A COMPARATIVE STUDY OF SPATIAL DATA COLLECTION METHODS FOR INFORMAL SETTLEMENT LAND TENURE MAPPING IN GOBABIS, NAMIBIA

NOKOKURE NGUTJINAZO
July 2021

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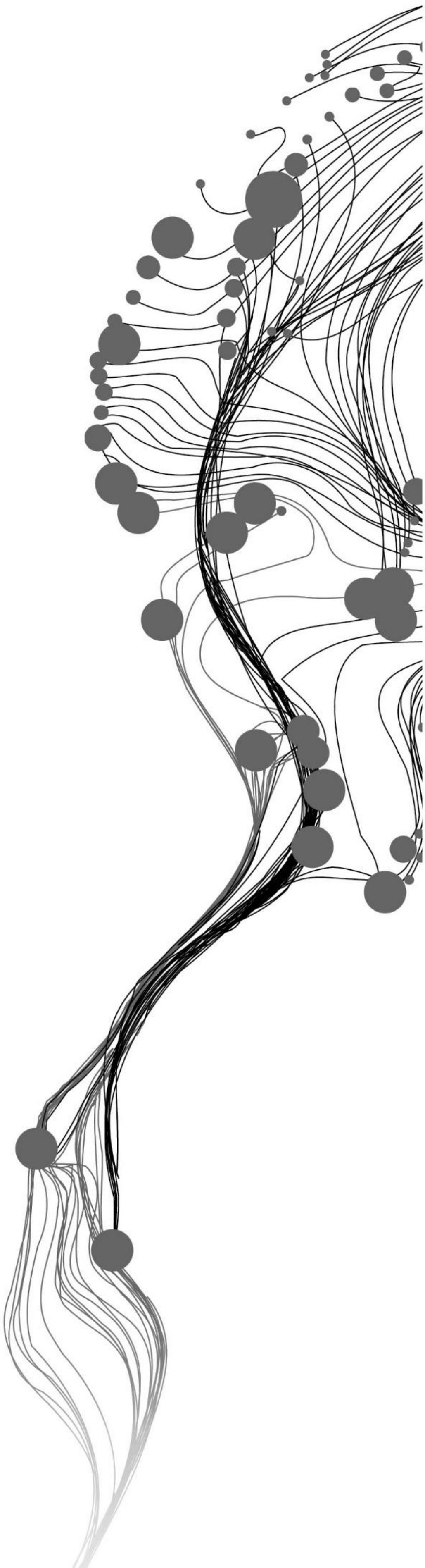

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NOKOKURE NGUTJINAZO
Enschede, The Netherlands, July 2021

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Land Administration

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ABSTRACT

The Fit-for-purpose land administration approach provides flexible solutions in the way spatial data is captured, and they are inclusive, participatory, affordable, reliable, attainable, and upgradable. FFP land administration consists of the spatial, legal, and institutional framework. The spatial framework mainly provides information on how land is occupied. It is also the foundation for land administration functions of recording and managing land tenure, assessing valuation, and managing land. As part of the spatial framework, a variety of cadastral mapping methods enabled by technological and technical advances have been used in land registration projects worldwide. Each method has its own characteristics, requirements, and outcomes, making them unique. Th conventional methods are regarded to be expensive, time-consuming and have high accuracy requirements. Therefore, they do not accommodate the needs of developing countries and communities living in informal settlements. To meet the needs of the developing countries, alternative systems and approaches have been developed over the years, including the development of innovative land tools. However, there is limited studies done on comparing the innovative spatial data collection methods against conventional methods. There is also a lack of criteria for selecting spatial data collection methods for a specific country context. This study carries out a comparative research of the new its4land innovative methods, SmartSkeMa and Automatic Feature Extraction to identify indicators and use the indicators to compare the suitability of their suitability in Namibia.

The research objective is to compare innovative methods against conventional methods. To meet the objective the research adopted a case study approach of the qualitative method. The research was conducted in Freedom Square, Gobabis. Semi-structured interviews, ranking questionnaires and parcel mapping were used to obtain primary data. In addition, aerial image, layout plan and reference points were obtained as secondary data. Data from the semi-structured interviews helped in identifying the methods used in Namibia, their characteristics and the actors involved. The ranking questionnaire provided the indicators which were used for comparing the innovative methods against the conventional methods. The parcel mapping was used in SmartSkeMa and the output was overlayed on a layout plan of Freedom Square. Automatic Feature Extraction used the aerial image for boundary delineation. The results revealed that the spatial data collection methods used in Namibia are conventional and they are supported by the legal framework. The legal framework does not support the use of photogrammetry and the UAV regulations are currently a challenge. The indicators which were ranked as the most important when selecting spatial data methods were, implementation, compliance with common standards, accuracy, and reliability. These indicators were used for comparison and the results showed that the main similarities between the methods are that they involve community members. The main difference is the data collection procedures because innovative methods make use of GIS experts, and the conventional methods require surveyors. Further, the research identified that the innovative methods do not comply with the legal framework in terms of accuracy, and the data collection procedures. The accuracy requirements are high and are based on fixed boundaries whereas with the innovative methods, general boundaries are used.

However, there is potential for innovative methods to enhance the conventional methods especially regarding time and data processing. Both the innovative tools could be useful as the first step to data collection for local authorities who do not have any spatial data on the informal settlements. These methods could also be used in combination with the conventional methods, whereby surveyors could improve the accuracy of the data obtained at a later stage.

Keywords: data collection methods, innovation, conventional, informal settlement, mapping

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LIST OF ACRONYMS

RRR - Rights, responsibilities, and Restrictions
FFP – Fit for purpose
UAVs – Unmanned aerial vehicle
GNSS - Global Navigation Satellite System
STDM – Social Tenure Domain Model
GPS – Global Positioning System
GLTN – Global Land Tool Network
FLTS – Flexible Land Tenure System
FLTA- Flexible Land Tenure Act
GIS – Geographic Information System
UN Habitat – United Nations Human Settlement Programme
FAO – Food and Agriculture Organization
NHAG – Namibia Housing Action Group
NUST – Namibia University of Science and Technology
RTK – Real-time kinematic
NGO – Non-Governmental Organisations
SDFN – Shack Dwellers Federation of Namibia
GIZ – Deutsche Gesellschaft für Internationale Zusammenarbeit
QGIS – Quantum Geographic Information System
SVG – Scalable Vector Graphics
LAS – Land Administration System
GCP – Ground Control Points
EPSG – European Petroleum Survey Group
MCG – Multiscale Combinatorial Grouping
ISO- International Organisation for Standardization
LADM – Land Administration Domain Model
LARSI – Low Altitude Remote Sensing Image

1. INTRODUCTION

1.1. Background & Justification

Land administration is a broad domain concerned with collecting, managing, organizing, and disseminating rights, responsibilities, and restrictions (RRR) to change the way people relate to land (Bennett, Wallace, & Williamson, 2006). Furthermore, land administration is implemented through various functions to organize land tenure, land value, land use, and land development. Seventy-five percent (75%) of the world's tenure are not registered to date, and less than a quarter of the countries in the world maintain complete land administration systems (Zevenbergen, de Vries, & Bennett, 2016). This means that most countries have no access to a formal land administration system, or if they do, it is incomplete. The effect of this is that the land rights of most people are not recognized by law and are also not institutionally supported (Enemark, Bell, Lemmen, & McLaren, 2014). As a result of no or incomplete land administration systems, 4 billion of the world's approximate 6 billion land tenures remain outside formal governance arrangements (Zevenbergen et al., 2016). Due to a lack of information about the people to land relationships, decision-makers and citizens are challenged because decision-makers cannot make and implement plans when they do not have any records on who occupies which land. Citizens on the other end face the risk of being evicted, relocated, and living in poor conditions because of a lack of recognition. Having a functional land administration system is essential because the information aids in implementing pro-poor land administration. For instance, the implementation of land rights recordation aims at protecting the informal rights of the vulnerable and low-income households (Zevenbergen, Augustinus, Antonio, & Bennett, 2013a). In addition, it is vital for implementing interventions for poverty reduction by governments (A. Christensen, 2017). Land rights recordation provides landowners with tenure security, sustainable livelihood, better infrastructure, and increases financial opportunities (Crommelinck, 2019).

