model fit of how well individuals are assigned to membership (reputation) categories. An entropy value close to one shows a good model fit and a clear separation of categories (Nylund *et al.*, 2007; Jung and Wickrama, 2008). In short, this methodology investigates volunteer reputation by examining how well a volunteer correctly classifies 30 pre-defined land parcels. These labels were later compared with aggregated experts' labels through cross-tabulation to determine the accuracy of the participant's classification. LCA then analyses the trends of the cross-tabulation results (observed variables), to compute the reputation of the volunteers (unobserved variable) using Bayes Theorem. Volunteer reputation works on data provenance: as such, establishing 30 pre-defined land

parcels would facilitate a sufficient investigation and computation of how well participants correctly classify objects of different land uses in the study area (Foody *et al.*, 2013).

Implementation of the Latent Class Analysis in the study area

Volunteer reputation enforces the reputation element of TRM. Latent Class Analysis (LCA) methodology uses multiple contributions of an individual to infer the quality and reliability of the data they produce. It takes observed variables provided by volunteers to compute information on the unobserved (latent) variable, here representing volunteer reputation, using Bayes Theorem. Initially, contributions from volunteers were compared against consensus-based classification values of trusted intermediaries via cross-tabulation, to represent final land parcel tags. The obtained tags were then used as input for volunteer reputation computation in Mplus Statistical Analysis software. The basis of LCA is that a set of observed labels derived from volunteers' contributions convey information on the true label of the unobserved (latent) variable. Therefore, the methodology identifies reputation classes (very good, good, bad, and very bad) to which participants belong, based on the accuracy of their classifications.

A user's class was evaluated by computing entropy, obtained through an iterative process in Mplus. Entropy in LCA is used to examine the model fit of how well individuals are assigned to membership (reputation) classes (the scale of entropy ranges from 0 to 1). An entropy value close to 1 shows good model fit and a clear separation of classes (Nylund *et al.*, 2007; Jung and Wickrama, 2008): In this study, the highest entropy value of 0.986 was achieved from the iterative process, when four classes were selected to determine model fit. Therefore, a four-class model was adopted. A four-class model of Green, Yellow, Orange and Red was selected to distinguish reputation classes that volunteers belong to, based on how well they correctly classified land parcel parameters. These four classes were allocated reputation categories as follows: Green – very good, Yellow – good, Orange – poor and Red – very poor. For example, a cross-tabulation of participant 4's contributions against consensus-based classifications revealed that they belong to the 'Yellow' class since they correctly classified an above average proportion of land parcels: the 'good' reputation category. In short, reputation categories of 'very good' and 'good' depict trustworthiness, which can be used by participants to establish credibility in interacting with others in participatory initiatives like VGI.

A Covariance structure analysis methodology can be used to evaluate a user's class (van Hell *et al.*, 1996). According to Ployhart and Oswald (2004) it is a methodology that tests the

precision with which a class can reproduce sample covariances assessed using fit functions, to measure the overall goodness of fit of the model to the observed data. In short, the methodology seeks to outline the relationship among a set of observed variables in terms of unobserved or latent variables.

5.2.4 Positional accuracy determination

Positional accuracy describes the extent to which a geospatial entity deviates in space from ground truth. A common scientific measure of positional accuracy is the RMSE (FGDC, 1998). This accuracy measure can be used to determine the extent to which planimetric coordinates of contributed datasets deviate from similar coordinates of ground truth (Girres and Touya, 2010; Haklay, 2010; Fairbairn and Al-Bakri, 2013). However, developing countries are characterised by a lack of ground truth, as such an RTK survey as outlined in Section 5.1 was conducted to mimic ground truth. Moreover, geometric accuracy of public contributions was determined against digitized datasets of experts (officials) to determine if datasets from the latter could be used as ground truth in the absence of RTK survey data or ground truth.

The positional accuracy measure has applied BSMS standards for digital geospatial data outlined in Section 2.7. The standards provide an acceptance criterion that geospatial data must conform to, such that it can be considered acceptable for certain uses. For their mapping activities, Land Boards currently use a 25cm high-resolution orthophoto coverage of map scale 1:5000. To increase the legitimacy of the RMSE computations, the same orthophoto was obtained from the Land Board and used in the VGI application. The extent to which the planimetric coordinates of contributed datasets deviated from ground truth were then compared against the thresholds of Table 2-1 to determine the accuracy class they belonged to. Furthermore, these classes inform the potential uses of the contributed datasets in official systems.

5.3 Summary

This chapter presented a methodology for establishing an FFP LAS based on VGI for Botswana. It has elaborated on how the data collection in the study area was conducted successfully by engaging key stakeholders to provide an understanding of the current successes and challenges of land administration processes in the area. The information was used to develop a VGI application that enabled volunteers to contribute land information of their community. The

contributions by the public were then assessed by trusted intermediaries to determine the extent to which they identified and classified the pre-defined land parcels. It is anticipated that the assessments can build trust and confidence of potential consumers including officials to consider VGI in their official databases.

The methodology presented here is based on participatory approaches that consider capacities in local communities and norms, as advocated by the institutional framework of the FFP approach (Zevenbergen *et al.*, 2013). It has outlined six components necessary for a participatory LAS that incorporate guiding principles provided by FIG and GLTN (Enemark *et al.*, 2015) for agencies intending to establish FFP LAS in developing countries. Even though the guiding principles stress that accuracy should relate to the purpose rather than conformance to standards-based processes, the data collection study has revealed that officials at the Land Board would trust and consider VGI use in their official systems if it had some accuracy and reliability measures. However, most developing countries have insufficient datasets in official systems to be used as ground truth. In addition, the involvement of the public who in most cases are not geographic information experts means that the contributed datasets are likely to have varying quality. Therefore, this study proposes a novel TRM methodology to establish the quality of contributed datasets and credibility of contributors.

Even though TRM addresses positional accuracy, it concentrates on attribute accuracy determination which has received less attention from the research community. The lack of ground truth means that quality assessment cannot be conducted using the common scientific measure of RMSE. Nonetheless, an RTK survey was conducted in the study area to mimic ground truth and a further positional deviation computation was conducted on contributed datasets against expert data. The objective of the latter was to investigate if it could be used in the absence of ground truth and where surveys cannot be conducted. For attribute accuracy determination, TRM uses: the many eyes principle to determine thematic accuracy; human computation for semantic accuracy determination; and data provenance to establish volunteer reputation. The anticipation is that these quality assurance measures can establish trust and confidence in officials to consider VGI in their official databases. By proposing separate metrics, this study takes into consideration that feature ratings are based on an individual's perception of the quality of an entity on an FFP basis. Therefore, every user can view the features differently because of the purpose intended. For example, a feature rated as good by one user can be rated as bad by another, depending on whether it serves their purpose and needs.

As volunteers classified more land parcels, they became familiar with the application and could effectively navigate through it, identify and correctly classify the pre-defined land parcels. On average, the cross-tabulation results showed improvements in the contributed labels in the last ten of the 30 classified land parcels: a large proportion of experts agreements on volunteer labels were observed. It was concluded that the more participants interacted with the VGI application, the more they became familiar with its contents, which subsequently improved their accuracy. Chapter 6 presents the results obtained from the data collection study using the methodologies outlined here and discusses their significance and potential uses in improving official systems at Land Boards.

Chapter 6. Analysis and significance of volunteered geographic information collected from the study area

This chapter presents results obtained from all the three phases of data collection conducted in this study. The first phase outlines the results of the preliminary data collection study and their significance in informing and guiding the development of the participatory VGI initiative with a potential to add value to official LAS. This chapter further presents results from the third phase of the data collection study (Section 5.1) where members of the public identified and provided attribute data of the land parcels in their local community and further digitized land parcels of different land uses within the same area. Experts later assessed, rated and commented on the accuracy and reliability of the contributed datasets. The results obtained from the consensus agreement of experts about public contributions were then used to measure the 'proxy' quality of contributed datasets and credibility of the public (volunteers) using TRM indicators outlined in Figure 5-8. The objective of the digitizing activity was to examine how well participants could semantically identify and accurately digitize visible boundaries of the pre-defined land parcels. The extent to which VGI deviates from ground truth was then computed to determine how well it conformed to standard specifications of official systems, which informed its potential application areas in formal databases.

6.1 Results of the preliminary data collection study

A mixed method approach was used to analyse the preliminary results obtained. The approach proved to be valuable, as strengths from both qualitative and quantitative methods were satisfactorily integrated to produce information beneficial to the study. The results of the study provided understandings about perceptions of the public and civil servants regarding the status of land administration in the country. The consensus is that current systems are outdated, prone to abuse, and lack the policies and standards, which are prominent in well-functioning LAS. From the study, it can be deduced that participants are aware of technological developments of Web mapping applications.

Respondents in the **public** stressed their unhappiness about the current state of LAS in the study area. Their concerns were that the current systems and procedures were outdated and did not meet their requirements. Furthermore, they themselves suggested practices that could improve service delivery at the Land Board, including a) proper recording of land transactions, particularly transfers and property sales, b) shortening of land transfer processes, c) strict

adherence to service standards, d) improvement of the filing system by using modern computerized systems for effective storage, management and discovery of land information, e) transparency, f) systematic surveying and adjudication of land rights to provide citizens with title deeds instead of certificate of land rights documents, and g) inclusion of public participation in land related activities. Most participants from the public indicated that they would use and contribute land information to a Web map application if it existed. Furthermore, they suggested functionalities and services that they would like to have in the Web map application. These included capabilities to a) securely log into the application, b) update and modify their own land records, c) perform simple spatial analysis for informed decision making, d) report illegal and mismanagement of land related activities, e) initiate or request for services online, and f) subjectively assess and comment on inputs contributed by their peers (Figure 6-1).

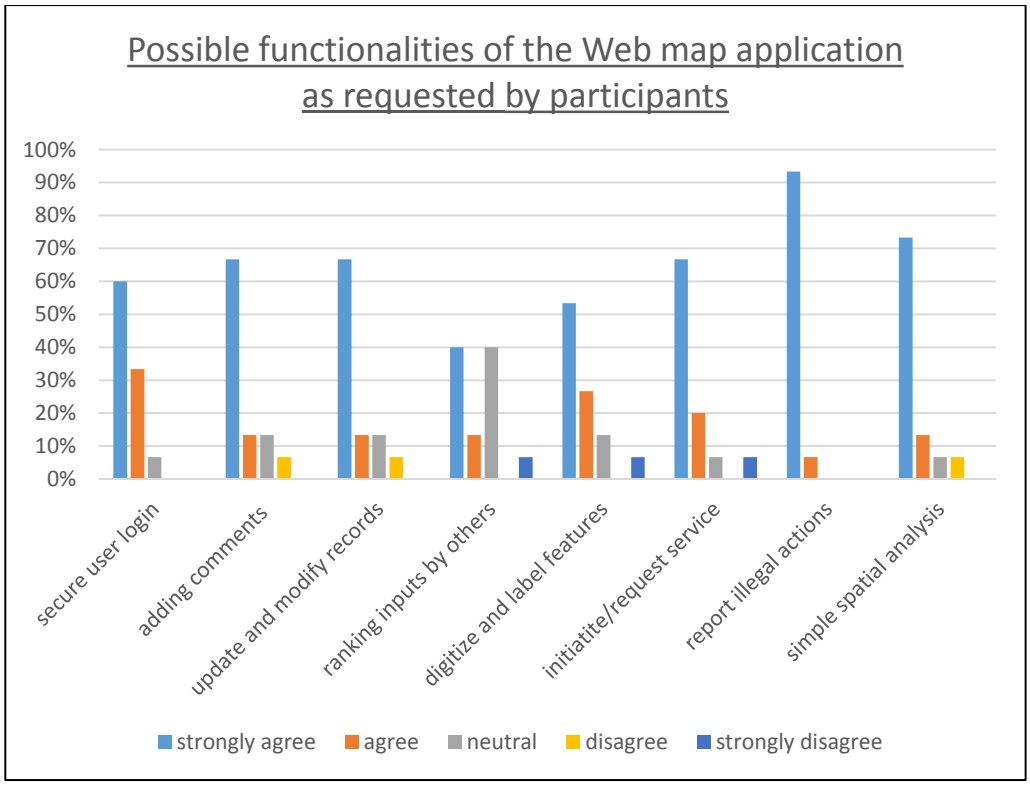


Figure 6-1. Possible functionalities of the web map application as requested by participants.

Participants from the public have stressed their desire to have a Web map application to support existing LAS that enables them to contribute information, such as updating their land records, and initiating and requesting for services from Land Boards at their convenience. Data accuracy and reliability are major concerns in existing VGI platforms (Comber *et al.*, 2013). However, many respondents (80%) from the public believed that the contributions could be reliable and

accurate enough to be used on an FFP basis. Currently, official systems are reliant on strict standards-based procedures: they only recognise cadastral datasets obtained from high accuracy GPS-sourced land surveys, produced by professional land surveyors; their current laws and regulations do not have provisions for public participation in terms of geospatial data and land information production. As a result, they do not have measures and procedures that recognise the FFP approach.

The results obtained from **civil servants** indicate that they are genuinely concerned about current land administration procedures as they are outdated and do not fulfil the mandates they were initially established for: the effective and efficient management of land and its resources in the jurisdiction. Despite technological advancements in Web-based technologies which have eased data sharing activities between organisations, respondents stressed that Land Boards have failed to take advantage of them to ease and expedite land transactions. Some of the barriers cited by participants inhibiting data sharing include (Figure 6-2): a) lack of policies and standards, b) lack of enabling infrastructures, c) insufficient public engagement and consultations in land issues resulting in lack of awareness and trust by local communities, d) high costs of geospatial data, and e) over-reliance on manual filing systems. These barriers are non-mutually exclusive as they can occur simultaneously. For example, the lack of an enabling infrastructure may be a reason why there is over-reliance on manual filing systems at Land Boards.

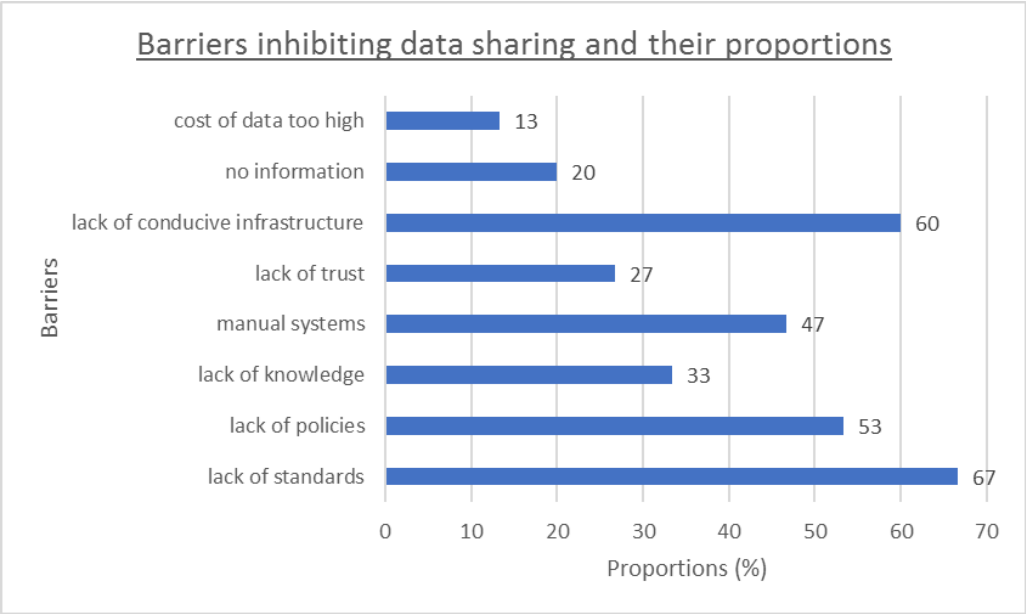


Figure 6-2. Barriers inhibiting geospatial data sharing and their proportions as highlighted by civil servants.

Participants from the civil service trust that the public can play an active role in contributing positively towards current LAS. They are confident that public contributions can be trusted and used to improve existing land records. The expectation regarding a Web-based participatory system is that it could improve the public's awareness of land related issues, thus result in better management of land and its resources. Despite these endorsements by the civil servants, they also outlined some concerns and issues likely to be brought about by a participatory system: a) protection and security of confidential information, b) prevention of abuse of the system, c) detection of fraudulent activities to increase trust in the system, d) storage, manipulation and dissemination of geospatial data contributed by the public, and e) quality assurance measures of contributed datasets. It is evident that the civil service supports the idea of a Web-based participatory system as they are confident it can improve current LAS especially in updating current records, creating new local information, and securing tenure for undocumented legitimate land parcel owners.

6.2 Assessment and evaluation of data collection results

The innovative TRM consists of four data quality indicators to quantify trust and reputation of VGI, which include: a) thematic accuracy, b) semantic accuracy, c) credibility assessment, and d) geometric accuracy measures. The results and significance of these indicators are elaborated in the following sub-sections.

6.2.1 Thematic accuracy results

Geographic information has individual qualities that require modelling to capture agreements between users (Goodchild, 2009). For **currency evaluation** of contributed datasets, experts assessed and rated the **development status** parameters as classified by participants. Fleiss Kappa, a statistical measure of inter-rater reliability was then used to quantify agreement among experts' ratings about volunteer contributions.