In sub-Saharan Africa, about 62% of the urban population reside in slums and informal settlements. Therefore, the global land administration community concluded that to deliver security of tenure, it should be done through a continuum of land rights (Zevenbergen, Augustinus, Antonio, & Bennett, 2013b). Alongside this, several tools and methods have been developed to assist the process of recording formal, informal, group, or individual rights. Examples of these tools are the Social Tenure Domain Model (STDM) (Lemmen, 2010), Cadasta, Solutions for Open Land Administration, etc. The its4land consortium developed tools such as the SmartSkeMa and Automatic Feature Extraction based on the continuum of land rights and fit-for-purpose approach (Koeva et al., 2020). These tools all have a common focus, and that is to generate tenure security for all by combining faster and cheaper technical options and also acknowledging the different land rights (Zevenbergen et al., 2016).

Fit-for-purpose (FFP) land administration has been introduced to provide a cost-effective and sustainable system that identifies the way land is occupied (Enemark et al., 2014). Further, FFP also provides alternatives for managing land issues more flexibly, rather than following the higher technical standards or conventional ways to address the land registration backlog and scale up the land registration process (Enemark et al., 2014). The FFP approach provides flexible solutions in the way spatial data is captured, and they are inclusive, participatory, affordable, reliable, attainable, and upgradable. The FFP land administration consists of the spatial, legal, and institutional framework. The spatial framework mainly provides information on how land is occupied. It is also the foundation for land administration functions of recording and managing land tenure, assessing valuation, and managing land (Hull & Kingwill, 2020). As part of the spatial framework, a variety of cadastral mapping methods enabled by technological and technical advances have been used in land registration projects worldwide. Each method has its own characteristics, requirements, and outcomes, making them unique (Rahmatizadeh, Rajabifard, Kalantari, & Ho, 2018). Some of the methods used over time include; measuring tapes, theodolites, electronic total station, Global Navigation

Satellite System (GNSS), and semi-automatic delineation of boundaries in aerial imagery, (Ramadhani, Bennett, & Nex, 2017). Some of these methods have previously been used for small-scale, informal land tenure documentation projects run by NGOs and by large-scale formal and authoritative projects such as the Land Tenure Regularization projects in Rwanda and Ethiopia. Owning to the fact that there are many different methods, Rahmatizadeh et al. (2018) developed a framework and indicators for selecting an FFP spatial data collection method for land administration. A combination of mapping methods is selected based on the precision/accuracy, speed, scalability, cost, and availability of requisite skills. However, there is a lack of comparative studies that evaluate the different methods against each other to establish an explicit criterion for selecting one approach over another. Furthermore, Rahmatizadeh et al. (2018) suggest that further research is required to build upon the framework they have established to identify indicators for comparing the performance of data collection methods concerning the identified parameters in their study. Therefore, this research seeks to identify indicators for a particular country context and use the identified indicators to compare the suitability of new FFP spatial data collection methods with the conventional methods.

The research will focus on Freedom Square in Gobabis, Namibia and the methods that will be compared are from the recent its4land project, SmartSkeMa and the Automatic Feature Extraction (Koeva et al., 2020) and the conventional survey methods used in Namibia. The SmartSkeMa and the Automatic Feature Extraction are selected because these are new tools and there has not been many studies done on them.

1.2. Problem statement

The Namibian government recently started implementing the Flexible Land Tenure System (FLTS), which aims at providing an opportunity to improve tenure security and improving the living conditions of communities residing in informal settlements. The documentation of the people to land relationship is of vital importance, and in Namibia, there is a lack of informal settlement documentation. Previous attempts of mapping informal settlements in a few towns were initiated under the jurisdiction of the Ministry of Agriculture, Water and Land Reform, Namibia Housing Action Group (NHAG), and Shack Dwellers Federation of Namibia (SDFN) using aerial images and Global Positioning Systems (GPS's) (SDFN-NHAG, 2013). However, despite trying to fill this gap, the continuous growth of informal settlements and the establishment of new informal settlements still results in the land administration agencies and governments, especially in the Global South have insufficient or outdated information of informal settlements (Lamba, 2005).

A consensus has been reached that one of the key bottlenecks to providing an effective land administration system lies with the spatial data collection process. This process takes up much time and is considered expensive (Rahmatizadeh et al., 2018). Under the FLTS standards, a professional land surveyor surveyed the outside block of a scheme according to the legal procedures and registered in the Deeds Office. This formal process is usually too lengthy and costly for the low-income earners who reside in informal settlements (Mabakeng, 2015). The Global Land Tool Network (GLTN) supported implementing the Social Tenure Domain Model (STDM), which enabled the measurement of the inner blocks by a survey technician, referred to as a land measurer in the FLTS. Some relaxations to surveying procedures are allowed, and regulations to support this can be made. However, the accuracy and reliability of the results should be maintained. Moreover, "Eradicating informal settlements" (2019) states that the Namibian government urged the country to use new technologies to improve the situation in the country. Doing this study in Namibia will be useful to determine whether these innovative tools can be incorporated into what is currently being used to scale up the registration of informal settlements.

1.3. Research objectives

1.3.1. Main Research Objective

The main objective of this study is to compare the different spatial data collection methods for informal settlement land tenure mapping in Gobabis, Namibia.

1.3.2. Research Sub-Objectives & Questions

a. To identify the characteristics of spatial data collection methods to understand why some spatial data collection methods are preferred over others by the actors.
    a. What are the conventional and innovative spatial data collection methods currently used in Namibia?
    b. What are the main characteristics of the conventional and the innovative spatial data collection methods?
    c. Who are the actors involved in implementing these methods?

b. To identify indicators for comparing the performance of data collection methods.
    a. What are the indicators for measuring the performance of the data collection methods?
    b. What are the criteria for selecting spatial data collection methods?

c. To compare the innovative methods against the conventional methods.
    a. What are the gaps between the conventional and innovative spatial data collection methods?
    b. To what degree do the innovative data collection methods enhance the current conventional methods used?
    c. How can the innovative spatial data collection methods be incorporated with the conventional spatial data collection methods?

Sub objective 1 has the sole purpose of setting the scene to understanding spatial data collection methods and this is achieved by finding out which data collection methods are used, what their specific characteristics are and identifying the different actors involved. This then leads to sub-objective 2, the indicators will be determined based on the characteristics identified in sub objective 1 and literature. Sub objective 3 defines the similarities and differences of the spatial data collection methods by way of comparison.

1.4. Conceptual framework

Figure 1 below shows the link between mapping informal settlements, the spatial data collection methods, the spatial data collection methods characteristics, selection criteria, and the different indicators. Informal settlements can be mapped using innovative spatial data collection methods or conventional methods. The innovative spatial data collection methods selected for this study are the SmartSkeMa map and Automatic Feature Extraction which are compared against the conventional surveying. These spatial data collection methods all have different characteristics, and these characteristics will assist in identifying indicators to be used to compare the performance of the methods. A criterion for selecting methods will be derived from the different characteristics identified.