The degree of agreement of experts who assessed citizen's interpretation of residential land parcels' development status was 80%: thus, the vast majority of experts agreed that the land parcels investigated had been correctly classified by the participants. A Kappa statistic measure of 0.65 (0.36 – 0.94, 95% confidence interval) was obtained (Table 6-1). This represents a 'substantial agreement' of experts in the public's decisions (Landis and Koch, 1977). The Kappa value obtained shows an above average degree of agreement between experts on contributed datasets, but with low precision (large confidence interval margin): confidence and trust can be placed on the development status classifications of contributed datasets, but caution should be observed. A value of Kappa more than 0.5 shows that there is an agreement between the raters. In this study, the coefficient of the agreement is 0.65. Nonetheless, a large confidence interval (0.36 – 0.94 at 95% confidence) was obtained, which indicates that the extent of agreement is moderate.

Table 6-1. Thematic accuracy measures of contributed datasets.

Parameter	Kappa Measures for each Block						Average Kappa	Confidence interval margin	Agreement level
	Blk 1	Blk 2	Blk 3	Blk 4	Blk 5	Blk 6			
Dev. status	0.518	0.607	0.572	0.844	0.718	0.653	0.650	Large – low precision	Substantial
Land use	0.703	0.813	0.820	0.750	0.796	0.795	0.780	Small – high precision	Substantial

Adverse outcomes and variations were observed between expert ratings in the assessment of development status classifications of agricultural land parcels. Many classified as 'developed' by the public were regarded by some experts as incorrect. Further investigation revealed that there were no clear distinctions in official systems of what constituted a developed agricultural land parcel and what did not: for example, a land parcel cleared of vegetation and with a boundary fence was classified as 'developed' by the participants, while seven of the 15 experts considered it 'undeveloped' due to a lack of a habitable structure. This is a sign of a lack of clarity in official systems of the definition of appropriate levels of alteration in an agricultural

entity. This is not a challenge to VGI when adopted on an FFP basis, because the emphasis is on purpose rather than conformance to strict standards-based processes. An initiative based on FFP principles concentrates on providing services that fulfil customer needs, rather than adapting to standards-based procedures which may be expensive and unaffordable to many developing countries. For example, one of the key principles of the FFP approach states that land information accuracy should be understood as a relative issue, concerned with the use of the information to control land use and increase the security of tenure, rather than following advanced technical standards (Enemark *et al.*, 2014). Other land uses investigated showed minor variations among experts' ratings with the modal rating values considered final classifications of the entities. For example, an entity would be rated 'true' by eight experts and 'false' by seven experts, meaning that its resultant classification would be considered 'true'.

TRM relies on the 'power of the crowd' principle, and in this case, land parcels whose land use classes had been rated by at least six experts were considered for the **land use classification measure**. It has been argued that the first five contributions made to a feature have the most influence in producing statistically significant and acceptable results for establishing geospatial data quality, and gauging participants' reliability in a participatory initiative like VGI (Basiouka, 2010; Haklay *et al.*, 2010). There are six common land use types in the study area (industrial, commercial, residential, civic and community, parastatal/government department, and agriculture) and these were used for the classification activity. These land parcels of different land uses were pre-defined with push pins for volunteers to tag and classify. A six-point rating scale related to the classes was designed to help experts provide subjective ratings based on a land use weighted matrix table (Wang *et al.*, 2013): rating values of four and above represented values denoting positive accuracy measures of a land use classification, while those of three and below denoted negative accuracy measures.

The six-point rating scale was determined by the six common land use types in the study area, such that the classified land parcel could belong to one land use class only, thus simplifying the classification and measurement activity. In short, the weighted matrix table was used to measure the extent to which volunteers correctly identified and classified land use parameters according to experts' interpretations. For example, a land parcel classified by a volunteer as 'civic and community', yet it is actually 'residential' (by expert's interpretations) would carry more weight than if it was classified as 'industrial' by volunteers. According to the weighted matrix table, civil and community and residential land parcels belong to the same land use zone, thus carrying more similarity weighting, when compared to those in more varying land use zones.

Even though Foody *et al.* (2013) stress that the first five contributions are sufficient for determining the quality of a contributed dataset through classification, this study engaged six participants for the activity. The anticipation was that better quality results could be achieved with increasing the number of participants.

Out of the 180 (30 in each of 6 land use zones) land parcels considered for land use classification accuracy determination, 165 records contributed by the public had been rated by experts. Of these, 138 had average ratings of four and above (Figure 6-3): 84% of the rated land parcels contributed by the public. 19 land parcels received average rating scores of four, 69 got a rating of five and 50 land parcels received maximum average rating scores of six. The remaining 27 land parcels received average rating scores of less than three denoting incorrect classifications.

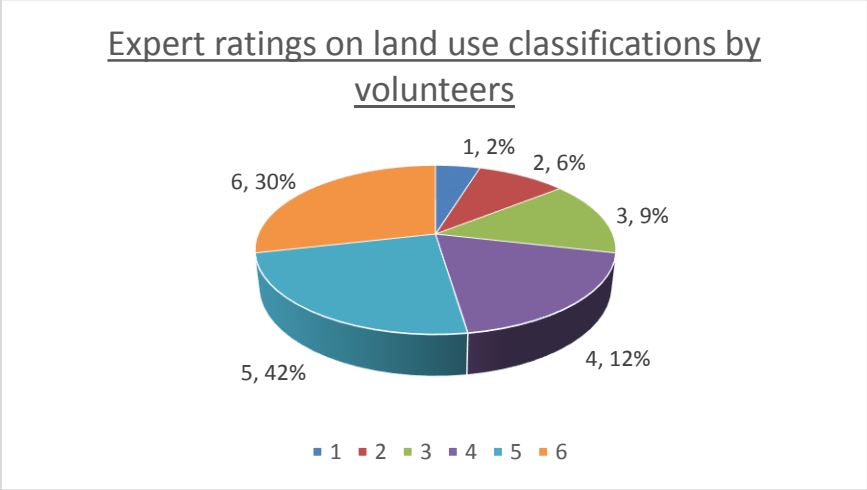


Figure 6-3. Expert ratings of land use parameters classified by volunteers using the six-point rating scale.

To measure the validity of the results from the frequency distribution calculation, an inter-rater agreement of expert ratings was computed. Land use classes accepted as the final classifications from expert ratings of volunteer inputs were computed to determine the degree to which experts agreed with them. A Fleiss Kappa coefficient value of 0.78 (0.69 – 0.87, 95% confidence interval) was obtained (Table 6-1): this is a 'substantial' level of agreement, with a small confidence interval range showing a high degree of agreement of experts with land use classifications contributed by the public. This means that confidence and trust can be placed on the reliability of land use classifications by the public in this case.

Overall, it can be resolved that thematic accuracy enforces the trust element of VGI when trusted intermediaries are tasked with an objective of assessing and rating the reliability of volunteer contributions: Kappa statistic measures can be used to determine agreement between

trusted intermediaries. A high degree of agreement of experts' ratings has been obtained from volunteer contributions, classifying land parcels' development status and land use parameters. This implies that confidence and trust can be placed in such data sets in any VGI initiative. The high degree of agreement of experts on contributed datasets by the public implies that participants are familiar with their environment and its surroundings. Therefore, they can be trusted to produce accurate and reliable results in a participatory initiative like VGI. Despite the use of mathematical computations, the basis of Kappa is on consensus-based principles. These principles are like adjudication measures practised in traditional Kgotla set-ups in developing countries. The familiarity of the public with consensus-based practices suggests that they can be trusted in policing themselves and use diplomatic means to adjudicate of contributed datasets from their peers.

6.2.2 Semantic accuracy results

For the **semantic accuracy** measure, multiple labels from volunteers who tagged pre-defined land parcels were used as input data. In this instance, participants used freehand to classify occupancy parameters of 30 land parcels based on their local knowledge. On average, each land parcel was classified by 15 volunteers. This meant that at least 15 multiple records were received for each land parcel **occupancy classification**. The aggregation algorithm of SPARQL was used to merge classifications with similar descriptions (Table 6-2).

Table 6-2 shows a sample of the consolidated output of the HC approach with the SPARQL query results indicating occupancy parameters, their aggregated outputs and percentages, and a list of volunteers who provided the consolidated occupancy classifications. The latter specifies those volunteers who provided similar classifications of the land parcel's occupancy in large numbers for an eventual aggregation and placement has the final occupancy label. The table is merely an extract of the full dataset which shows five land parcels chosen at random to demonstrate the consolidated SPARQL query results of the occupancy parameter. The structure of Table 6-2 is as follows: a) volunteers independently contribute land parcel occupancy labels in the Web map application (Field 1), b) the labels are then converted to RDF for easier manipulation and computation using SPARQL in Datalift software, c) SPARQL computation involves aggregation of labels with similar lexical terms and providing an output of labels with the most number of contributions (Field 2), and d) the software then provides an output that

consists of the above-mentioned Fields together with a Field about percentages of Field 2 and a list of volunteers who provided the aggregated labels in Field 1.

The table provides a detailed understanding of final land parcel occupancy label based on the classification which gathered the most similar lexical terms. For example, it shows that 'Pilane brick moulding plant' received a maximum of six similar labels (40%), and the six volunteers have been listed under the volunteers' field. Moreover, two Supermarkets (Sefalana Hyper and Saverite) have received the highest percentage of similar classifications (80%) from volunteers. The consolidated outputs can later be incorporated into the VGI application as the final occupancy labels of the land parcels. This increases the semantic accuracy of the land parcel's classification, as the occupancy label with the highest number of similar contributions is consolidated as its final classification label.

Table 6-2. SPARQL consolidated output of land parcel occupancy and volunteers.

Land parcel occupancy label	Aggregated count	Percentage (%)	Volunteers (V)
Pilane scrap yard	7	46.7	V1, V2, V3, V6, V9, V13, V15
Pilane brick moulding plant	6	40.0	V1, V4, V7, V8, V11, V14
Nutri Feeds Botswana	11	73.3	V1, V2, V3, V4, V5, V6, V8, V11, V12, V13, V15
Sefalana Hyper Supermarket	12	80.0	V1, V3, V4, V5, V7, V8, V9, V10, V11, V13, V14, V15
Saverite Supermarket	12	80.0	V1, V2, V3, V4, V5, V7, V8, V9, V10, V12, V13, V14
…	…	…	….

There were instances where final volunteer occupancy labels differed significantly from each other, and this was observed in some commercial enterprises (Table 6-3). For example, some participants preferred to describe a land parcel's occupancy with the entity's owner name (this is a norm in the area), others used a popular old name, whereas some used its current trading name. Table 6-3 demonstrates that certain norms within the community, like the common names used by the public to describe land parcel entities, have the potential to increase semantic heterogeneity and complexity of the VGI initiative. Such observations require further investigation by potential stakeholders for the classifications to be trusted and relied upon.

Table 6-3. SPARQL consolidated output of different land parcel occupancy labels.

Land parcel occupancy label	Description of label	Aggregated count	Percentage (%)	Volunteers (V)
Ga Thabo (Thabo's place)	Owner's real name	4	26.7	V3, V6, V8, V10
Masakeng Restaurant	Popular old name	4	26.7	V1, V4, V5, V13
Phaphane Supermarket	Current trading name	4	26.7	V2, V9, V12, V15
Unknown	Unknown	3	20.0	V7, V11, V14

Out of the 180 (30 parcels * 6 zones) land parcels considered for the occupancy parameter, 171 records had been completely classified by volunteers (Figure 6-3). The extent to which the occupancy labels was defined as high, medium and low. Clear occupancy labels with most volunteers fit in the 'high' proportion level, while those records exemplified by Table 6-3, belong to the 'middle' proportion level. Lastly, the records that had the least commonly aggregated values were assigned the 'low' proportion level. Of the 171 records, 123 had the highest proportion of similar aggregated values: 72% of occupancy parameters were correctly classified in 'high' proportions. 36 land parcels had 'medium' aggregated values similar to those depicted in Table 6-3: this was approximately 21% of the total classified values. The remaining 12 parcels (7%), had 'low' varying aggregated values which required further investigation, together with the 36 parcels where participants prefered to use a particular occupancy name because of its popularity. Figure 6-4 implies that trust can be placed on a high proportion (72%) of participants to produce reliable datasets that can be consolidated into a single value to represent final occupancy labels of the contributed land parcels.

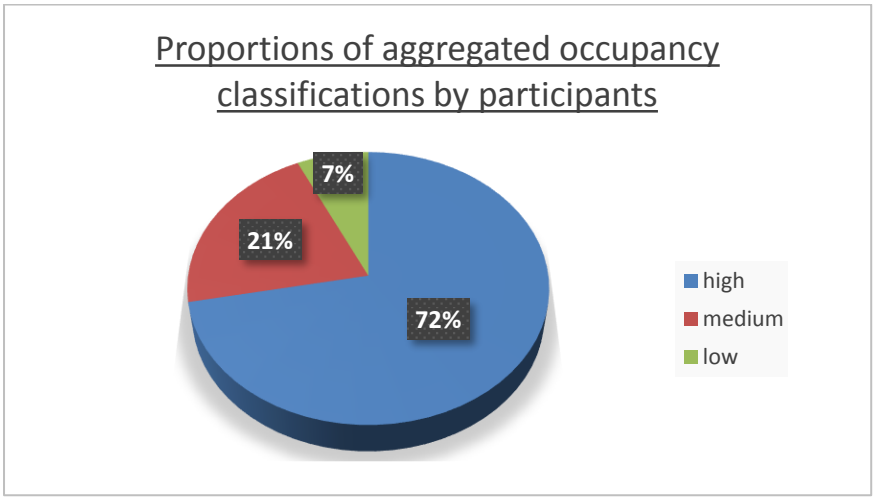


Figure 6-4. Proportions of aggregated occupancy classifications by participants.

The semantic accuracy measure has shown that semantic heterogeneity of contributed datasets can be addressed through HC methods to establish their trustworthiness and reliability.

6.2.3 Volunteer credibility results

With regards to VGI, LCA tests the reputation of volunteers to infer the quality and reliability of their contributed datasets: volunteers with good reputations are expected to produce high

quality and reliable datasets, which potential re-users can confidently utilize for informed decisions. The class with the highest probability is chosen to represent the overall reputation of the volunteer. For example, Table 6-4 shows that volunteer 1 has a single Green class membership, whereas volunteer 2 has two partial class memberships of Orange and Red: his class membership with the highest posterior probability is Orange, so his reputation is allocated there. A labelled snippet of the output file is shown in Table 6-4, which is a sample of the first 30 land parcels (Par1, Par2,….., Par30) classified by 5 volunteers, and their partial class memberships.

Table 6-4 shows four main fields, with Field 1 representing volunteers who took part in the data classification activity (in this case, the first five volunteers are shown). Field 2 shows sample land parcels that were classified by each volunteer and the classification results: a value of one shows a correct classification, while zero shows the opposite. These values were obtained from comparing volunteer classifications against consensus-based classification values of trusted intermediaries, to represent final land parcel tags to be used as input for volunteer reputation computation in Mplus. Field 3 shows Mplus results of partial class memberships, outlining the extent to which volunteers classified land parcel parameters. Lastly, Field 4 (final class) shows the class with the highest posterior probabilities derived from Field 3 (class memberships), which is the reputation class to which a volunteer belong: in this case Green for volunteer 1.

In short, LCA analyses trends and qualities of multiple contributions from a volunteer, which in this case is their land parcel classification competency. This competency is then used as a demonstration of the capabilities of volunteers to produce quality and reliable datasets which a trust element can be placed against them.

Table 6-4. Posterior probabilities of class memberships of volunteers.

Volunteer	Sample Land Parcels						Class Memberships				Final
	1	2	3	4	…	30	Green	Yellow	Orange	Red	Class
1	1	1	0	1	…	0	1	0	0	0	Green
2	0	1	1	0	…	1	0	0	0.997	0.003	Orange
3	1	0	0	1	…	1	1	0	0	0	Green
4	0	1	1	1	…	0	0.987	0	0.013	0	Green
5	1	0	1	1	…	0	0	1	0	0	Yellow
…	…	…	…	…	…	…	…	…	…	…	…

The four-latent class model was equated to a Likert scale to define the reputation categories (r), of very good ($75\% \leq r \leq 100\%$), good ($50\% \leq r < 75\%$), poor ($25\% \leq r < 50\%$) and very poor ($0 \leq r < 25\%$).

A scrutiny of the posterior probabilities for the whole of Table 6-4 shows that the Green class has the most volunteers presenting correct classifications, followed by Yellow, Orange and lastly the Red class. These classes were allocated reputation categories as follows: Green - very good, Yellow - good, Orange - poor and Red - very poor. As a percentage, the class category thresholds were awarded values as shown in Table 6-5. Therefore, a volunteer who belonged to Green class would fall under the 'very good' reputation category and within the 75 – 100 percent range.

The significance of Table 6-5 is that it shows the four possible reputation classes that volunteers can belong, based on their reputation. Field 2 categorizes the reputation classes into four distinct class memberships. Even though LCA allows partial class memberships, there is only one class to which they can belong, and this is the class with the highest posterior probabilities. Lastly, Field 3 indicates thresholds of reputation categories as a percentage for easier comprehension and to enable statistical conclusions to be made on the results obtained. For example, trends, correlations and cluster analysis computations can be computed from the data when proportions are incorporated for more informed decision making.

Table 6-5. Posterior probability classes, their reputation categories and thresholds.

Class	Reputation Category	Thresholds (%)
Green	Very good	75 - 100
Yellow	Good	50 - 74
Orange	Poor	25 - 49
Red	Very Poor	0 - 24

Table 6-6 shows the overall numbers of volunteers who took part in the classification activity and the reputation categories they belong to. The category with the highest number of volunteers is the Green class (very good reputation) at 38.9%. It was followed by Yellow class, the 'good' reputation class which gathered 23 volunteers (25.6%). Combining the two reputation categories (very good and good) provides a total of 58 volunteers out of the total 90 (64.4%). It can be concluded that approximately two-thirds of volunteers were able to correctly classify land parcels in high proportions. This positive sign indicates that volunteers engaged in the data collection activity have awareness about land information in their local community.

Lastly, a minority of participants, 17 (18.9%) and 15 (16.7%) had 'poor' (Yellow class) and 'very poor' (Red class) reputations respectively. These low numbers are an indication that confidence can be placed on a high proportion of participant's contributions about their local community. Content from volunteers with a good record of positive contributions can be trusted by potential consumers on an FFP basis. LCA uses a person's ability to correctly identify and classify several land parcel parameters to represent a reputation category they belong: volunteers with good reputations are characterised by producing geospatial data of good quality and belong to either very good or good reputation classes.

Table 6-6. The overall number of volunteers engaged and their reputations.

Reputation Category	Number of Volunteers	Percentage of Volunteers (%)
Very good	35	38.9
Good	23	25.6
Poor	17	18.9
Very Poor	15	16.7
Total	90	100

Volunteer reputation can be used to infer the quality of VGI. In this case, it can be concluded that about two thirds (64.4%) of volunteers who participated in the activity can be trusted to contribute quality and reliable datasets to the VGI initiative.

6.2.4 Positional accuracy results

The positional horizontal accuracy of contributed land parcels was computed by comparing planimetric coordinates of their well-defined points with coordinates from an independent source of higher accuracy (RTK survey datasets and experts' digitized datasets).

To measure the **positional accuracy** of contributed datasets, an RMSE statistic was computed in the horizontal plane. Three assessments were conducted (Table 6-7): 1) built-up areas (residential), 2) agricultural areas (ploughed fields), and 3) overall RMSE of all data collected. The anticipation was that the three assessments could provide insights about how well participants identified and digitized land parcels with different levels of detail in the orthophoto. Built-up areas are more detailed than agricultural areas, hence expected to produce smaller positional deviations. The tested horizontal accuracy of contributed features in built-up areas against RTK survey datasets was found to be 0.74 meters at 95% confidence interval. Since a 1:5000 map scale orthophoto was used, this conforms to a horizontal data accuracy Class I of the BSMS accuracy threshold (Table 2-1): such high accuracy mapping-grade geospatial data

can be used for the following purposes: a) policy formulations, b) planning, c) decision making at the village level, d) land registration and e) cadastral mapping of sparsely populated areas (GeoManual, 2014).

Table 6-7. RMSE computations for different land uses.

Land Use	RMSE for Volunteers – RTK (m)	RMSE for Volunteers – Experts (m)	Horizontal Accuracy Class
Built-up areas	0.74	0.66	I
Agricultural areas	2.07	1.73	II
Combined land uses	1.59	1.16	I and II

The horizontal positional accuracy determination of agricultural land parcels against RTK survey datasets had an RMSE deviation of 2.07 meters at 95% confidence interval. Despite not having clearer boundaries, agricultural land parcels produced positional deviations of an acceptable Class II category of the GeoManual (2014) specification. Such land parcels can be used for the following mapping purposes: a) standard mapping and geographic information systems (GIS) work, b) general boundary surveys, c) land registration, d) reporting of illegal activities, e) land rights recording of monumental sites, and f) water points location determination. An overall RMSE error of all contributed datasets (residential, commercial, industrial, civic and community, parastatal/government department, and agricultural) was 1.59 meters at 95% confidence interval. The significance of such a result is that confidence and trust can be placed on contributions made by the public regardless of their land uses or spatial location. It implies that when a high-resolution orthophoto is used in the VGI application, high accuracy vector data can be produced by on-screen digitizing at an overall acceptable Class II accuracy level.

Further scrutiny of how well experts digitized similar land parcels to volunteer contributions was conducted to establish the amount of deviation between the two datasets. It was observed that the overall RMSE of volunteer contributions against experts' datasets was 1.16 meters at 95% confidence interval, which was lower than the amount of deviation obtained from RMSE of volunteers against RTK survey data (1.59 meters) (Table 6-7). This result suggests that volunteers can produce land parcels of acceptable Class I (built-up) and Class II (agricultural) accuracy levels of geospatial data when compared to digitized datasets of experts. Moreover, these computations have less positional deviations compared with RTK computations, whose data was acquired through high accuracy surveys. Therefore, digitized datasets by experts can

be trusted and used as ground truth to measure the positional accuracy of volunteer contributions, if survey data is unavailable. To eliminate contributor bias, experts digitized datasets freely without the knowledge that the information would be used to assess the accuracy of volunteer contributions.

6.3 Discussion

This chapter presented results obtained from the data collection study and their assessment using the innovative TRM methodology proposed in this research. The methodology has demonstrated that data quality indicators can be used as 'proxy' measures of VGI quality and credibility of volunteers. The four quality indicators include: a) thematic accuracy, b) semantic accuracy, c) volunteer reputation, and d) positional accuracy.

Thematic accuracy enforces the trust element of VGI when trusted intermediaries are tasked with an objective of assessing and rating the reliability of volunteer contributions: Kappa statistic measures were successfully applied to determine agreement between trusted intermediaries on volunteer classifications of the development status and land use parameters. The substantial levels of the agreement obtained further indicate that experts trust volunteer contributions, particularly development status parameter since it obtained a small confidence interval, symbolizing that there is a high likelihood of agreement among experts, compared to the land use parameter which obtained a large confidence interval. This means that trust can be placed in such datasets in a VGI initiative to improve LAS.

The second indicator (semantic accuracy) also enforces the trust element indicating that similar content produced by many volunteers can be consolidated into a single value using a W3C standardized language for improved VGI quality, and clutter reduction. HC methods have been used to improve semantic heterogeneity common in VGI through the consolidation of contributed land parcels occupancy labels with similar lexical terms, thus reducing clutter and enhancing semantic rigour. This can increase the prospect of adoption of VGI into official databases, as HC argues that a correct classification of an entity can be obtained from an aggregation of contributions with similar vocabulary. The aggregated occupancy parameters of the contributed land parcels demonstrate the success of the HC method applied here, to improve the semantic accuracy of the datasets. About three quarters (72%) of contributed datasets were successfully aggregated, and a final occupancy label presented. This means that the awareness

of volunteers about land parcel occupancies in the study area is very high: their contributions can be relied upon based on this parameter.

The third indicator (volunteer reputation) enforces the reputation element of TRM, indicating that, using LCA methodology, multiple contributions of an individual can be used to infer the quality and reliability of the data they produce. A good reputation is a sign of trustworthiness, which can be used by participants to establish credibility in interacting with others in participatory initiatives like the VGI application developed in this study for land administration purposes. From the results obtained, it can be concluded that a high proportion of volunteers (64.4%) who participated in the data collection activity can be trusted to contribute quality and reliable datasets to the VGI initiative.

The fourth indicator (positional accuracy) enforces the extent to which digitized datasets produced by volunteers deviate from high accuracy GPS cadastral surveys, experts' data, or ground truth if it exists. Standards and specifications used in official systems were used to inform the extent to which datasets from the VGI initiative could add value to official databases. Two computations were conducted: 1) an RMSE computation of contributed datasets against RTK survey datasets produced average positional accuracies of Class II as per the specification document of the study area, and, 2) an RMSE computation of contributed datasets against datasets digitized by experts which produced average positional accuracies of Class I as outlined in Table 6-7.

Overall these positional accuracy results suggest that volunteers can produce land parcels of acceptable Class I (built-up) and Class II (agricultural) accuracy levels of geospatial data when compared to both RTK survey data and digitized datasets of experts. Section 6.1 outlines the potential uses of these datasets in official databases. Therefore, the positional accuracy was positively used to inform the potential uses of VGI in official databases on an FFP basis.

VGI quality assessment in this study is taken as a citizen science initiative to harness volunteer skills to execute tasks of contributing land information and to promote reputable volunteers to trusted intermediary status. Moreover, quantifying data quality and credibility in VGI underpins its usefulness in terms of reliability and trustworthiness. It further informs its potential for incorporation into official systems. The lack of ground truth in developing countries should not be a hindrance for investigating the possibility of VGI adding value and flexibility to official systems. The TRM methodology proposed here is not suggested as a replacement for conventional and rigorous accuracy measures but as an alternative means of providing valuable

land information to LAS in developing countries. This method has been applied to successfully demonstrate that VGI can produce accurate and reliable data sets which can be used to conduct regular systematic updates of geographic information in official systems. Moreover, it has revealed that the positional accuracy of VGI conforms to geospatial data specifications of the study area. Therefore, they can be considered for use in official databases to improve the content and coverage of records contained therein. The following chapter presents the research output of this study and outlines how VGI can be applied as an operational component in the administering of land at the Land Board on an FFP basis.

Chapter 7. A conceptual framework for fit for purpose land administration for Botswana

This chapter presents the research output of this study: a conceptual participatory framework for an FFP LAS based on VGI. It then outlines how this framework can be applied in the context of customary land tenure in Botswana. The conceptual framework demonstrates how a participatory and FFP LAS should appear, by highlighting the important social, legal, technical and institutional aspects for a successful implementation.

The development of the conceptual framework was informed by results obtained from structured interviews conducted in phases 1 and 2 of this study. For example, suggestions provided by civil servants and land law lecturers included the view that is necessary for Botswana to have an enabling infrastructure for the public to actively participate in land administration activities of their communities, which is currently lacking. Moreover, beliefs of civil servants that public contributions could be trusted and used to improve current LAS are positive signs that conducting research on how the latter could be engaged in land issues could produce positive results. In terms of legal issues, insights from land law academics informed the development of Legal Aspects (7.1.2) of the participatory framework, regarding regulatory frameworks facilitating access to land information, public participation, and possible legal issues of utilizing VGI in official systems.

The objective of the conceptual framework is to demonstrate the role that VGI can play in adding value and flexibility to official LAS in developing countries. Part of the context is an acknowledgement by the global community that securing land tenure for citizens in developing countries implies that less conventional forms of land tenure, and its recording, should be recognized and given better forms of security and protection (Payne, 2001; UN-Habitat, 2012; Zevenbergen *et al.*, 2013). Examples of less conventional methods of recording land rights include the use of participatory approaches like VGI which can contribute to an FFP system with low cost and positive time efficiencies. Previous studies have lacked the conceptual framework underpinnings as they only concentrated on the specific benefits, opportunities, challenges and potential risks of implementing a participatory LAS. The framework provides a better understanding of the initiative by identifying wider aspects involved and how they can be leveraged to provide a solid foundation that supports the adoption of VGI in official systems.

7.1 Main aspects of VGI in land administration

The aim of this research is to investigate the role that VGI can play in adding value and flexibility to current LAS in developing countries. Therefore, the conclusion of this research is that there are four major aspects which need to be addressed such that VGI is recognized and utilized in LAS in the study area described in Section 2.7. These are a) social, b) legal, c) technical, and d) institutional aspects. These can highlight potential benefits and key issues that organizations should investigate and address for successful adoption and incorporation of a flexible, inclusive and collaborative initiative into official databases. They were identified and investigated by Zevenbergen *et al.* (2013) and Enemark *et al.* (2015) and used by Rahmatizadeh *et al.* (2016a) to formulate a generic framework to serve as a basis for collecting land rights information from volunteers in a participatory initiative. The aspects are the building blocks of a conceptual participatory framework for an FFP LAS.

7.1.1 Social aspects

The social aspects of VGI projects deal with measures that facilitate active participation, motivation, retention of volunteers and conflict resolution measures. Furthermore, they are concerned with outlining guidelines and procedures in which volunteers can contribute land information with ease, and encourage revisits and improve volunteer experience. Figure 7-1 outlines the main social aspects of VGI which can affect its consideration and application for land administration in official systems. The social aspects stress that understanding the characteristics and behaviour of volunteers is essential to the use of VGI for authoritative purposes. For example, understanding volunteer characteristics and behaviours can help organisations develop participatory applications that focus on meeting their needs: if volunteers believe that the application can improve current land administration processes, this can motivate them to contribute accurate and reliable datasets.

The initial data collection study (phase 1) revealed some user characteristics that include a) eagerness to support and participate in initiatives that aim to improve current conditions regarding land administration in their jurisdiction, b) their loyalty and devotion to local leaders who act as gatekeepers to activities taking place in their community, c) tolerance and patience when interacting with the VGI application, and d) fairness and cooperation in assessing contributions made by their peers. These characteristics are very important for VGI since the overall initiative is dependent on user buy-in, acceptance, optimism, and determination. Furthermore, they indicate that the public is eager to become active stakeholders in an initiative

that promises to address challenges related to land in their area neglected by the Land Authority in the past.

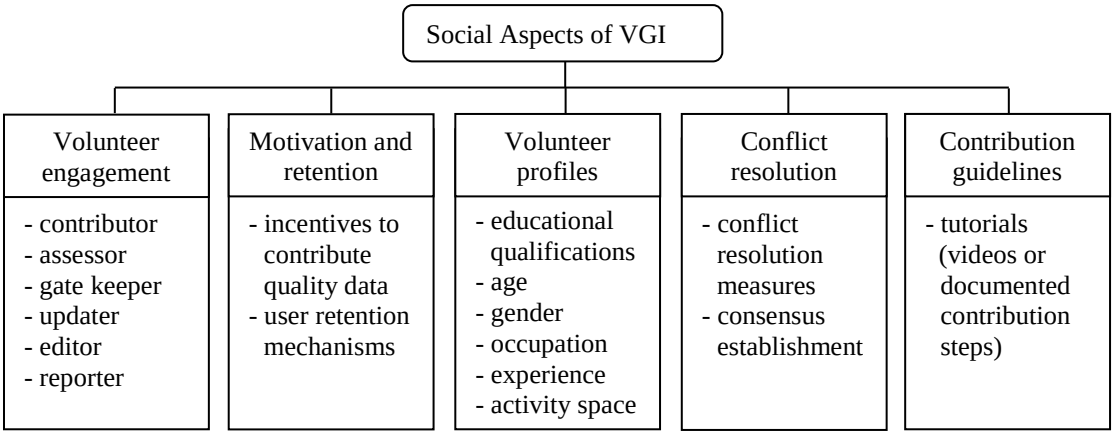


Figure 7-1. The social aspects of VGI in land administration.

Volunteer engagement strategies: A well-defined strategy defining how participants can be engaged in a participatory initiative increases the likelihood of volunteer contributions and the production of reliable datasets about land use, occupancy and cultural heritage sites. Moreover, it is crucial to devise approaches that can promote the initiative and outline its potential benefits towards improving land related issues in the society. For example, the VGI initiative can provide a platform where issues like illegal sand mining, litter dumping and other land mismanagement activities occurring in the community can be reported and acted on by the Land Board. Once engaged, however, volunteers can participate as contributors, assessors, gatekeepers, updaters, editors or reporters of activities taking place in their local community.

Volunteer motivation and retention: Motivations of volunteers vary greatly depending on the nature of the project. For example, volunteers may be driven by altruism or a desire to improve the land administration and cadastral processes of their local area. Some volunteers may have targeted reasons such as the desire to speed up and reduce the costs of official processes. Other motivational factors include social enhancement, career advancements, understanding, self-promotion, personal satisfaction (Tulloch, 2008; Basiouka *et al.*, 2015), financial rewards and reciprocity (Budhathoki, 2010), the pride of place, and protection of personal investments. For example, it was reported in (UN-Habitat, 2012) that slum dwellers in Uganda acknowledged the significance of STDM in addressing their information requirements: the information was successfully used by the slum dwellers to influence policy and development by advocating for their needs to the Ugandan government. Publishing and acting on volunteer contributions in a

timely manner is a major retention factor that encourages participation in future activities (Johnson and Sieber, 2013).

In this instance, participants were motivated by the desire to have a system that engages them as stakeholders in the administration of their land rights through VGI to improve their awareness in land and its related activities of the local area. Moreover, they were motivated by the optimism that VGI could improve current slow and expensive processes at Land Boards, where many opportunities were lost because of such shortcomings.

Volunteer profiles: Collecting volunteer profile information in a participatory initiative can help establish their credibility and reputation, such that the quality of their contributions can later be established and relied upon. Volunteers with experience in handling spatial information, either from their educational qualification or occupation, are more likely to produce better quality information than those without. The information can also help administrators keep track of volunteer contributions for data provenance checks, and reduce abuse of the initiative. For example, during the mapping of Kibera slum in Kenya, volunteers with persistent and consistent contributions were elevated to trusted intermediary status and awarded leader positions in their mapping groups (Panek and Sobotova, 2015). The main challenge is that collecting such personal details from volunteers may discourage potential participants who prefer to contribute anonymously (Flanagin and Metzger, 2008).

In this study, volunteer profiles were collected with the objective of determining the credibility of volunteers and establishing quality trends with regards to their contributions. For example, it was discovered that volunteers with prior experience in dealing with land related matters (mostly land parcel owners) correctly identified a high proportion of land parcel occupancies (87%) and land parcel uses (79%). In contrast, volunteer contributors with no or less experience in land related matters (mostly tenants and aspiring landowners) correctly identified the parameters of interest, land parcel occupancy and land use in low proportions, of 45% and 40% respectively. Therefore, trust and confidence can be placed against contributions from volunteers with more experience in dealing with land related matters, compared to those with little experience.