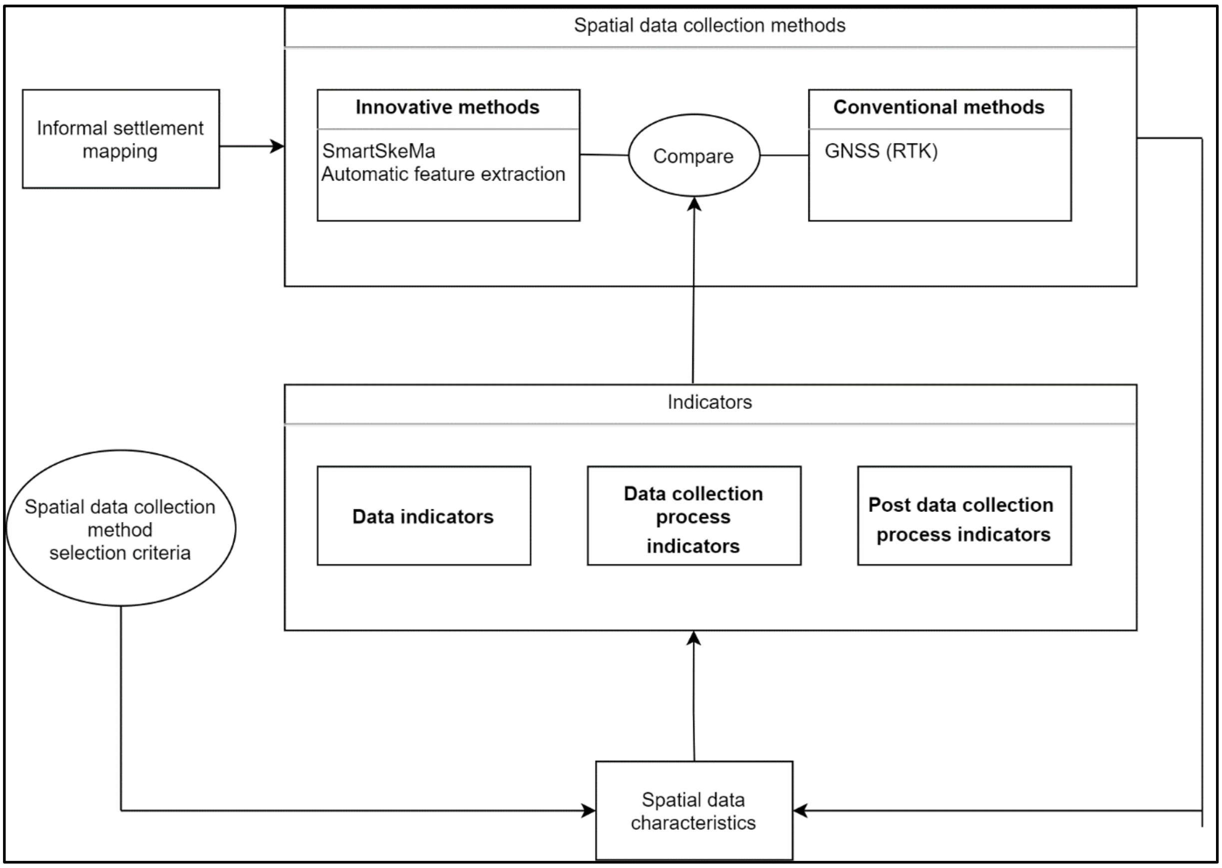


Figure 1: Conceptual framework

1.5. Scope of the study

The focus of this study is to compare conventional methods against the innovative methods. The specific focus is on Freedom Square and the methods which were used for the upgrading of the informal settlement under the FLTS. This study area is taken as potentially representative of other informal settlements in Namibia. The legal and institutional aspects are outside the scope of this study. The focus of the work is on the spatial aspects with special focus on the technical procedures relating to cadastral surveying.

1.6. Thesis structure

The thesis comprises of six chapters that will be undertaken in three phases of pre-fieldwork, fieldwork, and post fieldwork.

Chapter 1: Introduction and background

This chapter introduces the study and gives the background, justification, research problem, research objectives, and research questions. This is followed by a description of the study area, description of the conceptual framework and thesis structure.

Chapter 2: Literature review

This chapter entails relevant literature related to spatial data collection methods, fit-for-purpose land administration and other relevant scientific literature are reviewed in this chapter.

Chapter 3: Research methodology
Provides a description of the research design, discussion on the data sources and collection process adopted. The methods for analysing the data collected are also presented in this chapter.

Chapter 4: Results
This chapter presents the results obtained from the field mapping of parcels, semi-structured interviews, ranking questionnaire and literature review.

Chapter 5: Analysis & discussion
This chapter contains the discussion of the findings with reference to existing scientific literature.

Chapter 6: Conclusion and recommendations
This chapter closes the thesis with concluding remarks and recommendation for future research.

2. LITERATURE REVIEW

The previous chapter deliberated on the concept of informal settlements and the lack of tenure security due to land rights which are not recognized. It also highlighted the limitations of the conventional land administration approaches and the need for innovative approaches. This chapter reviews literature related to conventional and unconventional land administration, informal settlements in Namibia and fit-for-purpose land administration.

2.1. Conventional Land Administration

According to UNECE (1996), land administration refers to the process of identifying, documenting, and disseminating information related to land ownership and land use when enforcing land management policies and their associated resources. Land administration provides the background information for change regarding land tenure, land value, land use, and land development. Land administration is a broad term that encompasses land registration and cadastre (Zevenbergen, 2002). Land registration is described by Henssen (1995) as a process of the official recording of rights in the land through deeds or title. In most developing countries, 70% of the land is not included in the land administration system and this resulted in many living in unfavourable conditions in slums and informal settlements (Enemark, McLaren, & van der Molen, 2009). There is a need for complete Land Administration System (LAS) and alternative methods of mapping land rights in developing countries. Land registration and cadastre supplement one another, they work as interactive systems. Land registration focuses on who occupies the land and the relationship they have towards the land. The cadastre focus is on identifying where the communities live (Henssen, 1995). A cadastre is defined as an official Geographic Information System (GIS) which identifies geographical objects within a country. It is like a land registry as it records attributes concerning parcels of land, the difference being that a land registry relates to deeds in conveyance and other land rights. At the same time, cadastre focuses on the measurements, the location, size, and value of the parcels (Stubkjær, 2017). The surveying community consider handheld GPS and satellite imagery inaccurate while the traditional surveying methods do not cater for the communities residing in informal settlements. The traditional surveying methods are costly and time consuming (Uitermark, Van Oosterom, Zevenbergen, & Lemmen, 2010).

For the Namibian legal cadastral mapping context, the parcel is the term used for describing any site without formal legal measurements, and as soon as the parcel is registered for Freehold title, it is then called an erf (plural erven). Under the FLTS, blockerven and plots are described, and block erf is the whole area, which is to be upgraded under the FLTS process, and for this study, it will be referred to as outer boundaries. The block erf consisting of 25-100 households, and a plot is then the respective parcel of a single household. The plot becomes an erf once it is upgraded to freehold. For this study, an erf will be referred to as a parcel. In the Namibian legislation, traditional surveying is the term used which refers to the measurement techniques being used and available within the development of the Land Survey Act, and these include total stations, prisms, tapes, and ropes (Republic of Namibia, 1993). For this study traditional surveying will be referred to as conventional surveying.

2.2. Unconventional land administration

To meet the needs of the developing countries, alternative systems and approaches have been developed over the years, including the development of alternative and innovative land tools. For this study, unconventional land administration will be referred to as innovative spatial data collection methods. Innovative new tools were developed to cater to the needs of everyone in a society. Most conventional land administration systems adopted during colonial times are not responsive to the needs of different groups because they acknowledge formal land tenure types only and work with highly accurate land records preventing marginalized from acquiring land tenure security (Zevenbergen et al., 2013b). Further, to acknowledge informal tenure types, development of tools for spatial data acquisition and recordation was needed to support the continuum of land rights (Enemark et al., 2014). Advantages of innovative tools are their flexibility because it makes it possible to adapt and develop the system during usage and that registration and maintenance are less expensive in terms of capacity and resources (Zevenbergen et al., 2016). It is suggested to combine different tools to increase the responsiveness and the tools to complement each other. For instance, it is possible to combine different techniques, e.g., SmartSkeMa, Unmanned Aerial Vehicle (UAV), Automatic Feature Extraction, and geo-cloud services (Koeva et al., 2017). Measurement combinations can be either between conventional and innovative methods or a set of different alternative methods, depending on the country context (Koeva et al., 2017).

2.2.1. Social Tenure Domain Model

The STDM was developed to close part of the technical gap in developing countries that lack coverage of land by a land administration system (Lemmen, 2009). It is likewise implied for post-conflict regions and the focal point of STDM is on all connections among individuals and land, freely from the degree of formalization or legitimateness of those connections. STDM allows for all types of land rights to be recorded, providing a flexible land information system. In addition, STDM applies a pro-poor approach and is less expensive, faster, and less bureaucratic (Augustinus, Lemmen, & van Oosterom, 2006). It depends on open-source advancements making the device accessible to all, and the idea adheres to the standards of the International Organization for Standardization (ISO) Land Administration Domain Model (LADM). STDM can be customized to meet the needs of the country context, and it has been applied in Kenya, Uganda, the Philippines, Nepal, and Namibia, amongst other countries (FIG, 2019). With this approach the focus is on securing land rights and spatial accuracy can be updated at a later stage.

2.2.2. Automatic Feature Extraction

The Automatic Feature Extraction is an alternative, cost-effective tool that uses high-resolution UAV data to delineate visible land boundaries. High resolution satellite images has the potential to be used for cadastral surveying when the area to be covered is large and high positional accuracy is not a concern (Yoo & Ju, 2012). Manual methods using high resolution images are prone to errors and requires a lot of labor, therefore computer-based (semi) automatic image analysis have been developed (Wassie, Koeva, Bennett, & Lemmen, 2018). Automatic Feature Extraction supports the delineation of boundaries by automatically retrieving boundaries from an orthorectified image (Koeva et al., 2020). It was developed as an alternative to cadastral mapping, which is considered expensive and applies indirect cadastral surveying methods (Crommelinck, 2019). The method involves less experienced operators and are best when there is a time constrain. Further, mathematical algorithms are used for computer-based (semi) automatic analysis to provide suitable information to the user (Wassie et al., 2018).

2.2.3. SmartSkeMa

Sketch mapping is not new as it has been an extensive tradition in modern geography (Boschmann & Cubbon, 2014). The use of local knowledge of places and boundaries is a vital aspect in understanding different processes which impact inhabitants, and sketch maps are therefore used to collect, analyse, and communicate that local knowledge (Amsing, Bennett, & Ho, 2017). Smart sketch technologies and processes allow for converting hand-drawn sketch maps into topologically and spatially corrected maps, which is achieved by applying Computer Vision and Artificial Intelligence (Chipofya, Jan, & Schwering, 2020). Sketch maps are helpful in land administration and frequently used in developing countries where cartographic and spatial knowledge is usually limited. SmartSkeMa operates as a software application that is accessible via a web browser, and the aim of developing it was to support documentation of land tenure information for communities (Koeva et al., 2020).

2.3. Fit-for-purpose land administration

Statistics indicate that 75 percent of the world's population do not have access to formal systems to register and safeguard their land rights. This, therefore, proves that current solutions to delivering land administration services have minimal global outreach (Enemark et al., 2014). The critical bottleneck in land administration has been identified as the use of traditional, high accuracy, expensive land surveying techniques to record land rights. Therefore, it became imperative to rethink the approaches used for securing tenure for all, which is how the FFP land administration was birthed (Lengoiboini, Richter, & Zevenbergen, 2018). The FFP land administration is an approach that advocates for building Land Administration Systems (LAS) that are flexible and that serve the purpose in a specific community (Enemark, 2013). The focus is less on top-notch technical solutions and high accuracy surveys but focuses more on being able to be improved over time according to the community's needs. The FFP land administration essential components are to use affordable modern technologies to build a spatial framework, such as using orthophotos or aerial images to show how the land is occupied and used. A participatory approach is applied to identify and record the various legal and social tenure rights. The third component is to adopt a legal framework that would support the implementation of flexible techniques.

The FFP land administration has three frameworks, the institutional, legal, and spatial framework. This study focuses on the spatial framework, which shows how land is divided into spatial units such as plots or parcels. This framework provides the basis for land administration functions such as recordation and management of legal and social tenure, planning for future land use and development, assessing land and property value, and taxation (Williamson, Enemark, Wallace, & Rajabifard, 2010). In many developed countries, spatial frameworks have been developed and implemented as large-scale cadastral mapping. They are maintained by using advanced technical standards and techniques for adjudication, boundary marking, and field surveys with high accuracy according to legal frameworks (Enemark, 2013). This, however, is not possible to be adopted in developing countries because implementing and maintaining such a cadastre system is too expensive and usually require too much time. This results in only a specific population of the developing nations catering to and excluding the poor communities residing in informal settlements. The FFP investigates fast, cheap, complete, and reliable methods that can be upgraded and updated over time. This FFP approach can be outlined in four fundamental principles; general boundaries rather than fixed, aerial images rather than field surveys, accuracy relating to the purpose rather than the high technical standards, and opportunities for updating, upgrading, and improvement (Mclaren, Enemark, & Lemmen, 2016).

2.4. Boundaries

Zevenbergen (2009) describes cadastral boundaries as "the line on where the right of one subject's right ends and another subject right begins" (p. 5). begins and the other ends." Cadastral boundaries may be natural or artificial and can be represented either by visible features on the ground, or by lines on a map (Luo, Bennett, Koeva, Lemmen, & Quadros, 2017). Fixed boundaries make use of located coordinates such as beacons that are surveyed to identify the boundaries rather than boundary features(Kaufmann & Steudler, 1998). They are usually determined by a land surveyor, are very accurate and are legally binding between two parties For rural areas, linear features such as fences, and hedges can serve as cadastral boundaries in rural areas (Wassie et al., 2018) and such visible boundaries are useful in land management and land information systems (Zevenbergen & Bennett, 2015). The advantages of the visible lines are that it allows the use of cheaper photogrammetric approaches to surveys (Wassie et al., 2018). General boundaries can be determined from using photogrammetry using topographic and orthophoto maps

2.4.1. Continuum of land rights

In many urban and peri-urban area of developing countries, there is upsurge of many informal or unrecognized tenure. Tenures such as customary, religious, and statutory can be considered as lying on a continuum. Across a continuum, various tenure systems may operate and may change in status in future. At one end are formal land rights, where the owner is an individual, who holds a set of registered rights to a parcel of land that are recognized by law. The owner on the formal end has the right to construct permanent structure on the land, the parcel is delineated on a map; held in a record office; the owner has the right to occupy the land, sell it, rent it out, transfer it to his or her heirs, and prevent other people from coming on to it. At the informal end of the continuum are informal rights: a group of individuals may have traditional rights to use a piece of land, or a group of people illegally or informally occupying land which does not belong to them. The boundaries of the land may not be clearly marked on the ground or on a map, and there may be no official paperwork certifying who owns or has what rights to the land. In between these two extremes are a wide range of rights including customary, occupancy, alternatives to eviction, adverse possession, and group tenure (Barry & Augustinus, 2016).

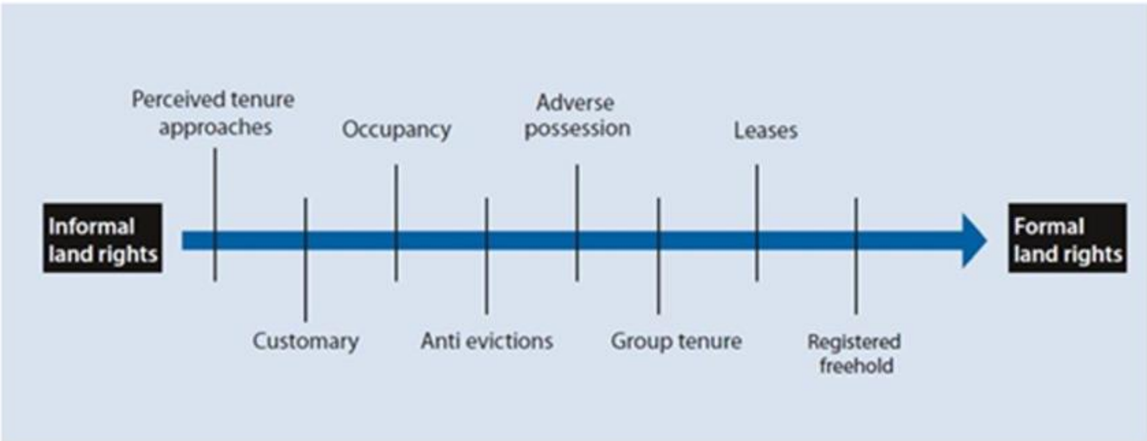


Figure 2: Continuum of land rights diagram

2.5. Informal settlements in Namibia

The Shack Dwellers Federation of Namibia has been doing mapping and data collection since 1999. In 2004 the City of Windhoek agreed for the Greenwell Matongo C community to plan and upgrade their community following a settlement enumeration. A comprehensive agreement was signed which enabled the community to plan their area and install bulk infrastructure, with the support of Namibia Housing Action Group. The City of Windhoek got involved when allocation procedures started. Although the re-blocking was done, blocks of land were registered, and savings continued.

Besides the numerous from, the Namibian government realized that the lack of data regarding informal settlements was the main challenge. Therefore, the Shack Dwellers Federation of Namibia with Namibia Housing Action Group in 2016 agreed with the then Ministry of Regional, Local Government and Housing to do a national profile of informal settlements. The outcomes were combined and then it was found that there was already an estimate of 134,800 households living in 235 informal settlements. In 2012 Gobabis Municipality agreed to do a bottom-up upgrading, following a city-wide enumeration and a feedback session in Freedom Square in Gobabis. The area was mapped, and a planning studio conducted with Namibia University of Science and Technology (NUST). The layout was prepared, 1000 household re-blocking was done, the community installed their water lines and sewer lines (Integrated Land Management, 2018)