Conflict resolution: VGI may involve many volunteers contributing spatial information to an initiative. Consequently, there are likely to be conflicting datasets where consensus or synthesis must be agreed upon, involving some datasets taking preference over the other. VGI can involve the handling and representation of multiple views, so there must be well-defined means of

determining how conflicting datasets, analyses and interpretations can be solved in the initiative. Customary conflict resolution measures can be employed to resolve misunderstandings between volunteers, since they encourage dialogue to seek consensus, negotiate tradeoffs and are credited with high legitimacy (Smith, 2003). For example, traditional conflict resolution measures bring consensus to a problem by involving all parties involved and stakeholders to establish a shared understanding between contrasting volunteer contributions.

In this study, whenever conflicting datasets were received, as in the example of land parcel occupancies described either by a trading name, owner or the most common previous name, consensus-based conflict resolution measures were employed. This strategy involved further consultation with community members for adjudication and consensus building. Eventually, the name with a majority vote was adopted as the final land parcel label of the entity of interest.

Contribution guidelines: To ensure that volunteers contribute quality and reliable datasets, there should be appropriate documentation and guidelines of how they can interact effectively with the initiative. Proper documentation can further improve the usability of the initiative, facilitate the production of reliable land information and promote buy-in from all stakeholders.

The VGI initiative depends on the active participation of volunteers, hence there should be well-defined strategies of how they can be engaged, motivated, and retained for it to be sustainable. Understanding volunteer characteristics is important as research (Budhathoki, 2010) has shown that data quality can be inferred from the experience that volunteers have in handling spatial data. Conflicting datasets are anticipated in the initiative, from the variety of volunteers many of whom are non-experts in handling geographic information: measures of addressing conflict in volunteer contributions should be put in place. To improve the confidence of participants interacting with the application and increase the likelihood of producing accurate and reliable datasets, it was ensured that demonstrations of system use (Figure 5-7) were a two-way dialogue procedure between the researcher and participant. The usability evaluation measure conducted in the case study further strengthened the technical, usability and overall interactivity of the VGI application used in the implementation stage (Section 5.1) to produce reliable datasets as evidenced by the TRM methodology.

7.1.2 Legal aspects

Legal issues likely to arise with the use of VGI in official systems, particularly those which have a statutory or jurisdictional role, are determined by the nature of the information and activities to be performed with it (Figure 7-2). Developers of VGI-based initiatives in LAS need to be aware of possible and emerging legal issues of utilizing VGI in official systems. Most of the data in official systems have legal status, therefore caution must be practised when dealing with data contributed by volunteers.

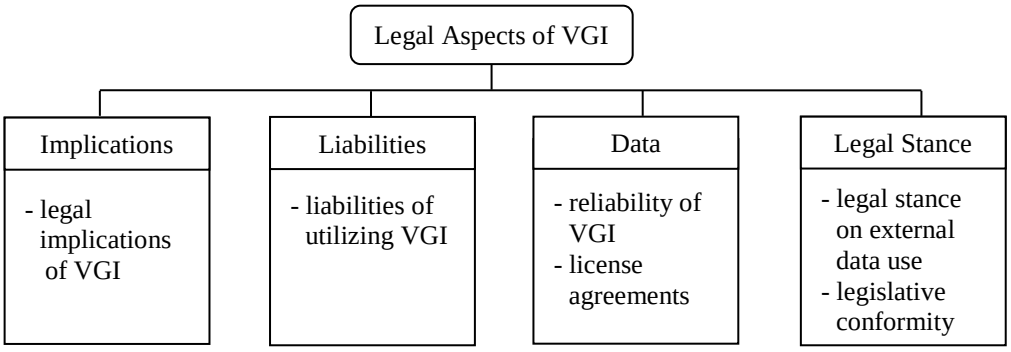


Figure 7-2. The legal aspects of VGI in land administration.

Legal implications of VGI: VGI quality and collection processes differ significantly from those employed for formal and official datasets, and constraints for its adoption in official databases can emerge. Currently, VGI is unlikely to have legal standing such that, for example, liability can be identified when contributed data is incorrect. In contrast, authoritative datasets have legal implications and strict measures can be taken against data collectors who contribute misleading or incorrect datasets. This disparity may marginalize VGI as an alternative source of valuable land information. Rahmatizadeh *et al.* (2016a) suggest that distinguishing between mandatory or legislative data, and other types of useful datasets not legislatively prescribed would be useful. According to their study, VGI could be used at an indicative level rather than for legally binding decisions. Moreover, it could be adopted for improving land information with no or fewer legal consequences, especially where it does not require a high level of governmental guarantees (Bennett, 2008).

Potential liabilities: VGI may consist of land information that is of insufficient quality, and this is a liability issue that requires consideration. VGI initiatives, like OSM, can use disclaimers and notices to exclude any potential liability that may arise from the use of the contributed datasets, when their quality cannot be verified (Basiouka *et al.*, 2015). Since contributors cannot be held legally responsible for their contributions, VGI initiatives should

establish procedures that address the publication of insufficient quality data through legal disclaimers or license agreements.

Data reliability: According to Scassa (2013) license agreements in VGI platforms should specify that contributions are voluntary and that volunteers acknowledge that they have no claims to the composite work, which shall become ownership of the platform owner. In contrast, OSM has an approach which declares that the copyright of the whole dataset belongs to all contributors (O'Rourke, 2013). For contributed information considered as 'works' (e.g. photographs), license agreements must ensure that the rights of volunteers are clear as to what they retain and those retained by the site operator (Scassa, 2013). This is particularly important when site operators wish to publish and distribute such contributed content, and whether they should seek exclusive (or non-exclusive) rights from the contributors.

Legal stance on external data: Countries like New Zealand have a legal stance that VGI should not be integrated into the fundamental cadastre, and that all information be lodged and certified by licensed cadastral surveyors (Grant *et al.*, 2014). The lack of legal standing and possible liabilities of VGI can reduce its suitability for consideration in official systems. Developing countries with their limited resources should be open to such VGI contributions as information that can be adopted to improve official LAS. For example, this research has demonstrated that the public can produce land information that can be valuable to official systems. Valuable land information, in this case, can refer to land use, occupancy and development status classifications on contributed datasets that the TRM methodology has proved to be of acceptable 'proxy' quality: thus, it can be considered in updating official databases on an FFP basis.

From discussion with experts, the consensus is that VGI does have a role to play in improving official records. However, the following legal aspects should be considered for a successful implementation and utilization: a) since VGI currently does not have any legal validity, experts concluded that it could be used for improving land information which does not require any high level of governmental guarantees with no legal consequences. For example, it could be used for updating ownership information like contact details, postal address, certificate type, occupancy and land use parameters; b) since VGI can contain land information of insufficient quality, experts suggested the use of legal disclaimers and notices to exclude any potential liability resulting from the use of the contributed datasets; c) for data reliability, experts suggested the

drafting of policies and specifications in line with official procedures to improve the trust and reliability of the contributed datasets.

VGI can be unreliable, therefore there should be license agreements or declarations regarding the use of the contributed datasets. These can help protect both the contributor and the consumers if the eventual use of the data does not meet the needs of the consumer, as there cannot be legal suits on clearly stipulated declarations. To ensure that VGI adds value to official systems, authorities should develop policies, standards and specifications that allow external data to be incorporated into their authoritative systems. Even though the study area does not have a legal stance regarding external data, it recognizes that it can be beneficial in rural areas without coverage to support current systems as outlined in Section 2.7. Moreover, this research has demonstrated that the public can produce reliable geospatial datasets that can be utilized for various land uses as shown in Section 6.1.

7.1.3 Technical aspects

A sound technical environment facilitates the generation of VGI and should be implemented such that a developed system is easily accessible, encourages continuous participation and ensures the contribution of good quality data (Figure 7-3). For example, the system should have established checks and balances, like authentication systems and topology checks to reject incorrect or impossible contributions for volunteers to provide reliable datasets. The use of available IT resources within local communities and the development of enabling platforms should allow volunteers to actively contribute, update, review and share land information of their local environment.

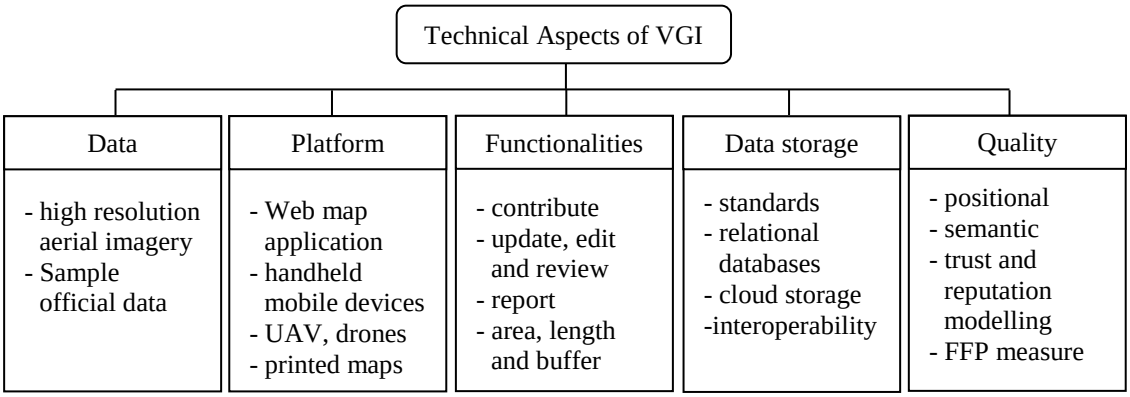


Figure 7-3. The technical aspects of VGI in land administration.

Data: The FFP concept advocates the use of high-resolution satellite images to collect geospatial data, and the adoption of general boundaries mapping (Enemark *et al.*, 2014) to address challenges of outdatedness and lack of data in official systems to meet consumer needs. Sample datasets, where existent, can be used to determine the extent to which contributed datasets deviate from ground truth, which establishes how well it conforms to institutional standards and specifications of the study area. This could well involve the calculation of positional accuracy measures used to inform possible uses of VGI in authoritative systems based on the specifications of the official agency. Attribute datasets like ownership, land use and occupancy details are also important parameters in LAS. Methodologies like TRM can be used to establish trust and confidence of potential consumers on the datasets, particularly where ground truth is non-existent.

Aerial photography is preferred in this study as a primary data source because it provides pictorial views of land parcels, buildings, topography and landscapes that cannot be captured from the ground. However, it has limitations that should be noted such as user interpretation errors, environment, and cost of acquisition. These effects can be mitigated by the following solutions: a) some errors caused by human interpretation can be addressed by ground truthing and a better understanding of the technology involved to perform the required tasks; b) weather factors like cloud cover, fog and rain can also impede the acquisition of quality aerial images: to address this challenge, experts suggest the utilization of sensors attached to space-based platforms and sensors such as Synthetic Aperture Radar (SAR), since they are rarely affected by weather; c) there may be costs associated with setting up of control points on the ground to correlate images collected with ground-grid coordinates and elevations.

Control points can further be used for ground truthing using analytical triangulation which is a process that correlates ground control points with aerial imagery data. To address this challenge of cost, the use of Airborne Global Positioning Systems (ABGPS) can be employed to overcome the need for setting up ground control points (McRoberts *et al.*, 2018). According to the authors, ABGPS always facilitates the knowledge of the aircraft's position relative to the earth, thus reducing the number of ground control points required which saves time and money.

Platform: Instruments like GPS enabled smartphones, hand-held GPS units, tablets and Web maps can be used to address place-based aspects where governments impact everyday life (Drummond and French, 2008). Participatory initiatives can use these instruments to actively

engage local communities to provide land information about their environments, capable of improving and updating official LAS.

Functionalities: Functionalities that enable the creation and management of VGI, especially those which promote the capture and handling of information which is non-existent, or excluded, in official systems, can facilitate the management of land information with a potential of adding value to them. The main functionalities can include input (e.g. volunteer contributions), analysis (e.g. volunteer analysis of existing information), management (e.g. assessment of volunteer contributions by trusted intermediaries) and presentation (e.g. information dissemination). System functions may also involve the updating, reviewing and confirming of existing land information in official databases, by volunteers.

Data Storage: There are many database storage options that can be used to effectively store contributions from volunteers for easier retrieval and manipulation: a) relational databases, b) schema-less databases, and c) cloud storage services. These options can also provide security and authenticity to VGI if properly implemented. To further improve its chances for consideration in authoritative systems, VGI should be stored in database schemas compatible with official databases to allow for seamless integration when necessary (Siriba and Dalyot, 2017). For example, a relational database can be developed for VGI to mimic official database schemas to enable a seamless data integration.

Quality assurance: Currently, there are no agreed-upon quality measures to filter and classify information contributed by volunteers, many of whom are non-geographic information experts. This results in a reluctance of organizations to consider VGI as alternative information of value to support official systems. Establishing stable data quality measures of VGI can increase its possibility of consideration and use in official systems. Studies on quality assurance of VGI have been conducted extensively in the past, addressing the characteristics of spatial and non-spatial elements. Quality aspects have been considered under the headings of: a) thematic accuracy, b) semantic accuracy, c) positional accuracy, d) trust and reputation modelling (TRM), and e) FFP fundamental characteristics (Section 3.2.6).

Inter-rater agreement measures like Kappa are commonly used to establish the level of agreement between two or more raters regarding the classification accuracy of an entity. If more raters agree with the classification of the contributed dataset, a conclusion would be drawn that it was correctly classified. Positional accuracy determination is concerned with comparing contributed data to those in official databases or established ground truth. Such comparison

suffers major drawbacks since it requires access to datasets of known quality, often expensive and/or inaccessible for developing countries (D'Antonio *et al.*, 2014). Semantic accuracy determination uses data provenance as an indicator of VGI quality. In this instance, multiple records of the same entity are aggregated to define a final label and improve semantic rigour. TRM establishes a 'proxy' quality and credibility measure of VGI without reference to ground truth. It uses the power of the crowd principle to establish the level of trust of VGI and characterise the credibility of volunteers. The rationale of the principle is that inaccuracies in contributed datasets can be identified and corrected by many participants, thus reducing errors. Lastly, the FFP accuracy measure is concerned with the capability of a dataset to meet explicit and/or implicit needs of a consumer for a given application in a particular location (Devillers *et al.*, 2010).

Technical aspects outline the quality, storage, usability and consideration of VGI if submitted to official systems. Datasets contributed in such initiatives should be FFP, by ensuring that the platform allows the use of aerial imageries, as used in the VGI application (Section 5.1) for volunteers to delineate and digitize general boundaries of land parcels known to them. Insights gathered from engaging experts in the study area include the observation that data contributed by the public, despite its accuracy concerns, can be used to update databases in official systems since data currency is a major challenge in the area. Experts further believe that platforms like GPS-enabled smartphones, hand-held GPS units, tablets and Web maps have the potential to produce value-added information to complement existing limited datasets in official databases. In a properly functioning VGI initiative, contributed datasets should address deficiencies of current systems. Therefore, experts argue that the initiative should have functionalities that enable participants to input their contributions, analyse existing information, and have capabilities of enabling trusted intermediaries to assess datasets contributed by the public for quality assurance purposes. In addition, the initiative should provide functionalities that enable volunteers to update, edit, and review their land records, and report mismanagement activities as well as contribute land information of their community.

Volunteer contributions should be stored adequately in facilities that allow straightforward retrieval and manipulation. Unfortunately, there are no established quality assurance measures of VGI, and this can increase the reluctance of organizations to consider it for official purposes. Research in the past has shown that the positional accuracy of VGI can be computed against ground truth using RMSE methodology. However, developing countries are characterised by the lack of ground truth, and this has motivated this research to investigate TRM which uses

data quality indicators to establish the quality and reliability of VGI. TRM was successfully demonstrated in Section 6.1 that it can be used to establish the quality of contributed datasets and credibility of volunteers without reference to ground truth.

7.1.4 Institutional aspects

Institutional aspects are concerned with the creation of entities to manage, structure, maintain, secure, and position geospatial data contributed by volunteers, such that it produces accurate and reliable information capable of adding value to official systems. Figure 7-4 shows important components to be taken into consideration for institutions interested in coordinating VGI initiatives that produce valuable land information.

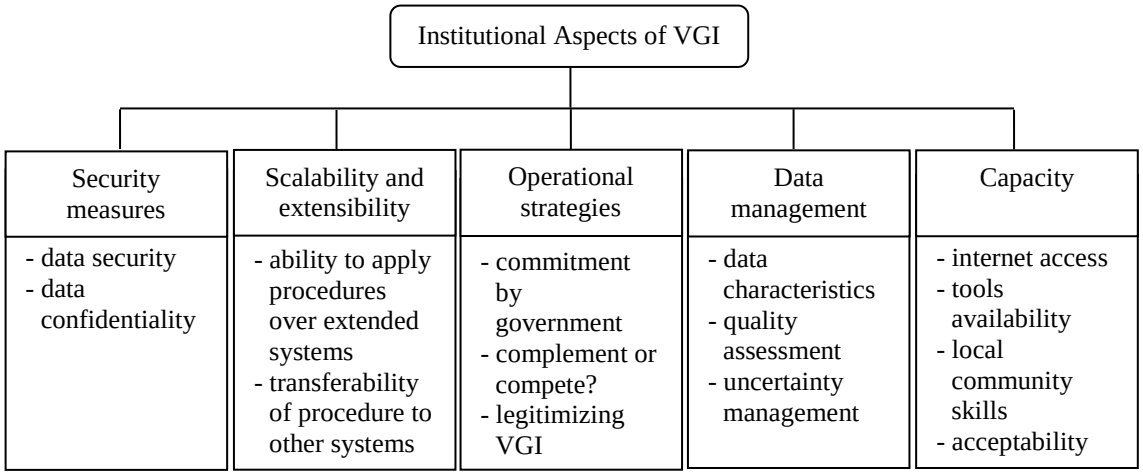


Figure 7-4. The institutional aspects of VGI in land administration.

Security measures: Security and authentication measures should be put in place to prevent the misuse and abuse of the application and to improve its integrity. According to Basiouka *et al.* (2015), the reason why OSM is trusted and valued by its users is because of its functional security and authentication processes. For VGI to be considered in official systems, experts argued that data confidentiality and security are key areas to be sufficiently addressed to curb abuse and fraudulent activities on datasets contributed by the public. These sentiments were further highlighted by participants from the local community, who stressed their fears of losing their possessions if the initiative was not secure enough to protect their contributions.

Land information consists of confidential data that, when exposed to fraudsters, can lead to land parcel owners losing their valuable assets because of unregulated land transactions like sales, land grabbing, theft or forging of certificates of ownership. Therefore, suggestions by both

groups of participants stressed the need to have a VGI initiative which could secure confidential datasets with proper authentication systems.

Scaleability and extensibility: Most institutional departments are under-resourced (either financially, in skills competency, or understaffed). Therefore, there is a need for a low cost, scaleable and extensible system that can help governments to reach most of their citizens. For example, institutions can adopt STDM to provide a scaleable and affordable system which can be customized to meet the needs of local communities. STDM is derived from the LADM, thus it can be deployed countrywide with ease and positioned, such that it is interoperable with other systems from different jurisdictions.

The VGI initiative is expected to grow over time to handle an increasing amount of work. As a result, experts suggested the incorporation of scalability design principles into the initiative, including a) constant availability – for the initiative to maintain its reputation, its uptime is important and it is necessary to provide for quick recovery of system failures and interruptions, b) high performance – to facilitate a rapid response to queries and fast retrieval of information, c) manageability – it has to be easy to operate, maintain and update, and d) cost – what it takes to develop, operate, train, scale and own the VGI initiative.

Operational strategies: The success of a participatory initiative about land administration is dependent on the national government's commitment, as evidenced in the Map Kibera project in Kenya. Such a commitment also helps in the formulation of strategies in line with national policies of the country (Enemark, 2013). Hence, it is necessary to establish mechanisms that could help align the VGI initiative to conform to legal and regulatory frameworks of a country of interest.

Suggestions from experts are that the VGI initiative should develop strategies and operational plans for Land Boards to consider the potential value-added information likely to be produced by actively engaging residents. These include a) challenging officials regarding the way they think about their daily operations, b) conducting detailed strategic and operational analysis to identify gaps and problems in the current systems and providing insights into how they could be addressed through VGI, c) developing clear, achievable action plans to deliver the strategy of incorporating a participatory initiative into the formal processes of Land Boards, d) supporting Land Boards in implementing the initiative, and e) developing key performance indicators, action plans and measurement tools to assess the effectiveness of the initiative over a period of time.

VGI consideration in formal LAS can either be in a complementary and accommodating approach or a competing and substitutive approach (McLaren, 2011; Johnson and Sieber, 2013; Siriba and Dalyot, 2017). It can be positioned such that it is independent of official systems and only used to inform policy development on public lands to validate land registry contents. Such an approach has been termed competing and substitutive by Siriba and Dalyot (2017) and occurs when the VGI-based LAS co-exists with an ineffective formal system. In a complementary and accommodating approach, VGI can fill gaps left by official systems without violating their rules and regulations to enhance their efficiency (McLaren, 2011). Usually, a complementary and accommodating system exists in a stable and effective formal system, while a competing and substitutive system exists in contexts of weak and unstable formal systems (Siriba and Dalyot, 2017). The interplay between which approach is adopted by an institution depends on the strategic intent and the potential value that VGI has in improving their official databases.

Legitimacy defines a popular acceptance of a practice. In terms of land rights, legitimacy is strengthened by material evidence held in organized records (Whittal, 2014). In informal and customary settlements, such material evidence may not exist. To address this challenge, alternative solutions of determining the legitimacy of land rights in such settlements include: a) the use of trusted intermediaries (McLaren, 2013), b) mobilizing public opinion (Foody *et al.*, 2013), c) the use of International Non-Governmental Organizations (NGOs), and d) development of new specific indicators because of the lack of official records (Bishr and Kuhn, 2013; Antoniou and Skopeliti, 2015). These four solutions are also applicable in establishing the quality and credibility of VGI.

Data management: The characteristics and nature of the data to be collected are crucial to its eventual consideration and adoption in official systems. For example, defining the accuracy and knowledge requirements of data and volunteers respectively can influence the adoption of VGI in official LAS (Clouston, 2015). Therefore, to increase the chances of volunteers contributing reliable information, VGI initiatives should allow them to contribute land information they understand and can observe, like land parcel boundaries, road network layouts, building locations, land use and ownership, vegetation extents, and drainage and water features.

For VGI is to be discovered, used and reused to its potential, it must be properly managed. Experts engaged in this study stressed that the requirements for repeatability, transparency and independent evaluation, proper data management principles (FAIR principles) should be applied. These include a) **F**indability – through the use of unique identifiers, b) **A**ccessibility –

establishing appropriate documentation channels to create metadata, c) **I**nteroperability – communities should have well established and persistent approaches to data handling and sharing, like adopting open standards which allow data to be described, structured, discovered and exchanged, and d) **R**e-use – there should be sufficient management and curation of contributed datasets to enable new user groups to find value in reusing the datasets for their own purposes.

Capacity: Capacity development can be a catalyst for the long-term sustainability of the VGI initiative. For example, improving capabilities of land agencies on effective data update and management practices of the application and its products can increase their appreciation of the initiative. Moreover, local communities need to be equipped with the necessary skills to interact with tools that can enable the collection and production of reliable and accurate datasets of their local area.

From an institutional perspective, official systems are characterised by secure environments, so there is a need for VGI initiatives to establish security measures that can safeguard data contributed by volunteers. Developing countries have limited maintenance budgets which can render the scaleability of a participatory initiative unsustainable if it cannot be scaled and extended to other jurisdictions. Lessons learnt from previous initiatives and the tools adopted, like STDM or SOLA, can be implemented in similar projects to ensure that they are transferable, scaleable, extensible, and interoperable with other initiatives. Usually, for LAS, associated VGI should be developed such that it complements official systems and strategies, formulated in line with country policies to ensure commitment, legitimacy and buy-in from the government.

The VGI application in this research successfully utilized vector datasets and an orthophoto used in current official systems, such that conformance of volunteer contributions (particularly positional accuracy) could be determined against specifications of the study area (Section 5.1). Authorities should establish structures of managing uncertainties and heterogeneities likely to occur with VGI. For example, consensus-based approaches could be used to establish a dialogue in data quality assessment measures. Lastly, capacity development is crucial for the long-term sustainability of the initiative, the potential benefits of VGI in LAS should be acknowledged by government and citizens should be encouraged to realize the significance of their local knowledge and how it can add value to current systems.

This section has presented important aspects to be considered if VGI is to be recognized for use in official systems on an FFP basis. The adoption and implementation of these aspects can address the aim of this research: to advocate the recognition of VGI in official systems. Each aspect plays an important part in ensuring that VGI is accurate, reliable, trustworthy, secure, readily accessible, adequately stored and can be seamlessly incorporated into authoritative systems. This also helps in the formulation of strategies in line with national administrative and governance policies. It has been stressed that the success of participatory initiatives in LAS is likely to be dependent on the national government's commitment. The aspects discussed here can be integrated into a conceptual framework to provide a coherent structure to facilitate the production of reliable and trustworthy VGI.

7.2 Conceptual participatory framework for FFP land administration

This study has used the four aspects so far considered to develop a conceptual framework to help define a participatory LAS using contemporary methods, and show how all stakeholders involved can collaborate. Governments can demonstrate their responsiveness to specific concerns of citizens through VGI initiatives to establish two-way communication channels about land administration issues. By adopting VGI initiatives, governments can further reinforce their transparency and participatory components of democratic governance (Johnson and Sieber, 2013). The conceptual framework highlights the fitness of VGI within government and presents broad aspects to be considered prior to its recognition in official systems (Figure 7-5). It provides awareness to governments on how they can position themselves considering the aspects already discussed to adopt VGI into their current flowlines.

The conceptual framework does not claim to address all issues regarding participatory land administration in developing countries. It does not consider the following factors: a) cultural norms, b) religious beliefs, c) social status of volunteers, d) temporal considerations of contributed datasets, and e) real-time monitoring of volunteer contributions. Rather, it highlights important linkages between the four main aspects of land administration to better articulate registering of land in rural areas using participatory means. As suggested by Fast and Rinner (2014) there is a need for formal and standardized frameworks to create VGI for various purposes which can increase its accuracy, reliability, and usability. The proposed framework is based on the participation of citizens in a semi-hybrid approach (Budhathoki, 2010), where local community members are volunteers, and experts represent supervisors and team leaders

of the participatory initiative. The approach involves the active participation of all stakeholders interested in land related matters whereby a) community members participate as contributors (common members of the public) and adjudicators (trusted intermediaries) of contributed datasets using the TRM methodology, and b) experts participate as coordinators, assessors and overall managers of the initiative. It includes both amateurs and experts for its implementation and requires the active participation of NGOs and coordination by local and national land agencies for its success. According to Basiouka *et al.* (2015) projects that put citizens at the centre of decision making and adopt VGI techniques can flourish with the support of experts and governmental bodies.

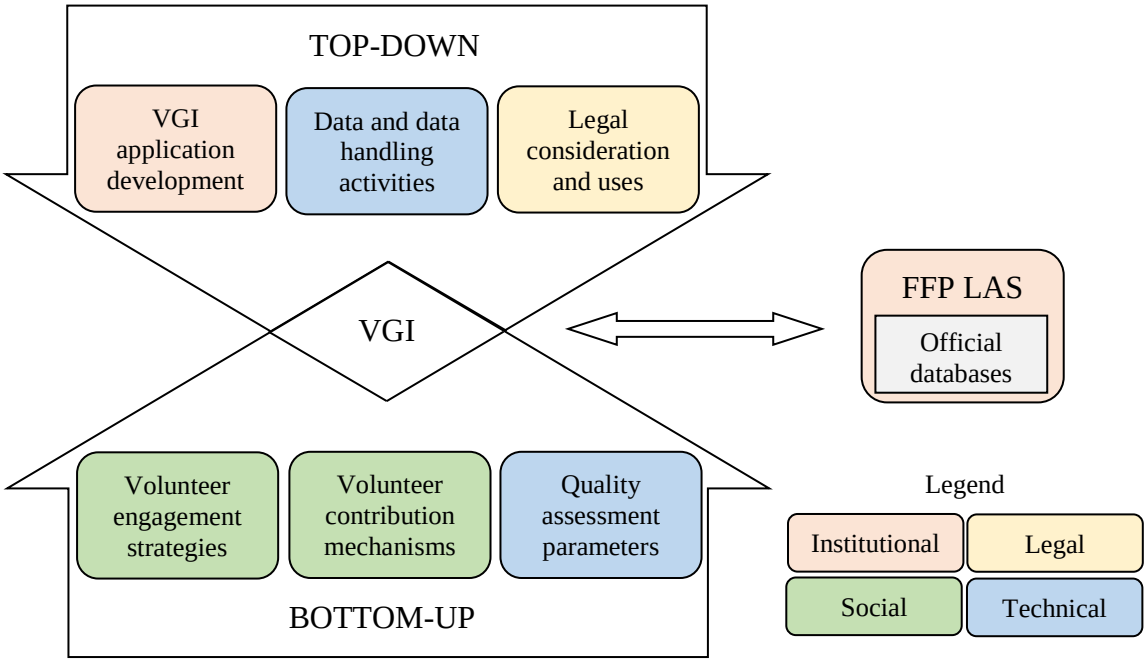


Figure 7-5. Conceptual participatory framework for FFP land administration.

The conceptual participatory framework consists of six components, with half complementary to a top-down approach and the other to a bottom-up approach. The former consists of a) VGI application development, b) data handling, and c) legal stages, while the latter is made up of a) user engagement strategies, b) volunteer contributions, and c) quality assurance stages. The social aspect is confined to the bottom-up approach, while the institutional and legal aspects are in the top-down approach. The technical aspect is contained in each of the approaches since it involves both data handling and quality assurance measures of VGI.

The top-down approach is concerned with the initial system design processes and how the data can be handled in the initiative, and its possible uses and legal implications in official databases. A VGI initiative requires a data collection, analysis and management platform. It should be designed such that it is scaleable and extensible to allow for application in broader areas and for interoperability purposes. Such instances can increase its capacity to handle large amounts of datasets. Furthermore, it should be secure enough to curb abuse and mischievous volunteers, such that trust can be placed on the contributed datasets. A VGI platform should have functionalities that enable participants to contribute their own land information either in the form of digitizing land parcel boundaries or adding descriptive information about land parcels in the application. Moreover, it should have a storage facility that captures all contributions for easier retrieval and manipulation. Eventually, officials are tasked with making the final

decision on the quality and reliability of contributed datasets by using the aspects discussed in Section 7.1 and their possible application areas.

The bottom-up approach deals with volunteers, their contributions and how they can police themselves using TRM to establish the quality and reliability of datasets contributed by other participants. For volunteers to contribute to a VGI initiative, there should be well-defined strategies to motivate and ease their interaction with the type of platform adopted. Furthermore, the development of the platform should allow volunteers to freely contribute land information, edit their contributions, comment and rate the quality of contributions made by other volunteers, as well as flag or report any misleading datasets. The implementation of quality assessment parameters in the bottom-up approach is to emphasize that the TRM methodology provides a platform for the public to police themselves in establishing the quality and credibility of contributed datasets: in this case, the assessment of volunteer contributions is conducted by trusted intermediaries within the community, using the four data quality indicators of the TRM methodology. Furthermore, the TRM methodology facilitates volunteer assessments so that trust and confidence can be placed on contributed datasets. With TRM, participants collaborate in land administration which consequently leads to an enhancement of transparency, decreases costs (McLaren, 2011) and mitigates against the shortage of manpower common in Land Boards.

This section has discussed the conceptual participatory framework which combines the four aspects outlined in Section 7.1, to demonstrate that VGI can be incorporated into official databases. VGI adoption in formal systems requires governments to embrace transparency and democratic governance since it facilitates two-way communication channels for the effective and efficient administration of land and its resources. Therefore, Figure 7-5 outlines a flow of events between the four aspects that include: a) a top-down approach where initial system design processes and its functionalities are discussed to enable active participation in the initiative, b) a bottom-up approach centered on the volunteers to ensure that there are strategies put in place to engage, motivate, and ease their interaction with the system, as well as police themselves to contribute reliable information, and c) another top-down approach concerned with the eventual use of VGI in official databases based on its quality, reliability and potential liabilities. In short, the conceptual framework provides a comprehensive overview and understanding of the complexities and interconnections of the social, legal, technical and institutional aspects necessary for VGI consideration in official LAS on an FFP basis.

7.3 Formalization of VGI into official systems in Botswana

The purpose of this section is to outline how VGI can be formalized in official systems (exemplified by Botswana), taking into consideration research results presented in Chapter 6, which are based on aspects of the Conceptual Participatory Framework. The legal and institutional frameworks of Botswana recognize that non-experts can actively participate in improving LAS especially in rural areas characterised by limited resources. Within the LAS of Botswana, the acceptance of information derived from VGI initiatives could range from the tacit acceptance that there is merit in the alternative system to the full government guarantee of the title (Moreri *et al.*, 2015). Rather than focusing on technical issues like standards, data integration and variable accuracies of the data, emphasis should be on the purpose and practical applications of the contributed datasets. This study implements VGI in a complementary and accommodative approach, and its recognition and involvement of officials shows trust and confidence in the initiative.

The objective of formalizing VGI in the conceptual framework is to increase its accuracy, reliability and potential for consideration and use in official systems. The framework provides an enabling platform to utilize VGI as a mechanism to build local capacity to support collaboration, enhance traditional geospatial data sources and inform decision-making. However, Siriba and Dalyot (2017) argue that processes by which geospatial data are collected (e.g. organizational practices, regulatory issues and technical specifications) can impede the acceptance of VGI in official systems. In this study, the comprehensive overview of the four aspects that make up the conceptual framework provides clarity on how pertinent issues can be addressed to improve the confidence of re-users of VGI. Therefore, the framework provides a formal standardized structure for practical implementation and adoption of VGI in official systems, for a successful implementation.

The formalization of VGI in land administration can be viewed in two forms: a) as an initiative that enables participants to contribute land information as passive collectors, where decision making is only left to officials, or b) as an initiative that provides a two-way dialogue where citizens contribute land information and are involved in decision-making processes as partners with officials (Johnson and Sieber, 2013). The latter provides a compelling argument for VGI acceptance and use and has been adopted in this study. It creates awareness and provides an opportunity for citizens to actively participate in the administration of their land. Rather than incorporating VGI into official databases, the legal aspect of the conceptual framework stresses

that it should be used to inform policy development of communal lands and to validate contents in the land registry, as these do not require any integration of spatial objects.