2.5.1. Flexible Land Tenure System

The aim of the Flexible Land Tenure Act, Act 4 of 2012 is to overcome problems related to land delivery for people with a low income. The problems are mainly attributed to the lack of affordable freehold land in urban and peri-urban areas. It creates a second property registration system, parallel to and interchangeable with the conventional system. The FLTS provides for an affordable, more secure, and simple right which can be upgraded according to what the government can afford at any given time (Christensen, Werner, & Hojgaard, 1999). It can only be applied within proclaimed villages, settlements, and towns; application to communal lands is excluded. The system can be applied to upgrade existing or develop new settlements. It introduces two new land rights: a starter title and a land hold title (Christensen et al., 1999). A starter title is a statutory land right whereby a piece of land is registered for a group of beneficiaries without delimiting the extent of each individual plot. A starter title can be given to a new settlement and the registration of Starter Title is based on a point cadaster approach. However, to prevent random settling, a layout plan may have to be prepared. This 'blockerf' may be held in ownership with a government body, community organization (group, association) or a private developer. The whole block is registered as a single entity in freehold ownership, both at the Registration of Deeds in Windhoek and at the Land Right Office located at the local authority. All (potential) inhabitants of the block must establish an association that has a constitution. Within the block, each member must abide by the rules set up by the association. The starter title is transferable; it cannot be used as collateral for credit. The blockerf is surveyed according to the land survey regulations. The land hold title relates to the plots defined for everyone. The Land Rights Office registers the land hold titles, and the cadastral layout is done by a land measurer. The land measurer is a land surveyor with lower qualifications, a paraprofessional. At this stage, there is no involvement by the Ministry of Agriculture, Water and Land Reform or other central authority. The land hold title can be used as collateral for credit and is, with respect to credit facilities, comparable to freehold. To upgrade to freehold, the scheme must be situated within the area of an approved township and at least 75% of the members must agree (Government of Namibia, 2018). The local authority may compensate those who refuse to upgrade and sell the plots to interested outsiders. It is assumed that the conversion from land hold to freehold would be less costly than registering freehold directly. A land hold title resembles freehold; the main difference is that servitudes, restrictive conditions, and long-term leases are not possible on land hold titles (Government of Namibia, 2018). Another difference is that the land hold titles are registered at the local Land Right Office whereas freehold titles are entered in the central Deeds Registry in Windhoek. Before any formalization, the concerned land must be subdivided or consolidated to ensure that the scheme is situated on one registered portion of land (Ministry of Land Reform, 2016). Any mortgage, usufruct, or similar land right must be cancelled in advance (Government of Namibia, 2018). In 2018, the official implementation regulation of the FLTS was introduced. After the approval of establishment of the Starter Title Scheme, a Professional Land Surveyor determines the location of the blockerf, and the Land Measurer specifies the reference points for each Starter Title right (Government of Namibia, 2018).

2.6. Prior studies on spatial data collection methods

Previous studies have been done where these FFP approach have been implemented using innovative spatial data collection tools. Innovative in this case means its methods which comply with fit for purpose principles. The Land Tenure Regularisation in Rwanda was done using the general boundaries approach, data was collected with high resolution orthophotos, satellite images and UAVs were used for acquiring aerial images (Gillingham, 2014). Namibia is another example that used fit for purpose approach for the Communal Land Registration where GPS and aerial images were used to map land parcels. A study by Mumbone was done using UAVs to understand whether the challenges faced with the conventional techniques in Namibia would be solved with UAVs and the results proved that UAV mapping approach enabled production of high accurate orthophoto maps that could be used for customary land mapping (Mumbone, Bennet, Gerke, & Volkmann, 2015). Furthermore, Ethiopia had success in completing "1st level certification" of over 12 million rural household land holdings using orthophotos. A study on innovative remote sensing methodologies for Kenyan land tenure mapping was done using the SmartSkeMa, UAVs and automatic boundary extraction based on the acquired UAV images. The aim of the study was to assess the applicability of remote sensing methodologies in Kenya and the results showed that SmartSkeMa was a more responsive tool for data acquisition to the community because it required less expertise. UAVs had a high potential for creating up-to-date base maps which are able to support the current land administration system and the automatic boundary extraction was effective for demarcating physical and visible boundaries (Koeva et al., 2020).

Rahmatizadeh et al. (2018) did a study which established a framework which could be used for selecting a FFP data collection method in land administration. They identified a set of indicators which could be used to select a fit for purpose method for data collection. The first indicator relates to the nature of the data and takes characteristics such as accuracy, reliability, and completeness into account. The second indicator refers to the process of data collection and what is taken into consideration are indicators such as time efficiency, repeatability, affordability, verifiability, ease of implementation and openness into account. The third indicator is about post data collection and has a long-term perspective because building a spatial framework is not a once of process and the indicators taken into consideration are compliance with common standards, data update mechanisms, upgradability, metadata services of method and sharing data mechanisms. When spatial data collection method has to be chosen, a good understanding of the current issue in the specific area of interest is very important because over or under estimation of the requirements could result in selecting the wrong methods (Rahmatizadeh et al., 2018).

Lauterbach (2020), did a study and the focus was on the analysis and evaluation of the following alternative surveying methods: orthophoto-based boundary demarcation, mobile mapping applications on mobile devices, measurements with hand-held GPS receivers, low-cost GNSS and GNSS RTK using the Namibian Continuously Operating Reference System. The methods mentioned are described, tested within the test area Onyika Erf 2330 (Windhoek, Namibia), and evaluated based on a self-designed catalogue. The evaluation criteria used addressed factors such as complexity, cost, time efficiency, technical performance, and feasibility. With this evaluation, the methods were divided into low-cost approaches (mobile mapping, and hand-held GPS receivers) and high-technology (GNSS, low-cost GNSS and orthophoto-based approaches). The applicability for Namibia is evaluated positively for all methods, although the potential areas of application and limitations of the individual methods vary significantly (Lauterbach, 2020).

A study which assessed Low Altitude Remote Sensing Image (LARSI) integrated participation procedures for urban adjudication in China was conducted. An assessment framework was designed and tested, and the results of the study showed that the new procedure contributed to efficiency, saving labor and reducing land adjudication cost (Jing, 2011). The procedure for this study was assessed on 4 indicators: data quality, time/efficiency, cost and law compliance.

3. RESEARCH METHODOLOGY

This study aims at comparing the different spatial data collection methods for informal settlement land tenure mapping in Gobabis, Namibia. This chapter explains the adopted research design and methods. It also gives an overview of Gobabis as a case study area as well as the limitations of this study and the ethical issues.

3.1. Study area

This study will take place in the Freedom Square informal settlement which is situated on the outskirts of Gobabis. Gobabis is the regional capital of the Omaheke region, located 200km east of the capital city of Namibia, Windhoek. The selection criteria for choosing this study area were that it has participated in the mapping and enumeration process, and it was part of the pilot for FLTS and the STDM, which is an advantage as the researcher can be provided with the needed data for the study.

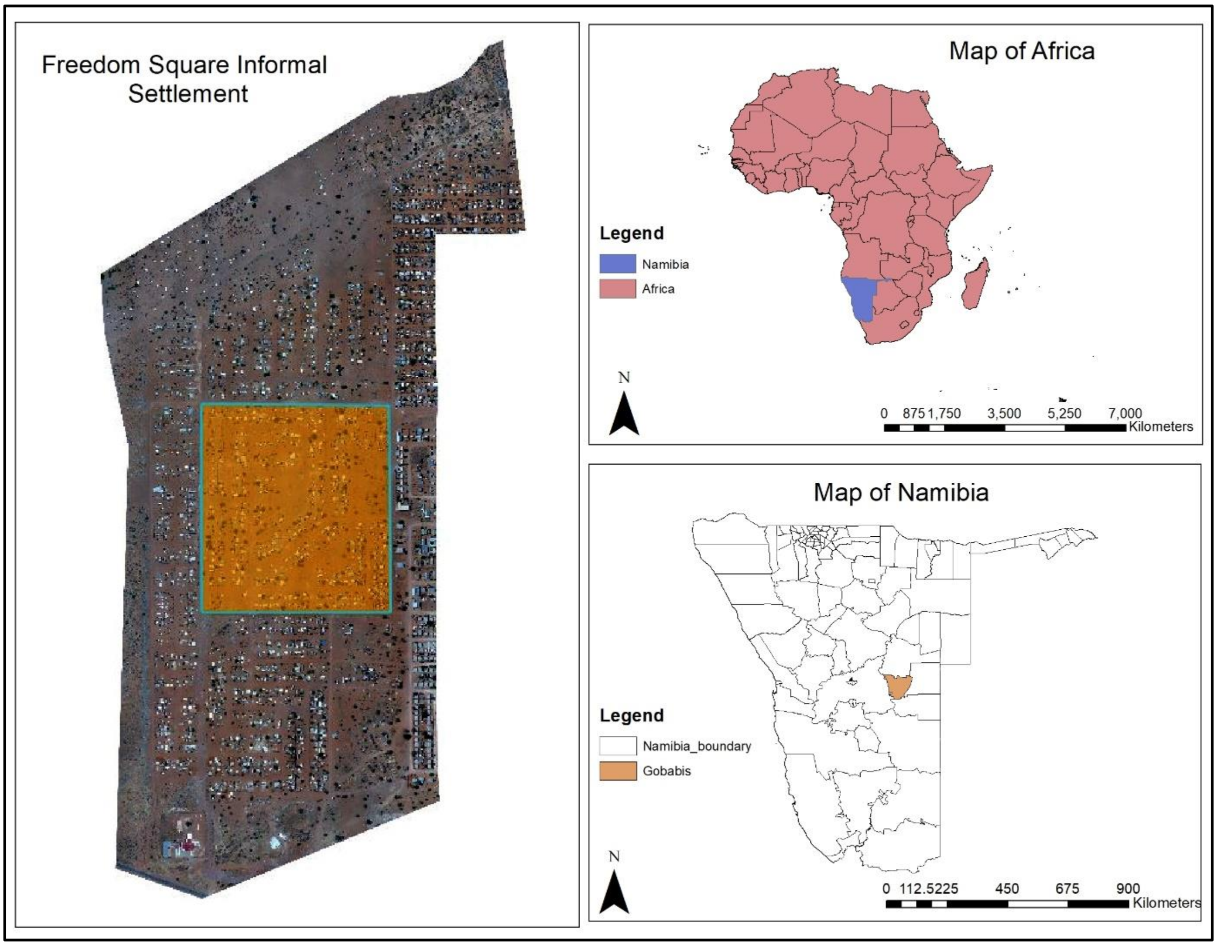


Figure 3: Study Area

3.2. Research design

This study adopted a case study approach and this strategy was chosen to compare the innovative methods against the conventional methods which were used in Freedom Square in Gobabis, Namibia (Dan, 2019). Further, the case study area was chosen because the area piloted the STDM and conventional methods were used for inner boundary surveying which was done by a survey technician known as the land measurer (Mabakeng, 2019). This therefore helped to understand the methods that were used, the purpose of use and to compare them with innovative methods to determine the suitability of the use of the innovative methods in Namibia.

3.3. Research methods

This section provides detailed information of all the tools used for data collection. Empirical literature comprising of previous studies were reviewed, such as studies on land tenure regularization, cadastral systems, the FFP, and spatial data collection methods. This helps the researcher to objectively validate the background facts concerning the problem, hence addressing the research problem meaningfully. This study has three main stages. Figure 4 below describes the steps which were taken for the research.

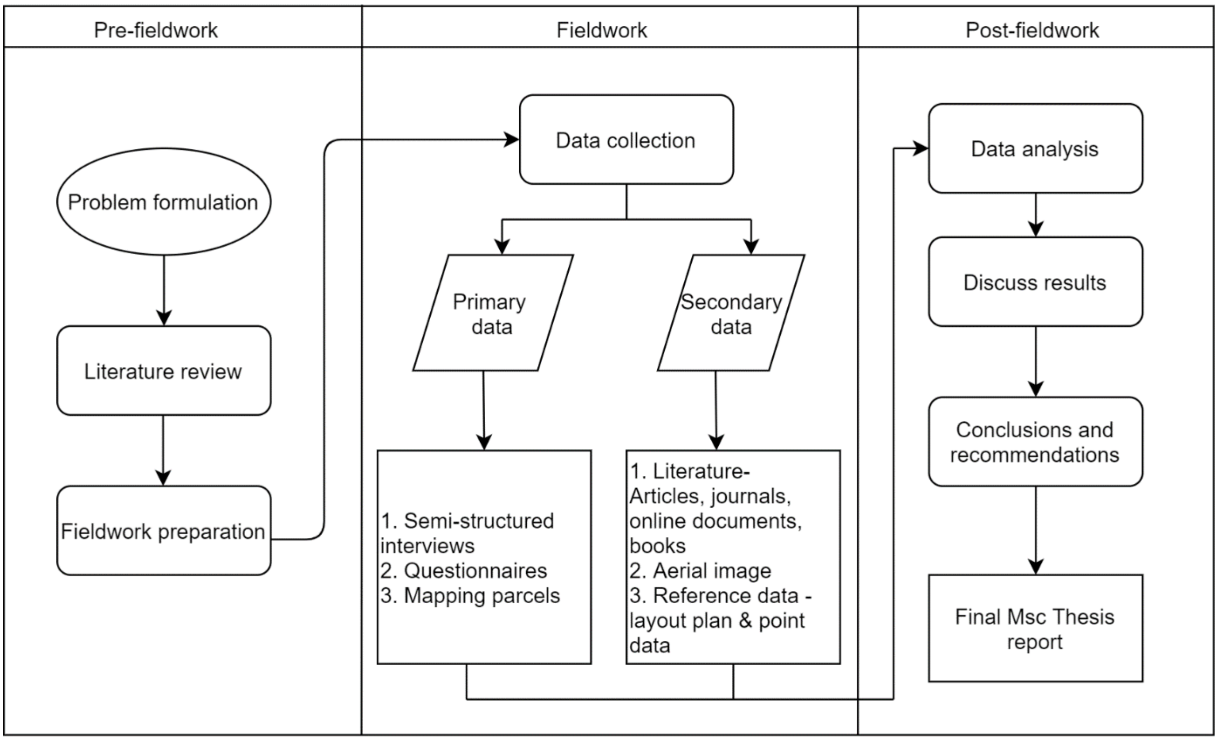


Figure 4: Research stages

The problem formulation was based of the literature. The FFP approach was reviewed with specific focus on the Spatial Framework which is the focal point of the research. The innovative methods fall under the spatial framework and the indicators which will be used are derived from fit-for-purpose principles. A literature review followed where all relevant literature was be studied, after the literature review preparation for fieldwork started. This included preparing interview questions, preparing orthophotos which will be required for fieldwork and then fieldwork where data was is collected. The study participants consisted of Land Surveyors, Municipality employees, NHAG officials, Academics from Namibia University of Science and Technology, Town Planners, Ministry of Agriculture Water and Land Reform and the land occupiers. The indicators for comparing the performance of the different spatial data collection tools were determined based on the responses from the fieldwork. Furthermore, a case study was selected to be used as a reference point. The STDM tool has been used in Gobabis before and conventional tools as well, so this made it a perfect study area to test the SmartSkeMa and Automatic Feature Extraction to enable a comparison to be done between the methods. Only 1 method which is GNSS RTK was selected from the conventional methods to be used for comparison. In addition, a mixed study design of both qualitative and quantitative methods was used.

3.3.1. Pre-fieldwork

This stage consisted of identify the research problem, formulating the research objections and questions. In addition, fieldwork preparation was done which involved designing the interview questions and ranking questionnaires. In preparation for the land parcel mapping, the land occupants were invited for a brief meeting to be informed about the activity that will take place in their settlement and they were informed about the date mapping will take place. The orthoimage which was used in the field was prepared by georeferencing it to the local coordinate system and by identifying Ground Control Points (GCPs) and printing of the map was done during this stage.

3.3.2. Fieldwork

Primary and secondary data was used during fieldwork to acquire the data for this study. A research assistant was appointed to collect the data, particularly the mapping of the parcels and this was conducted in Gobabis, Namibia. For the SmartSkeMa, mapping of parcels was required, and 50 parcels were mapped, and information of the occupants was also collected. An orthoimage was used in the field together with a transparent sheet of paper where the community identified their parcels and sketched it on a transparent paper which was overlayed on the orthophoto. To get the details of the community, an excel spreadsheet was used and basic information to link who lives where was collected. In addition, 15 interviews with key informants were conducted either via Microsoft Teams, Zoom or WhatsApp. 10 questionnaires were disseminated to informants to get an understanding of what they would take into consideration when selecting spatial data collection methods.

3.3.2.1. Primary data collection

Primary data is regarded as being the most reliable and authentic way of collecting data and it allows the researcher from gathering data from the source directly (Ainsworth, 2020). Purposive sampling, ranking questionnaires and semi-structured interviews were used to gather data about the different innovative and conventional spatial data collection methods, their characteristics, the actors involved, how they were chosen and how these innovative methods can be incorporated into the current methods being used. Semi-structured interviews can be described as a method of data collection that allows the interviewer and interviewee to interact and the questions posed are more flexible (Adams, 2018). This method was used to address questions from sub-objective 1, sub-objective 2 and part of sub-objective 3. Further, semi-structured interviews were selected because of they allow active involvement from the respondents and responses can be clarified (Al Balushi, 2016). Questionnaires were used to get feedback on the indicators which individuals found important during selecting spatial data collection methods. This gave the respondents an opportunity to rank the parameters from what they found most important to least important. Questionnaires are described as a series of questions asked to individuals to obtains statistically useful information about a specific topic (Roopa & Rani, 2012). The informants consisted of:

- Academics from the Namibia University of Science and Technology
- Municipal employees, Gobabis, and Windhoek
- Land surveyors
- Namibian Housing Action Group (NHAG)
- GIZ
- Ministry of Agriculture and Land Reform
- Town planners
- Survey technicians
- Community members
- Land Rights Office

3.3.2.2. Secondary data collection

Besides using primary data, secondary data was also used which consisted of various reports, legal documents, scientific literature, online reports, newspaper articles and academic articles. The secondary data which is collected is used to address some of the research questions and for the literature review. The collection of secondary data was done through various ways. During interviews, some respondents referred to certain documents, some provided documents which are not available online and they were emailed to the researcher. The legal documents including the Flexible Land Tenure Act 4 of 2012 and Land Surveyors Act 33 of 1993, and corresponding gazetted regulations were downloaded from the internet. The legal documents were consulted to get insight and better understanding on how the spatial data collection methods are chosen. Furthermore, it was done to acquaint the researcher with the legal framework as it plays an important role in administering land and decisions that are related to land.