Based on the findings of this study, there are three categories that VGI can be used by Land Boards: for informational, contextual and cadastral purposes (Haklay *et al.*, 2014). These categories can inform change detection activities, as exemplified by the Centre for Topographic Information in Canada (Haklay *et al.*, 2014). Informational data involves notifications that volunteers can make for the attention of officials (e.g. reports of land mismanagement practices). Contextual contributions involve volunteers updating land records or creating new ones, which can improve the currency of official records (e.g. land use and occupation data). Lastly, cadastral data involves the creation of spatial datasets (e.g. land parcel boundaries and other survey data) that official cadastres can rely on.

7.4 Application of VGI in key problematic processes at the Land Board

This section provides a comprehensive discussion of key problematic areas at Land Boards introduced in Section 5.1 and outlines how the issues can be addressed using VGI to improve service delivery. It further demonstrates that VGI does have a role to play in adding value to land administration challenges at Land Boards. Section 5.1 conducted a scrutiny of key problematic areas at the Land Board to identify and document land transaction delays and their main causes. The objective of the investigations was to understand the root causes of these problematic areas and provide recommendations on how VGI could address them. Moreover, these recommendations can help officials understand specific areas within their administrative processes where VGI can be applied to improve service delivery in current processes. The key land transactions investigated include: a) land transfers, b) lease registrations, c) change of land use, and d) water borehole applications.

7.4.1 Land transfer requests

Plot transfer applications require habitable developments, and their absence can lead to a rejection by Land Boards. However, Land Boards do not have platforms where clients can update their land records regularly and make requests for land transfers and extensions online. Current procedures require technical officers to visit the plot accompanied by both transferee and transferor for development compliance checks (development status and self-extensions). If it is discovered that the plot has an unregulated self-extension, the application is rejected and

the owner requested to revert to the original plot dimensions. It is common for plot owners to increase their plot sizes unlawfully to later demand more financial rewards for them during transfers. Plot allocations in the past had passageways in between them, which facilitate the unauthorized self-extensions to take place.

The allowed plot discrepancies are +/-10% of the plot size depicted in the lease document. These transactions (both the discrepancy checks and unauthorized self-extensions) can delay the land transfer process which could be addressed by the VGI application. For example, plot owners or officials could use the VGI application to verify plot measurements and compare them with those in the lease document to verify if they differ. This information can be used by officials to advise customers accordingly prior to visiting the site for final checks. The third phase of the data collection activity (Section 5.1) revealed that of the 118 requests investigated, 83% (98) of records exceeded the 1-month service period, and the main reasons for the delays were due to compliance checks (Table 5.2). Considering the site visit needed for verifications, a process that took approximately a month to complete can be done within a week with the use of the VGI application.

7.4.2 Lease agreement registrations

The standard timeframe for lease registrations is 2 months according to Land Board procedures as outlined in Section 5.1. 105 records were investigated for this activity and on average, about 75% (79) records were completed after 3 months of customer application date. Just like land transfers, lease registrations require a technical officer to visit the site with the owner to establish if there have not been any unregulated self-extensions. These have been reported by technical officers to be time-consuming and resource wasting as appointments are never adhered to by clients, while sometimes, the Land Board fails to avail transportation for site visits. The VGI application use can eliminate the need for site visits, especially for plots with clear boundaries as discrepancy checks can be conducted online. This procedure can shorten the time taken for applications, and thus enable the Land Board to process requests within the stipulated timeframe of two months. A process that took close to a month to arrange and complete can be conducted successfully in a day with the use of the VGI application.

7.4.3 Change of land use requests

About 69% (52) (Table 5-2) of change of land use records were completed beyond the allocated timeline of 2 months, with key delays identified at the technical office to produce locality sketch

plans. Within the 2-month timeframe allocated for a change of land use requests, sketch plans are expected to be completed during the first month of the customer application. However, more than half of the investigated sketch plans were completed on average after 2 months, thus delaying the application process. A change of land use request requires a land use officer to produce a land use map depicting the current use of the plot in question and those surrounding it to establish the zoning of that area. According to Land Board procedures, change of land use can only be accepted if the change requested is within the zoning of that area. For example, an industrial plot cannot be changed to commercial or residential.

Currently, Land Boards do not have readily available and up-to-date land use maps, which could eliminate the need for site visits. Therefore, officers must visit the site with plot owners every time a change of land use request is received. This procedure requires officers to visit the site with plot owners, thus depleting the already limited capacities of the Land Board. A VGI application with online land use maps can be used for land use zoning checks to expedite change of land use requests, thus increasing service delivery at the Land Board. For example, land use verifications with an up-to-date online map can be completed within a week of receipt of application compared to the current average time taken of 2 months.

7.4.4 Water borehole applications

The timeframe for Land Boards for water borehole allocations is 3 months. About 66% (33) of records examined have been rejected because of non-compliance with allowable distance buffer limits from other neighbouring boreholes. The general rule at Land Boards is that borehole points should have a minimum buffer distance of 5km between them for conservation purposes. The current procedure requires the public to identify and apply for a piece of land to be used as a borehole. Technical officers upon receipt of applications are expected to schedule a site visit with the client to collect GPS coordinates of the area requested whose buffer distance computation is later performed at the office. The coordinates are mapped in a borehole distribution map from a desktop computer and buffer proximity measures calculated against existing nearby boreholes.

The success rate of this procedure is very low (34%) and applicants who fail are usually requested to look for alternative areas of which the same procedure described above will be repeated. A participatory Web application with a map showing existing borehole points of the study area and with functionalities like buffer and distance measures can help address this challenge of borehole rejections. The public can utilize the application to search and identify

suitable borehole sites, which they could apply for at the Land Board. While officers could reduce the current situation of multiple site visits as buffer computations could be conducted at the site using the offline mode capability of the application to determine a suitable borehole location that conforms to Land Board regulations. This could save time and resources for both the clients and officers and further increase success rates of applications. For example, an application that currently takes about 6 months to complete, can be processed and approved within a period of 2 weeks of receipt of a client's application with the use of the VGI application. One week could be reserved for office computations, appointments scheduling and transport logistics, while the other might be for the site visit to identify the suitable area to the customer.

In this section, problematic areas of key Land Board processes where VGI could be applied to improve their delivery time and success rates of applications were presented. An examination of the processes reveals that site visits by officers to produce locality sketch plans for compliance checks are very time consuming and resource wasting requirements which can be addressed using a VGI application. Moreover, the high failure rates of borehole applications due to non-conformance to allowed distance buffer limits can be reduced by using the VGI application, allowing preliminary detailed and accurate computations to be performed before site visits are conducted.

7.5 Summary

This chapter presented the output of this research: a conceptual framework for an FFP LAS based on VGI. Rather than focusing on the benefits, opportunities, challenges and potential risks of a VGI initiative, the framework presents a solid foundation to support the building of a participatory LAS and a better understanding of how the main aspects can be leveraged to produce reliable datasets. The four main aspects highlight parameters necessary for a successful implementation of the VGI initiative:

1. Such that it actively engages local communities and identifies means by which they can be motivated and retained;
2. Identifies legal issues likely to arise with the use of VGI in official systems, their potential liabilities and how they can be mitigated;

3. Presents mechanisms of how a technical environment that facilitates the generation of VGI should be implemented such that the developed system is easily accessible, encourages continuous participation and ensures the contribution of good quality data;
4. Outlines how institutions can manage, structure, maintain, secure, and position geospatial data contributed by volunteers so that it can be recognized in official systems.

Strategies for adopting VGI in formal systems have been presented as well. The semi-hybrid approach of engaging volunteers and experts, as well as the positioning strategies discussed in terms of coordination, are considerations that can lead to the success of the VGI initiative. STDM was successfully implemented in other developing countries with similar social tenures to Botswana. As such, it is considered a viable alternative model compared to proprietary software tools characterised by high license and maintenance fees. However, STDM was not utilized in this research due to its lack of proper documentation particularly on how a server environment and a Web map interface could be linked to QGIS software for a successful implementation of the VGI application. Therefore, technical knowledge is required for implementing open source systems to facilitate STDM.

VGI for land administration can be a participatory initiative where a two-way dialogue is created to involve citizens in decision-making processes of their land. A presentation of problematic areas of key Land Board processes, outlined in Section 5.1 was conducted to demonstrate potential areas where VGI could be applied to improve service delivery and increase the success rates of applications. Moreover, the extents to which VGI could improve these problematic areas have been outlined. It is anticipated that these recommendations can increase confidence in officials to recognize the potential value that VGI has in improving current land administration processes at the Land Board.

In summary, this chapter has outlined the important aspects necessary to design a conceptual framework and demonstrated how they can be incorporated for VGI initiatives to produce trustworthy and reliable datasets with a potential to improve current systems. VGI implementation strategies were outlined as well to provide guidance on the positioning of a participatory initiative such that it complements, rather than compete with current systems. The following chapter presents the key research findings of this study and outlines how they have added value to the body of knowledge of the role that VGI can play in LAS, particularly in developing countries.

Chapter 8. General discussions and conclusions

This chapter presents the key findings of this research and outlines their significance towards the recognition of VGI in LAS in developing countries. It analyses the following: 1) how the main findings of this research address the research objectives, 2) the key research findings, 3) how the research findings contribute to the field of VGI for LAS in developing countries, and 4) the outlook for future research prospects that this study has not investigated, that can be beneficial for VGI initiatives in LAS for developing countries. Lastly, a conclusion of the research will be presented.

VGI was presented in this study as an alternative land information source for official LAS in developing countries. Currently, available limited records in these countries are characterised by outdated, inaccurate and unreliable datasets, which makes it a challenge to properly administer and manage land and its resources. VGI has demonstrated that there is the potential to address this challenge by providing timely, affordable, up-to-date, flexible, and FFP land information to support the limited existing systems. The novel TRM methodology proposed here, has further shown that the public, through a participatory initiative, can collect and produce trustworthy and reliable land information of their local community.

To ensure that a scalable VGI system was developed, suggestions from experts presented in Section 7.1.4 were taken into consideration and incorporated into the final design of the application. For example, it was ensured that the system was constantly available during the data collection phase to establish reputation among its users. Moreover, to improve the performance of the system, map caches were created at different scales to enable the server to draw an appropriate portion of the map whenever a map request of a particular area was made. Map caching makes it quicker for the server to return cached images than to draw the entire map at once, which improves response times of the application. The CMV facilitated the development of an easy to use and cost-effective Web map application that is both scalable and resilient. Overall, the VGI application is based on a free Enterprise Geodatabase (Microsoft SQL Server Express) that allows the integration of geospatial data from multiple sources. Furthermore, it is based on general OGC standards which facilitate interoperability and the building of very flexible Distributed GIS. The latter brings together all types of geospatial data to be discovered and used directly as a map service.

The main output of this research, a conceptual framework for FFP LAS in Botswana, has illustrated how the participatory initiative could be applied to improve the currency, content and coverage of land information in official databases, considering the four aspects outlined in Section 7.1.

8.1 Revisiting research objectives

This research aimed to investigate the role that VGI could play in adding value and flexibility to existing formal LAS in developing countries. This aim was successfully achieved through the accomplishment of the original six objectives as follows:

Objective one: To undertake a review of LAS in developing countries to identify shortcomings in the design, implementation and delivery of LAS.

This objective was addressed in Chapter 2 through a critical review of literature about LAS in five different nations of Africa (Ghana, Uganda, Kenya, South Africa and Botswana) which have adopted modern LAS to better the lives of citizens in these countries. This objective involved conducting a review of LAS in these countries, with emphasis on participatory initiatives to support and advance land rights documentation for rural communities, and identified shortcomings in their design, implementation and delivery. These shortcomings and issues were then categorised, and an overall typology and list of problems encountered by LAS in Sub-Saharan countries presented.

Objective 2: To conduct research on VGI initiatives in developed and developing countries specifically dealing with land issues, and investigate how the initiatives can be adapted in broader land issues such as policy formulations, planning, and decision making in the context of land administration in Botswana.

This objective was addressed in Chapters 2 and 3 through a review of the cadastral system of Botswana as an engine for LAS in rural areas, to better understand how land is administered in the country particularly through *customary* tenure, which is the most challenging, yet covering the most land mass and population. The research has revealed that the government of Botswana has established laws and policies that guide the administration and governance of land tenure systems and further introduced land information systems to facilitate an effective and efficient administration of customary land. Moreover, it was discovered that the legal system of Botswana recognises that non-experts can actively participate in improving LAS, particularly

in rural areas. This discovery provided motivation towards developing, testing and implementing a VGI initiative in the study area. The objective was further addressed by conducting research on participatory activities in developed and developing countries that dealt with land issues, which provided an understanding of how they could be adopted to broader land issues of Botswana.

Objective 3: To conduct research in the study area to identify land information of significance to the local community and to examine how such information can contribute to, and be used to improve official databases.

This objective was addressed in Chapter 5 which involved conducting research in the study area in three phases, preliminary data collection, VGI assessment, and testing the VGI-based implementation. This involved interacting with key stakeholders to understand current processes of administering customary land and the potential of incorporating a participatory initiative capable of producing quality and reliable information to improve official LAS. The data collection study provided an understanding of perceptions of the public and those in the public service regarding the status of land administration in the area, and how a participatory system could be developed, tested, implemented and positioned such that it adds value to current systems in the local community. The land information of significance identified from the interaction with the public, yet not recognized in official systems, was outlined in Section 5.2. This includes social tenure relationships, such as undocumented 'legitimate' land rights; tenancy; subletting; cultural ceremonial areas; communal grazing land; community watering points; old burial sites; and communal ploughing fields.

Objective 4: To develop a VGI Web map application based on ArcGIS Server using ArcGIS Application Programming Interface (API) and Configurable Map Viewer (CMV) to provide a platform that the public can use to contribute land information of their local community.

This objective of VGI application development was addressed in Chapter 5, using the information collected from key stakeholders engaged in this research and insights gathered from studies about participatory systems in Chapter 3. The VGI application consisted of a Web map application based on ArcGIS Server and developed with ArcGIS API and CMV, and a rating system developed separately. The Web map application demonstrated possibilities in the practical handling of VGI by providing a test-bed for the public to identify, map and contribute land information of their local community. The application was successful in collecting important land information about occupancy, development status, land use, and boundary data

of land parcels in the study area from participants, which was used to determine how well the volunteers identified and described the parcels using the TRM methodology. Moreover, the extent to which the datasets digitized by volunteers deviated from high accuracy geospatial datasets were computed, to establish how well they conformed to official geospatial data specifications in the study area.

Objective 5: To develop a trust and reputation modelling system to assess the quality of contributed datasets by the public and credibility of contributors such that trust and confidence can be placed against the datasets.

Chapters 4, 5 and 6 have comprehensively addressed this objective. Chapter 4 presented a methodology for implementing an FFP land administration based on VGI, whose emphasis was on the establishment of quality measures of contributed datasets. Chapter 5 provided an understanding that the key stakeholders in the study area may be reluctant to utilize datasets from the VGI application if they do not trust or have confidence in the contents produced. Further, developing countries are characterised by a lack of geospatial datasets which could be used as ground truth to verify contents contributed by volunteers. This has motivated an investigation of innovative alternative measures of establishing the quality and credibility of VGI without the typical reference to ground truth. A rating system was developed in Section 5.1 to provide a platform where experts were engaged to subjectively assess, rate and comment on datasets contributed by the public. The rating system provided a mechanism for VGI consumers to gauge the quality and reliability of contributed datasets, without reference to ground truth. Therefore, a novel trust and reputation modelling methodology was proposed in Section 5.2 and its results analysed in Section 6.1, successfully demonstrating its effectiveness in inferring trust in contributed datasets using real-world geospatial datasets.

Objective 6: To design a conceptual framework for a fit for purpose land administration system based on volunteered geographic information and apply it in a case study in Botswana.

The output of this research, a conceptual framework for FFP LAS based on VGI was addressed in Chapter 7. The framework demonstrated how a participatory and FFP LAS should be implemented and positioned in a developing country, highlighting the important social, legal, technical and institutional aspects necessary for a successful implementation. It provided a clear understanding of how VGI could be applied in land administration processes of the Land Boards. These were applied in a case study in Botswana where key problematic areas of Land Board processes were highlighted. Furthermore, the strategies and extents to which VGI could

address these challenges (e.g. poor service delivery and application success rate improvement) were outlined.

It can be concluded that the research objectives of this study were successfully achieved. Initially, scrutiny and understanding of challenges in LAS of developing countries were conducted and presented, which provided insights into how a participatory initiative could be positioned such that it adds value to them. An investigation of the success and challenges of participatory initiatives in developed and developing countries was then conducted and this provided an understanding of how a VGI initiative could be adopted in broader land issues of Botswana, the case study area. To understand land information of significance in the study area that could be contributed to the VGI application, a data collection activity was conducted with key stakeholders (the public and officials).

The data collection activity further informed the development of the VGI Web map application as a test bed for the public to contribute land information of the study area. The interaction with officials during the data collection activity further revealed that they would be reluctant to utilize contributed datasets if there was no quality and credibility measure of VGI. This motivated the development of the rating system and the proposal of the TRM methodology which has positively addressed the need for a quality and credibility measure of VGI without reference to ground truth. Research in the past about VGI application in land administration has lacked a solid foundation to support the building of a participatory LAS. Therefore, the output of this research has presented a conceptual framework for FFP LAS based on VGI. The framework has demonstrated how an FFP LAS should appear by highlighting the important social, legal, technical and institutional aspects necessary for a successful implementation.