Additional information, such as samples of certificates were obtained from the respondents, one which was recently issued to the individuals of Freedom Square through the Flexible Land Tenure Act and one which was supposed to be issued using the STDM. A high-resolution orthoimage of Freedom Square which was acquired using UAV was provided and used for spatial analysis. The layout plan of the area which were produced by using the conventional methods were also provided in vector format together with the reference point data collected by the land measurer.

3.3.3. Sampling method

Purposive sampling was used to select the individuals to be interviewed. It is described as a sampling technique in which the researcher selects certain people deliberately to get important information that cannot be obtained from other sources (Taherdoost, 2016). The key informants were specifically selected because of their knowledge and involvement in informal settlement upgrading in Namibia. However, during some interviews, referrals to other individuals were made therefore making use of snowball sampling. Snowball sampling is a technique that uses a few cases to help encourage other cases to take part in the study (Taherdoost, 2016).

3.3.4. Post fieldwork

Post field work consisted of spatial data processing and analysis, although for Automatic Feature Extraction processing was done consecutively while field data was collected because the method did not require any data from the field. The second part that post field work consists of is data processing and analysing of the data collected during interviews and the ranking questionnaires. The 2 phases are described below.

3.3.4.1. Spatial data analysis

Most of the cadastral mapping and assessing of the innovative methods was done during this phase. The data generated from the fieldwork was geometric data (delineated orthoimage) and attribute data (land tenure information). For SmartSkeMa, the output was a transparent sheet with parcels delineated on them, a picture of this sheet was taken by the research assistant and forwarded to the researcher. This data was then processed in the SmartSkeMa system and the vectorized output was used in QGIS, this was overlayed over the aerial image to determine if they overlay. To increase the precision of the field results, a desk exercise was needed to be done to reproduce the process and print out smaller sections of the map on A3. This activity was done because the whole area was mapped on an A3 paper in the field which compromised on the accuracy and precision of the drawing. The Automatic Feature Extraction was processed with multiple software such as MATLAB and python were required for training the algorithm which was required to automatically identify the boundaries, in addition to these QGIS and ArcGIS were used as well. The boundary delineation plugin is available on QGIS only, therefore final processing and analysing was done on QGIS. To analyse the accuracy a buffer of 1m was created and the output from Automatic Feature Extraction and SmartSkeMa was overlayed over the layout plan.

3.3.4.2. Data processing & analyzing

Data collected was managed in two steps, the first one consists of data processing. Primary data collected from the field through interviews were transcribed either using Microsoft word or manually. This data was then further analysed and organized by identifying common themes and storing them accordingly and this analysis was done in an excel sheet (Akinyode & Khan, 2018). This was useful in categorizing information that is similar, such as the types of spatial data collection methods that are used in Namibia and for identifying the characteristics of these methods.

3.3.5. Comparative research

This study is a comparative one, and this included comparing the innovative methods, Automatic Feature Extraction and SmartSkeMa against the conventional DGPS RTK method. This was done to identify the suitability of the innovative methods in mapping informal settlement in Namibia. Comparison provides a basis for making conclusions and decisions and it is the basis to empirical social science (Miri & Shahrokh, 2019). The indicators which were used for comparison are – accuracy, reliability, ease of implementation and compliance with common standards. These indicators were derived from the ranking questionnaires from the respondents.

3.4. Ethical consideration

The research involved the collection of both primary and secondary data. For data collected from participants involved in parcel mapping, permission was obtained. The purpose of the research was explained to the respondents before carrying out the interview. Consent to record the interview and take notes was sought, and information collected was treated with confidentiality and used for education purpose only. Personal information about the respondents is kept anonymous to protect their privacy. Any other information obtained through interaction or official documents is kept confidential. The respondents will have the freedom to withdraw their consent, and in such a case, consideration for other respondents will be made.

3.5. Limitation in data collection

The biggest limitation was that the research was conducted during the COVID-19 pandemic and research had to be done remotely. Getting hold of the respondents to take part in the interviews and questionnaires was a challenge. This was caused by the busy schedules of the group of informants this study was interested in which comprised mostly of decision makers and surveyors.

3.6. Conclusion

The chapter provided an explanation of the study area and the methodology adopted for this study. Details on the methods of data collection, processing, and analysis to answer the research questions was also presented. The next chapter presents the results obtained from the data collected.

4. RESULTS

This chapter presents the findings obtained from the field through semi-structured interviews, ranking questionnaires, mapping, and literature related to sub-objectives 1, 2, and 3. Data obtained are presented in tables and figures, followed by subsequent analysis of the findings. Section 4.1 presents the spatial data collection methods in Namibia, and section 4.2 presents the indicators which are preferred for selecting spatial data collection methods.

4.1. Spatial data collection methods used in Namibia

This sub-section presents the results relating to the first objective of identifying the spatial data collection methods used in Namibia. The conventional spatial data collection methods are described in section 4.1.1., innovative spatial data collection methods are described in section 4.1.2, and the innovative spatial data collection methods in section 4.1.3.

4.1.1. Conventional data collection methods used in Namibia

This section depicts the conventional spatial data collection methods in Namibia and describes the purpose of using them.

Table 1 shows the data collection methods which were either used or are still used in Namibia and what their purpose was. A surveyor stated that "*there are two aspects to spatial data collection in Namibia; the first one is mapping to be used for spatial planning and the second is mapping to determine who lives where*." For spatial planning, the town planners must use base maps for participatory planning, the township layout, and demonstrations with the community. The engineers require these base maps for planning engineering services; therefore, detailed maps are required for engineers. A municipal respondent further commented that detailed aerial images captured with UAV's helped determine how the settlement is growing, who is invading the settlement, and seeing what has been planned already. Further, an individual from the enumeration team from GIZ stated that "*during socio-economic data collection and collection of data to be used for land hold title registration, detailed maps of the area are required for orientation purposes, and for marking the households where data has already been captured*." Table 1 below summarises the data collection methods used in Namibia.

Method	Tools	Purpose	Still in use or not
Aerial surveying	Airplane flights	Spatial planning & boundary identification	Partly in use
	Drone technology	Spatial planning & boundary identification	Partly in use
	Lidar	Cadastral surveying	Seldom used
Terrestrial surveying	Pentagon prisms	Cadastral surveying	Not used
	Tapes	Cadastral surveying	Not used
	Total stations	Cadastral surveying	Partly in use
GNSS	GNSS (RTK)	Cadastral surveying	In use
	DGPS	Cadastral surveying	In use
	Handheld GPS	Cadastral surveying	In use

Table 1: Data collection methods used in Namibia

Traditionally, only data obtained from airplane flights were available for the orthophoto-based approach, resulting in additional costs for flights. Further, respondents indicated that using airplane flights was very expensive because a specialized plane was required together with a team of photogrammetry experts, which

Namibia did not have at the time. Some Local Authorities, such as the City of Windhoek and Government Officers would hire a team of international photogrammetry experts and this activity would in turn be expensive. It was further highlighted that there are economies of scale when choosing methods and airplane flights could only be used for very big projects which would then be cost effective. In the most recent years, private surveyors and some Municipalities like the City of Windhoek started using drone technology also known as UAVs to obtain aerial images, especially for smaller areas such as informal settlements. Mapping with drones is based on structure form motion photogrammetry which is different from the old metric photogrammetry method previously used with airplane flights. Numerous respondents indicated that UAVs are occasionally used to capture images of informal settlements although the air traffic controls and regulations makes it difficult for people to use them. Respondents especially from the surveying community indicated that, "*the directives from the directorate of civil aviation require individuals who would like to fly drones to get permission by [applying] two months in advance before flying and requires them to be licences drone pilots. All these requirements result in people not using drones at all or use them illegally without following the legal procedures*." UAV regulations prohibit users from flying near an airport, not allowed to fly above populated area, not allowed to fly above 50m and all that is required when mapping informal settlements. In addition, all flights require authorization 30 days before flying. Namibian citizenship is required and a fee of 4500 Namibian Dollar (248 euro) is required when flying for commercial use ("NCAA - Aerodromes," n.d.).