8.2 Key research findings

Overall, the thesis has shown that:

1. VGI does have a role to play in adding value and flexibility to LAS of developing countries and can address challenges such as outdatedness, inaccuracy, lack of coverage, closedness, and corruption, by providing timely, accurate, affordable FFP land information through the engagement of all key stakeholders. For example, results of the positional accuracy measure suggest that volunteers in the study area can produce geospatial data, including positional data, for land parcels of an overall acceptable Class

II accuracy level when a high-resolution orthophoto is used in the VGI application. Such land parcels can be used for the following mapping purposes in official systems: a) standard mapping and geographic information systems (GIS) work, b) general boundary surveys, c) land registration, d) reporting of illegal activities, e) land rights recording of monumental sites, and f) water points location determination.

2. The public is eager to contribute land information of their local community to improve: their security of tenure, advocacy in the recognition of communal and tribal heritage sites in official systems, the outdatedness of current systems, awareness and active participation in land related activities, and their closed land administration processes at Land Boards. For example, the interaction with different stakeholders in the three data collection phases has revealed the frustrations of the public towards current land administration challenges in the study area. According to some participants, opportunities have been lost because of outdated land records and slow land administration processes. These challenges have increased the eagerness of the public to actively participate in the VGI initiative which can improve their advocacy towards land related issues and address land administration challenges at Land Boards.
3. A VGI application can be developed considering legal and regulatory procedures of local areas to provide a platform where the public can actively participate in land administration activities of the local community, which has the potential of adding value and flexibility to official systems. The VGI application developed in this study considers legal procedures and regulatory frameworks of Mochudi village and this has been achieved by the following activities: a) thorough interaction and consultation with key stakeholders in the area (legal experts, experts in land related issues, land surveyors and adjudication officers at Land Boards), b) reading appropriate documentation and literature, and c) investigating key land administration challenges at Land Boards to identify areas that could be addressed by data collected in the application.
4. The quality of VGI and credibility of volunteers can be determined using TRM methodology proposed in the study, to produce quality and reliable datasets based on four data quality indicators (thematic accuracy, semantic accuracy, volunteer reputation and positional accuracy determination). The indicators were applied successfully and show that:
    a. Agreement measures such as Fleiss Kappa can be used to establish the thematic accuracy of contributed datasets in a VGI initiative. For example, Kappa statistic measures were successfully applied to determine agreement between trusted

intermediaries and volunteers on the latter's classifications of the development status and land use parameters;

b. Semantic accuracy of contributed datasets can be determined by HC methods by aggregating multiple records of the same entity to define a final label of a contributed land parcel and improve semantic rigour. More than two thirds (72%) of contributed datasets were successfully aggregated and a final land parcel occupancy label presented, which reduced semantic heterogeneity and improved their semantic rigour;

c. Volunteer credibility can be measured by LCA based on the content they produce to deduce the quality of their contributions. For example, multiple contributions of an individual were used in the study to infer the quality and reliability of the data they produce: a good reputation is a sign of trustworthiness, which can be used by participants to establish credibility in interacting with others. A high proportion of volunteers (64.4%) who participated in the data collection activity can be trusted to contribute high quality and reliable datasets in the VGI initiative;

d. Positional accuracies of planimetric coordinates of contributed datasets can be determined by computing the extent to which they deviate from ground truth. However, if ground truth does not exist, RTK survey data or digitized data from experts can be used instead. The positional accuracy results obtained in this study indicate that a) an RMSE computation of contributed datasets against RTK survey datasets produced average positional accuracies of Class II as per the specification document of the study area, and, 2) an RMSE computation of contributed datasets against datasets digitized by experts produced average positional accuracies of Class I as outlined in Table 6.7.

5. A conceptual framework for creating VGI can be designed using four connected aspects (social, legal, institutional and technical) necessary for its consideration in official systems.
6. A VGI initiative should be implemented in a complementary and accommodative basis, such that it provides a two-way dialogue whereby citizens contribute land information and are involved in decision-making processes as partners, with officials.

8.3 Implications of key research findings and recommendations

For VGI to be recognized in **official systems**, developing countries should have a legal stance regarding the recognition and acceptance of external data in their official LAS. They should have legal documentation and specifications on how organizations can manage uncertainties and liabilities possibly implied by using external data. By absorbing uncertainties in VGI, organizations take the risks associated with using the contributed datasets. For example, organizations can authorize particular datasets as being 'official', thus implying their acceptance by the government as more reliable than other competing products (Hunter, 1999). Uncertainty absorption strategies (Hunter, 1999; Devillers *et al.*, 2007) can further be implemented based on the types of tasks and decisions to be made with the data. For example, contributed data can be used for non-binding decisions like land use management, development covenant checks and updating of general information about land records.

Even though **citizens** see value in recording their land rights, strategies should be put in place to ensure they are motivated and have the capacities to interact with the VGI application. For example, prior to the commencement of the initiative, there should be a dedicated public education, sensitization and prioritization drive to highlight the importance and significance of improving current land administration processes. These can be achieved by utilizing the **social aspects** of the conceptual framework concerned with the bottom-up approach of promoting the importance of the initiative to potential clients (volunteers and consumers) and establishing means in which they can actively participate and police themselves to produce quality and reliable datasets.

The **VGI application** developed in this research has successfully demonstrated the practical handling of VGI by providing a test-bed where volunteers identified land parcels in their community and provided descriptive information about them. Furthermore, it allowed participants to digitize the general boundaries of pre-defined land parcels with differing land uses of varying detail so that comparisons could later be made of their abilities to identify and digitize the land parcels. Residential areas with detailed and visible boundaries produced fewer deviations from ground truth compared to agricultural areas. Therefore, it can be concluded that land parcels with clear boundaries are expected to produce digitized data with high positional accuracies compared to those with unclear boundaries.

To improve the legitimacy of its products, the VGI application was developed in accordance with legal and regulatory procedures of the study area. For example, it utilized official orthophotos and vector datasets used in formal mapping processes, with the anticipation that the contributed datasets could have positional accuracies that conform to specifications of the local area. If sample data exists, positional accuracy determination of contributed datasets can be established with the common RMSE methodology, which can increase the confidence of potential consumers of the datasets, including officials at the Land Board. Alternatively, high accuracy RTK surveys or expert data can be used as ground truth in the testing process.

To develop a participatory initiative that meets the needs of local communities, a comprehensive user needs assessment should be conducted of key stakeholders to obtain information including: a) identifying and documenting frustrations of citizens about current systems, b) how current systems can be improved, c) the role that citizens would like to play in improving current systems, and d) functionalities and transactions they would like to undertake in a participatory initiative, if it existed. Collecting such information can provide insights into how a participatory initiative can be developed and positioned such that it has the potential to add value to official systems.

In a local community, metadata about contributed datasets can be created by the development of rating applications for the public to police themselves in assessing and subjectively rating the accuracy of other volunteer contributions. **TRM** has demonstrated that the quality of VGI and credibility of volunteers can be determined using the four indicators outlined in Section 5.2. For example, **thematic accuracy** was determined by the Fleiss Kappa index, which established the 'proxy' quality of VGI based on the extent to which assessors agreed on the accuracy of volunteer contributions. Kappa is based on the wisdom of the crowd principle: if many people agree with participants' contributions, this provides valuable information on the reliability of the contributed datasets.

TRM through HC methods has demonstrated that the **semantic heterogeneity,** common in VGI, can improve the quality of contributed datasets by aggregating contents with similar lexical terms. This can increase the prospect of adoption of VGI into official databases, as HC methods have shown that a correct classification of an entity can be obtained from an aggregation of contributions with similar vocabulary. **Volunteer credibility** enforces the reputation element of TRM, indicating that, using LCA methodology, multiple contributions of an individual can be used to infer the quality and reliability of the data they produce. A good

reputation is a sign of trustworthiness, which can be used by participants to establish credibility in interacting with others in participatory initiatives like VGI.

The TRM methodology proposed in this study has demonstrated that VGI can address inefficiencies in administering land in developing countries, by producing quality and reliable datasets of Class II **positional accuracy**. These datasets which can be used to conduct regular systematic updates of geographic information in official systems. Moreover, positional accuracies of volunteer contributions measured against experts' contributions produced reliable datasets of an overall Class I accuracy level. This suggests that trust and confidence can be placed on expert contributions for use as ground truth if official datasets are unavailable or insufficient. The potential uses of the contributed datasets that conform to specifications in official systems were outlined in Section 6.1. The lack of ground truth in developing countries should not be a hindrance for investigating the possibility of VGI adding value and flexibility to official systems.

The defined aspects of the **conceptual framework** can help officials make informed decisions on how VGI can be incorporated into official databases to improve current systems, generate new spatial information and promote greater collaboration with citizens and other stakeholders. Nonetheless, as indicated in Section 7.1, considering the **legal implications** of VGI, soliciting and incorporating volunteer contributions directly into official databases cannot be considered an option at this stage. Rather, it could be used for user-driven change-detection purposes to fill gaps in existing databases. In such instances, a new geospatial system parallel to official systems based on VGI provides complementary data that is citizen-led and managed.

Due to limited maintenance budgets, **institutions** interested in implementing a participatory LAS should consider open source solutions like STDM or SOLA initiatives. Despite the use of proprietary systems in this research to demonstrate the practical handling of VGI in a rural area of Botswana, they have limitations that should be noted. Proprietary systems are costly and may not be affordable and sustainable for many developing countries. In addition, they have licence restrictions that control the use, redistribution and extensions. The adoption of open source solutions enforces one of the key principles of the FFP approach: that participatory systems should be designed to provide opportunities for updating, upgrading and improvement (Enemark *et al.*, 2015). However, ArcGIS was utilized in this study to demonstrate the practical handling and application of VGI in a land administration setup. It was successfully used to demonstrate that local communities can actively be engaged in producing land information

capable of use in official systems on an FFP basis to address existing land administration challenges at Land Boards.

Models like STDM are freely available and can be scaled and extended to other jurisdictions to facilitate environments where local communities are engaged to update and improve land records in their jurisdictions. However, the challenges with open source systems include the lack of dedicated documentation, limited established maintenance structures, and the steep learning curve required for a successful implementation. Nonetheless, experience and ongoing success may ensure that the aim of an open source model and system will ideally be adopted in future. The **technical aspects** of the conceptual framework in VGI are concerned with its quality, storage, usability and its FFP in official systems. Therefore, the lack of established quality assurance measures of VGI can increase the reluctance of its adoption in official systems: hence the proposal of the TRM methodology.

Organizations should implement VGI in a **complementary and accommodative** basis: this can provide an opportunity for the public to actively participate in the administration of land in their society, such that: a) VGI can be used as informational content where the public can police themselves to better manage land and notify officials for any mismanagement activities, b) the public can improve the currency, coverage and content of official systems by updating their land records and creating new land information of daily events as they occur in their communities, and c) the public can provide cadastral data that the official cadastre can rely on particularly in areas never mapped before. In a complementary initiative, an inclusive solution to land administration can be achieved where a network of trusted citizens for recording and registering land rights is created, which can be managed directly by officials at the Land Board. Initially, the contributed datasets could have a provisional status which would be formalized following quality and credibility checks using the proposed TRM methodology. Furthermore, a complementary and accommodative implementation can be achieved when initiating organizations identify, consult and engage key stakeholders in the participatory initiative for buy-in and acceptance, crucial to its success. The objective is for all stakeholders to consider issues that include a) provision of an outline on the purpose of the initiative, b) identification of important areas where key stakeholders can participate, c) identification of potential benefit areas for each participant, d) development of clear processes for contributed datasets, including issues of engagement and feedback to contributors into established systems, practices and procedures, e) provision of incentives to encourage public involvement, particularly in less densely populated areas, f) consideration of technical and capacity issues necessary for VGI

adoption in official systems, g) consideration of data ownership and specific licensing agreements, and h) establishment of clear ownership of the process and responsibility over the management of the initiative.

This research has further demonstrated that VGI can address **problematic areas** in key land transactions at the Land Board by eliminating the need for site visits and reducing the time taken to execute processes that require technical input like unregulated self-extensions checks, land use zones determination and buffer distance measures to determine potential borehole sites. The extents to which these problematic areas can be addressed have also been outlined, to further emphasize the potential and significance of utilizing VGI to improve current key processes at the Land Boards (Section 7.5).

8.4 Future work and outlook

Future work should investigate how the VGI initiative can be made sustainable for developing countries, in terms of maintenance, scalability and extensibility, such that it can be implemented in other parts of the country and other regions of Africa. This would enable the developed application tested in the study area to be extended to other districts within the country to facilitate active engagement of the public with land administration issues in those areas. Moreover, considerations of mobile applications are necessary to provide a platform and system where local communities can record or update their land rights data which can later be transferred to a VGI application for consolidation with other datasets. Currently, the VGI application designed in this study is desktop computer-based and does not have a mobile version. A portable version (e.g. on a tablet or mobile phone) would add value and flexibility by providing greater accessibility for citizens, bringing land related services to a wider range of society, many of whom are currently excluded. SOLA solutions for mobile applications can provide guidance to agencies interested in developing participatory initiatives to support current LAS in recording the social tenure relationships that communities have with their land. According to McLaren (2011), the wide geographic coverage of telecommunications infrastructure (90% signal coverage worldwide) especially in developing countries is an excellent channel for obtaining participatory land information to improve tenure security of citizens in rural areas of these countries. Therefore, future work should further investigate strategies of developing a mobile component of the VGI application created in this study to provide an alternative platform that volunteers could use to document their land rights.

The TRM methodology proposed in this research, establishes proxy qualities of VGI and credibility of volunteers based on four independent indicators. This provides an opportunity for consumers to trust contributed datasets based on the indicator they are most interested in. Future work could examine aggregation mechanisms to present the quality value as a single entity. Thus, regression analysis techniques, as introduced by Dalip *et al.* (2012), to combine various weighted quality values into a single quality value, could be used to represent an overall aggregated value of content quality. The data quality indicators can either be awarded equal or varying weights depending on the preference of the researcher or other mathematical functions that compute weights based on the significance of the indicator and the potential use of the dataset. For example, Chapter 5 of this study presented results of data quality determination of four indicators. Future work could investigate alternative ways of combining these indicators into an integrated data quality assessment value. However, the main challenge with VGI assessment based on FFP is that within the four indicators discussed, some may be of greater interest to a user compared to others. Therefore, a flexible rating system (Bordogna *et al.*, 2015) could be developed for potential re-users of VGI, which enables them to rank the importance of the different indicators, based on their preferences, and specify minimum acceptable quality levels for each indicator. In this case, the rating system would act as a filter and return only items from the VGI initiative that meet the minimum quality levels.

Future work could investigate strategies of incorporating the rating values of land parcels alongside their description in the pop-up window of the Web map application. The rating value should further indicate the number of people who rated the entity and the overall rating obtained. Such information, if readily available, and used as effectively as in e-commerce websites, can better inform potential users of the reliability of VGI. Apart from addressing frustrations brought by current systems and the need to improve them, future work should investigate innovative techniques that can motivate and retain the public in contributing trustworthy and reliable land information about their local communities. These techniques could include gamification activities (Antoniou and Schlieder, 2014), where clear incentives for collecting accurate and reliable datasets are outlined to contributors. Incentives could include an increase in ranking, or a collection of badges, which could be given to contributors based on the quality of the data contributed.

For volunteers with high reputations and persistent contributions, future work should investigate and design strategies of elevating them to intermediary status, to undertake the role of assessing contributions made by their peers. Demonstrations about the functions and

usability of the VGI application were conducted by the researcher: these could be conducted by trusted intermediaries or members of NGOs in future. Investigations should be conducted and strategies put in place to ensure that when the initiative is expanded to other jurisdictions of Botswana, such intermediaries have been sufficiently trained on the effective use of the application

For digitization activities, the developed Web map application lacks topological rules to reject impossible land parcel configurations: the focus of this study was to demonstrate that the public can produce quality and reliable information capable of adding value to official LAS. For example, topological rules that prohibit volunteers from mistakenly digitizing a land parcel in the middle of the road or river can greatly reduce the input of inappropriate content. Therefore, studies should be conducted on this aspect to increase the accuracy and reliability of contributed datasets. The TRM methodology proposed here is labour intensive and time-consuming. Therefore, future work should investigate automation techniques to improve the efficiency of VGI quality determination through data mining approaches (Senaratne *et al.*, 2016) that discover patterns and learn purely from contributed datasets.

Data mining methodologies are ideal for developing countries since they are not dependent on ground truth. Examples of these methodologies include automatic detection of outliers and supervised classification. The LCA methodology used for volunteer reputation determination in this study is another example of a data mining approach which could be automated to compute the extent to which contributors correctly classify land parcels based on the history of their contributions. However, the current process used in this study was labour intensive since it required the researcher to engage experts to classify similar land parcels to those classified by volunteers which were later aggregated, and a matrix table used to compare the two classifications. The output was then used as input for volunteer reputation determination using LCA methodology. Despite the attention that positional accuracy has received in the research community, automatic detection of outliers has not been investigated extensively and could be an interesting topic for future research.

Supervised classification techniques could be used to assess the quality of volunteer contributions for land use parameters in vegetated areas of Botswana, including agricultural and grazing land. In this instance, a user would select sample pixels in an image that are representative of specific land use classes, then direct the image processing software, to use the samples as references for classifying other land use classes in the image.

8.5 Conclusion

This research has examined VGI as a possibility by which land information can be collected through the involvement of local communities to improve official LAS in developing countries. It has demonstrated that VGI has the potential to address inefficiencies in administering land in developing countries, especially rural Africa, on an FFP basis. The FFP concept was applied in the case study to highlight its practicality and use in a participatory land administration initiative in Botswana. Furthermore, the innovative TRM methodology proposed has demonstrated that VGI can produce quality and reliable datasets of Class II positional accuracy which can be used for a wide variety of land administration purposes as outlined in Section 6.1. One key principle of FFP is that accuracy relates to the purpose rather than technical standards. However, computing positional accuracies using RMSE shows that the digitised land parcels conform to legal and regulatory specifications of the study area: this can improve the trust and confidence of authorities towards datasets produced by the VGI application. Furthermore, quantifying data quality and credibility in VGI underpins its usefulness in terms of reliability and trustworthiness.

The output of this research is a conceptual framework that breaks down the process of creating VGI into four connected aspects (social, legal, institutional and technical) necessary for its consideration in official systems. These aspects can help officials make informed decisions about VGI and understand how it can be incorporated into official databases to improve current systems, generate new spatial information and promote greater collaboration with citizens and other stakeholders. It further provides strategies of how contributed data from a VGI initiative can add value to official systems on an FFP basis. For the VGI initiative to be recognized in official systems, this research recommends that it should be implemented in a complementary and accommodative basis, such that it provides a two-way dialogue whereby citizens contribute land information and are involved in decision-making processes as partners with officials at the Land Board.

Appendices

Appendix A

Cover letter to participants

School of Civil Engineering &Geosciences

Newcastle University

Request for information about land administration issues in Botswana

Dear Sir / Madam

My name is Kealeboga Kaizer Moreri. I am carrying out a PhD study on land administration systems in developing countries. The specific topic is: 'The Role of Volunteered Geographic Information in Land Administration in Developing Countries'. I have chosen Botswana as a case study for my research.

In this regard, I hereby request your participation in this research as an individual who has an interest in land administration matters in the country. Please note that participation in this study is voluntary, anonymous and confidential. In addition, this research poses no harm to you as a respondent. You have the right not to participate and feel free to withdraw from participating even if you had agreed to do so.

You are requested to respond to this questionnaire within a period of three days, of which an in-depth structured interview will be carried out as a follow-up on the responses provided.

Thank you in advance for your cooperation.

Regards

Kealeboga Kaizer Moreri
PhD Student
Newcastle University, UK.
k.moreri@newcastle.ac.uk

Appendix B

Questionnaire to Principal Land Surveyors about mapping activities in the country

This questionnaire is designed to probe for understanding of current geospatial data flowlines, licensing arrangements and adopted standard measures between DSM and Land Boards for an effective and efficient land information delivery. Please feel free to respond to all the questions as far as you can.

Land Board: (Principal Land Surveyor)

1. What mapping activities exist in Land Boards?

   _____
   _____
   _____
   _____

2. What fundamental geospatial data does your organization receive from DSM?

   _____
   _____
   _____
   _____

3. What are the accuracies that this geospatial data is received in? For example, resolutions of satellite images from DSM.

   _____
   _____
   _____
   _____

4. What geospatial data maintenance responsibilities exist in the Land Board?

   _____
   _____
   _____
   _____

5. Does Land Board share its geospatial data with other stakeholders? (yes / no). If yes, please state two.

   _____
   _____

6. What licensing arrangements exist between the stakeholders that share data with Land Board?

   _____
   _____

_____
_____

7. In the Land Board, what are the acceptable positional accuracies and deviation tolerances (thresholds) that have been set to ensure there is production of high quality information for mapping activities?

_____
_____
_____
_____

8. What are the standard measures of determining accuracies of geospatial data in terms of the following:

    a. The geospatial currency of datasets, with regards to occupancy, development status, and land tenure,
    b. Land use classification accuracy,
    c. Positional accuracy of geospatial data?

9. How often does Land Board update its cadastral and mapping data?

_____
_____
_____
_____

10. What parameters do you use to measure the currency of geospatial datasets?

_____
_____
_____
_____
_____

11. What is the expectation of the public by the land board regarding the updating of their land records?

_____
_____
_____
_____

12. What is the significance of having up-to-date cadastral and mapping records in the Land Board?

_____
_____

_____
_____

13. How does the Land Board ensure that land owners update their land records when significant activities like change of ownership, chance of land use, and subdivision take place?

    _____
    _____
    _____
    _____

14. What percentage of land records in Mochudi would you say are up-to-date in terms of mapping?

    _____
    _____
    _____
    _____

Thank you very much for taking part in this survey. Your input is highly appreciated.

Appendix C

Questionnaire to officials at the Land Board

General Information of participant

Organization: ……

Position of participant: …….

Gender: Male ☐ Female ☐

Purpose of the Study:

To understand perceptions as to how authorities, feel about active participation of the public on land administration issues in their local areas.

Target personnel:

The targeted personnel are to be chosen on the basis that the system was designed for their daily administrative duties. For example: Land officers, Records assistants, IT personnel, Land Surveyors and other personnel involved in land administration.

Questions:

1) Please describe what your role is in your organization.

   _____
   _____
   _____

2) What is your take on the current land administration systems in the country?

   _____
   _____
   _____

3) How is spatial and attribute data stored in the current land administration systems? E.g. digital, paper based, etc.

   _____
   _____
   _____

4) What are the barriers inhibiting data sharing between departments in the country?

   _____
   _____
   _____

5) What do you think can be done to improve the situation in 4?

_____
_____
_____

6) How does the public interface with the current land administration systems, in terms of applications and request for services?

_____
_____
_____
_____

7) How do you think the current situation can be improved in your organization, if the right technologies and funds were available?

_____
_____
_____

8) How do you think the public can play an active role in contributing positively towards land administration issues in the country?

_____
_____
_____

9) Are you familiar with Web mapping applications like OpenStreetMap and Google Maps?

Yes ☐ No ☐

10) If a similar application could be built for a land administration system, what do you think could be the barriers? E.g. legal implications, procedural barriers, privacy issues.

_____
_____
_____
_____
_____
_____

11) Do you think smartphones should have applications that can allow people to interact with Web map applications like Google Maps?

Yes ☐ No ☐

12) Please elaborate on your response for 11).

_____
_____
_____
_____
_____
_____

13) Taking into consideration that land information is confidential, if there was a Web-based mapping platform, which land information would you like to see on the platform for public consumption? E.g. general land parcels and known public areas - shop names, hospitals, civic and community areas, etc.

_____
_____
_____

14) What are the most important functionalities that you would like to see in a Web mapping application that contains land information? Please rank the functionalities according to your preference (5 - strongly agree, 4 - agree, 3 - neutral, 2 - disagree, 1 - strongly disagree): (please tick)

Possible functionalities:

Secure user login.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to add comments to records (e.g. describing known areas).

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to update and modify records like postal addresses.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to rank inputs made by other users.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to trace (digitize) known areas and label them.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to initiating or requesting services, e.g. land transfers, subdivisions, land registration, extensions, etc.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to report on illegal land activities like sand mining in un-gazetted areas.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to measure objects. E.g. areas, length, and create buffer zones (could be beneficial in locating borehole points a certain distance from existing points), etc.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Please list other functionalities that you would like to have but not mentioned above.

_____
_____
_____

15) Do you think the public can provide good quality reliable data, if a Web map application is availed to them?

Yes ☐ No ☐

16) On a scale of 1 to 5, how reliable do you think information obtained from such Web applications can be? (5 – very reliable, 4 – reliable, 3 – somewhat reliable, 2 – not reliable, 1 – misleading).

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

17) Please elaborate on your response for 16).

_____
_____
_____

18) What other information do you think must be recorded in land administration systems? E.g. information on grazing areas and syndicates, ploughing fields without certificates of rights, water features like dams, wells, unregistered borehole points, etc.

---

19) In other countries (e.g Kenya with Ushahidi[2]), GPS enabled devices like smartphones and hand-held GPS units are utilized by the public to populate online maps. How do you think such information can be beneficial to developing countries like Botswana?

_____
_____
_____
_____

20) General Comments:

_____
_____
_____
_____
_____
_____
_____

Thank you very much for taking part in this survey. Your input is highly appreciated.

[2] https://wiki.ushahidi.com/

Appendix D

Questionnaires to the public

General Information of participant

Position of participant: …….

(E.g. current landowner, aspiring landowner, Land Board client, stakeholder).

Gender: Male ☐ Female ☐

Purpose of the Study:

To understand perceptions as to how the public feels about the possibility of actively participating in land administration issues in their local areas.

Target audience:

The public, landowners, aspiring landowners and Land Board clients, other stakeholders.

Questions:

1) How do you currently interact with the land Board? In terms of the procedure to be followed when requesting for service. E.g. when applying for land, requesting services like transfer, extension etc.

   _____
   _____
   _____
   _____
   _____

2) What are your main concerns regarding the current state of land administration in the country?

   _____
   _____
   _____
   _____

3) What do you think the land board should do to better serve its clients? Services like, timely responses to clients' queries and applications.

   _____
   _____
   _____

4) Do you own a smartphone or a GPS enabled handheld device?

Yes ☐ No ☐

5) How would you like to contribute to the improvement of the way things are currently done in land administration?

_____
_____
_____

6) Do you think there are land rights currently missing in land administration systems that you would like to see recorded and accounted for? E.g. tribal ceremonial sites, old burial grounds, community areas like grazing land, abandoned sites like burrow pits, borehole points, dwelling areas and unregistered ploughing fields, etc. If so, what are they?

_____
_____
_____
_____

7) Would you use a Web-based land administration system?

Yes ☐ No ☐

8) If yes, what would you like to do on it? Please rank the functionalities according to your preference (5 - strongly agree, 4 - agree, 3 - neutral, 2 - disagree, 1 - strongly disagree): (please tick)

Possible functionalities:

Secure user login.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to add comments to records (e.g. describing known areas).

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to update and modify records like postal addresses, etc.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to rank inputs made by other users.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to trace (digitize) known areas and label them.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to initiating or requesting services, e.g. land transfers, subdivisions, land registration, extensions, etc.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to report on illegal land activities like sand mining in un-gazetted areas.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Ability to measure objects. E.g. areas, length, and create buffer zones (could be beneficial in locating borehole points a certain distance from existing points), etc.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Please list other functionalities that you would like to have but not mentioned above.

_____
_____
_____
_____

9) On a scale of 1 to 5, how reliable do you think information obtained from such Web applications can be? (5 – very reliable, 4 – reliable, 3 – somewhat reliable, 2 – not reliable, 1 – misleading).

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

10) General Comments:

_____
_____
_____
_____
_____
_____
_____

Thank you very much for taking part in this survey. Your input is highly appreciated.

Appendix E

Questionnaire to land law lecturers

General Information of participant

Organization: ……

Position of participant: …….

Gender: Male ☐ Female ☐

Purpose of the Study:

To understand policies, standards and legislative statutes that govern geospatial data handling in the country. In addition, this study aims to understand what the law says about regulatory frameworks that facilitate access to land information.

Questions:

1. What is your current view of procedures of land transactions in the country?

   _____
   _____
   _____

2. Based on current challenges, what alternatives do you think are feasible for land tenure transfers and changes?

   _____
   _____
   _____

3. How can the general administration of land be improved in this country?

   _____
   _____
   _____

4. Do you think the law and legal system regarding customary land have a direct meaning, utility and applicability to people's daily lives?

   _____
   _____
   _____

5. Do you think current land practices in rural areas are aligned to the government's legal systems?

   _____
   _____
   _____

6. How do you think current customary procedures can be streamlined with modern systems for a more coherent whole and benefit to local communities?

   _____
   _____
   _____

7. Do you think current legal systems value participatory initiatives and consensus-based decision making?

   _____
   _____
   _____

8. What are the possible legal implications of participatory initiatives where the public is given the platform to contribute land information at their own will?

   _____
   _____
   _____

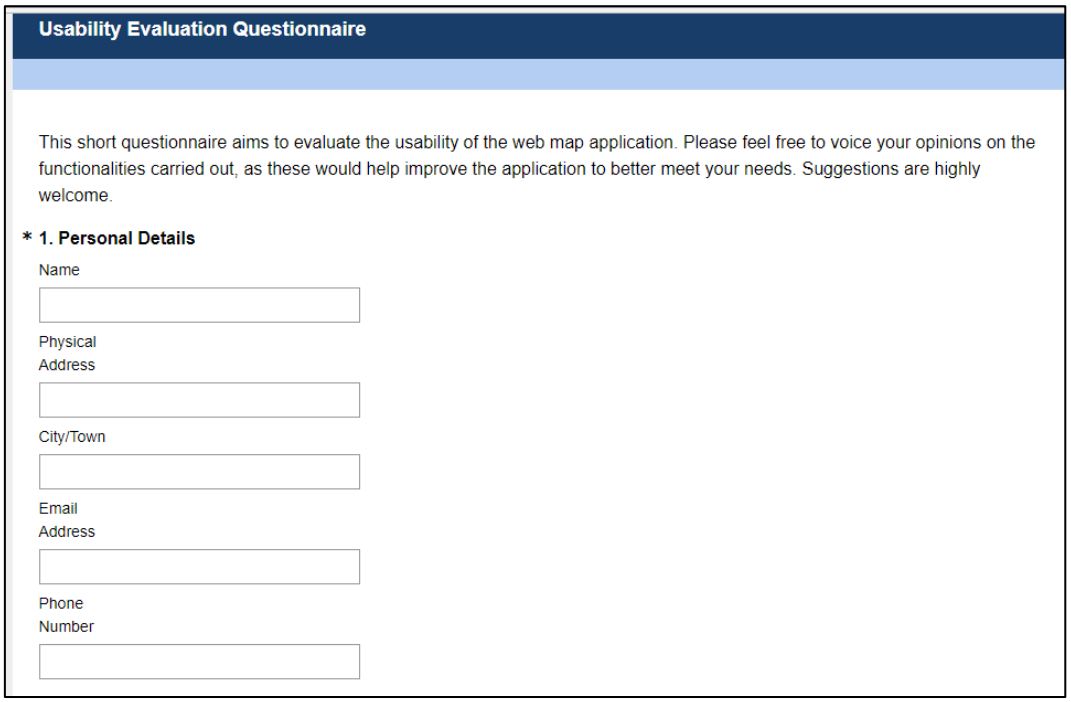
Thank you very much for taking part in this survey. Your input is highly appreciated.

Appendix F

Questionnaire on the usability of the Web map application

Target Audience:

All participants who took part in the second phase of the data collection activity.



Usability Evaluation Questionnaire

This short questionnaire aims to evaluate the usability of the web map application. Please feel free to voice your opinions on the functionalities carried out, as these would help improve the application to better meet your needs. Suggestions are highly welcome.

*** 1. Personal Details**

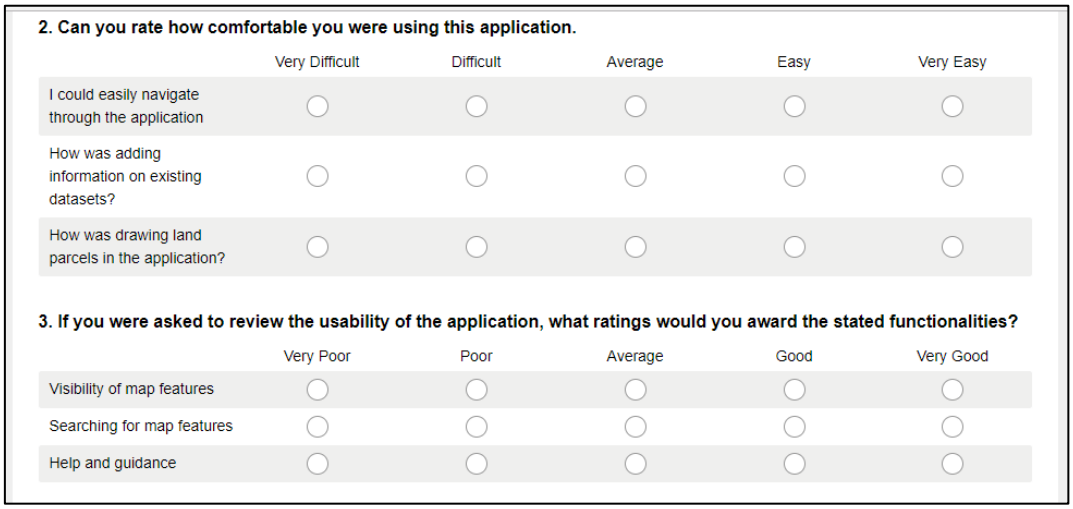
Name

Physical Address

City/Town

Email Address

Phone Number



2. Can you rate how comfortable you were using this application.

	Very Difficult	Difficult	Average	Easy	Very Easy
I could easily navigate through the application	○	○	○	○	○
How was adding information on existing datasets?	○	○	○	○	○
How was drawing land parcels in the application?	○	○	○	○	○

3. If you were asked to review the usability of the application, what ratings would you award the stated functionalities?

	Very Poor	Poor	Average	Good	Very Good
Visibility of map features	○	○	○	○	○
Searching for map features	○	○	○	○	○
Help and guidance	○	○	○	○	○

4. General questions about the application.

	NO	MAYBE	YES
Would you use this application to contribute land information of your community?	○	○	○
Would you trust information from this application?	○	○	○
Do you think such an application can improve the efficiency of Land Boards?	○	○	○

5. How likely is it that you would recommend application to a friend or colleague?

Not at all likely — Extremely likely

0	1	2	3	4	5	6	7	8	9	10

6. What is your preferred method of updating your land records?

- ○ visiting the land board
- ○ using web map applications in a computer
- ○ using web map applications in my mobile phone
- ○ Other (please specify)

7. What do you like best about this application?

*** 8. What do you find most frustrating about this application?**

9. If you could change one thing about this application, what would it be and why?

10. How can this application be improved? Give us your ideas and suggestions.

Done

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