A respondent during the interviews highlighted that orthophotos in Namibia are not formally used for cadastral purposes in urban areas where there are smaller plots, which is due to the legal requirements that do not make provision for photogrammetric cadastral mapping; therefore, amendments to the land surveying regulations are required. According to the response from a surveyor, Namibia generally has fuzzy boundaries, which makes it challenging to use orthoimages, but exceptions for areas like the Freedom Square where the settlement is well organized makes it possible for orthophotos to be used together with the assistance of land administrators to create land hold plans. He further stated that "*the land administrators or municipal team can help the community with putting proper fences that can be identified on orthophotos*." Orthophotos in Namibia are used for Communal Land Registration only, but the NUST researchers are busy researching how photogrammetry (UAVs) can be incorporated into the current system. Incorporation is considered because of the potential UAVs have to speed up land tenure mapping, especially in built-up areas. A professional surveyor further indicated that "*photogrammetry has advantages and is a better alternative in cases where getting access to the shacks, to place pegs becomes difficult and time-consuming*". The data obtained from this is usually passed on to the Town Planners to assist them with planning.

In addition to the methods highlighted above, a respondent from the NUST indicated that the surveying students also tested additional methods and experiments with pentagon prisms, tapes, and total stations. These resulted in very complicated procedures which were prone to error if used by paraprofessionals, although the accuracy and time estimates for these methods were reasonable (Lauterbach, 2020). Subsequently, responses and literature revealed that in Namibia, surveying is currently mainly carried out with total stations and with GNSS (RTK), and sometimes both are used together. According to the land measurer, "*the total station for Freedom Square was only used to place 1 point out of about 1000 points, and for the rest, DGPS was used*". The use of the latest technology, such as the smart GNSS receivers or robotic total stations, is encouraged by the Ministry of Agriculture, Water and Land Reform (Lauterbach, 2020). Another method that is seldom used but mentioned by a surveyor was lidar, "these *days lidar is becoming cheaper and is mounted on drones, but generally, [traditional] UAV and piloted aircraft are cheaper than lidar*." Lidar is used for smaller areas, and the advantages are that when there is vegetation, lidar can penetrate the trees and ground shots are obtained. A respondent indicated that, although lidar has advantages for smaller areas, lidar is usually more helpful for road surveys than cadastral surveys.

For cadastral mapping and determining who lives where, the conventional GPS method is used, and they are mainly used for planned areas, and they are considered more efficient than total stations, which are too slow. A respondent indicated that there is a link between base maps (aerial images) and other maps such as cadastral maps because if there is a detailed high quality base map, then it would not be necessary for the enumerators to go around with handheld GPS to determine who lives where because it can be done on the map. Further, it was affirmed by respondents that aerial images are helpful when used in combination with GPS in cases when surveyors struggle to get between houses to place pegs, "*this process can take hours; therefore, aerial images would be a viable alternative*." As stated by a respondent from NUST, the only setback with using aerial images is that "informal settlements normally do not have boundary walls, so it would be most efficient to just do it the conventional ways by using a GPS."

4.1.2. Innovative data collection methods used in Namibia

The innovative methods used in Namibia, with specific emphasis to Gobabis are the STDM and the open-source free data collection tool Kobo Collect. The STDM was a method chosen by the NHAG which supports the SDFN. The SDFN and NHAG are part of a network of saving groups that are affiliated to Shack Dwellers Federation International and they have used the tool in Uganda, and it was reported to be successful. Namibia therefore decided to propose STDM as a tool for Flexible Land Tenure Registration in Gobabis but according to two respondents, "*there was disagreements on the use of the tool. The Ministry of Agriculture, Water and Land Reform was working on implementing two digital systems namely Namibia Communal Land Administration System (NCLAS) and digitizing the deeds registry and these systems were still not integrated due to technical challenges, so they refused to introduce a third system for the FLTS*". Another respondent stated that, "*STDM was supposed to be used for certificate generation, but the Municipality of Gobabis said they don't want that certificate of occupation and that they would rather just wait for certificates from the FLTS*". Even though the government and Municipality of Gobabis refused to make use of the tool for land recordation STDM was piloted in Gobabis, and it worked very well, and the NGO further proposed to make use of STDM for certificate generation as indicated in appendix A, but implementation never went through.

In addition, Kobo Collect which is a free and open-source software which consists of tools for field data collection suitable for challenging environments was used. Most users of the software are people working in humanitarian crises, as well as aid professionals and researchers working in developing countries. The Namibian President declared the Informal settlements a humanitarian disaster in 2018, which enabled the GIZ team to officially make use of the free service provided by Office for the Coordination of Humanitarian Affairs (OCHA). The software can be used by anyone working for an organization which is providing humanitarian assistance is free to use the Humanitarian Server situated in Ireland, which is provided by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA). The Non-Humanitarian Server is not an option for utilisation because it is located outside of the EU boundaries but because informal settlements were declared a humanitarian crisis Namibia was able to use it. Moreover, it is possible to install the Kobo suite on a private (local) server, but this will require additional funding and IT skills. Data can be monitored directly on the Kobo webpage or downloaded in different formats. Excel is the most common program to use for this. The geolocations can be downloaded for viewing in Google Earth and the pictures taken should be downloaded separately.

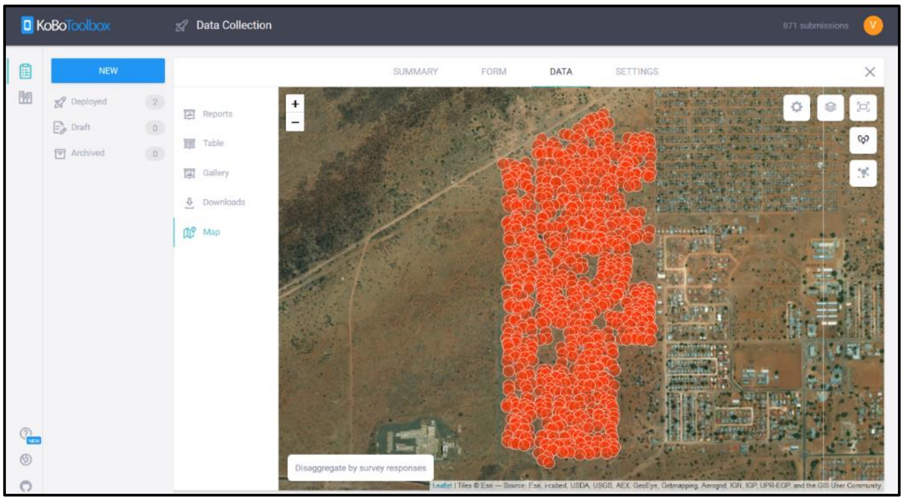


Figure 5: Geo-Coordinate position of the parcels in Freedom Square (Hamuteta, 2019)

Besides these methods mentioned above, the NUST are busy conducting research on innovative FFP methods to upscale land registration for informal settlements in Namibia. A respondent stated that, "*we proposed the complete mapping of all the informal settlements in Namibia using open street map that gives us the building footprint for most of the informal settlement and where we cannot or where we don't have access to the latest satellite images. We are working on finding ways to improvise. So, our entry point for complete sort of base data for information will be the use of the open street*". It was elaborated further that; this will help local authorities have base data that they can use for starting or initiating land recordation exercises. Local authorities currently issue occupation certificates that do not have spatial reference, it would just indicate the structure number, the settlement, and the details of the structure occupant.

4.1.3. SmartSkeMa and Automatic Feature Extraction

SmartSkeMa and Automatic Feature Extraction are tools developed by its4land and they will be compared against the conventional methods in this study. The purpose of this comparison is to determine the suitability for use in mapping informal settlements in Namibia. In addition, it is being conducted to support the current ongoing research on spatial data collection methods being done by the NUST.

This section describes how the SmartSkeMa, and Automatic Feature Extraction works by briefly describing the steps for each method. Detailed explanation of the processes of both SmartSkeMa and the Automatic Feature Extraction are provided in the chapter 5 and sub-sections below.

The SmartSkeMa has two workflows with overlapping functions depending on the type of input map used. The first workflow as used in this study requires sketching to be done by the local community over a georeferenced aerial map (see figure 6). The second workflow does not require any georeferenced map because sketching is done using freehand. After sketching with either of the workflows mentioned previously, steps which include vectorizing, image aligning and adding of land tenure information can be done. The land tenure information can either be obtained during fieldwork or after fieldwork via excel spreadsheet capturing personal information and land tenure relationships.

Figure 6: Locals delineating their parcels in the field

Automatic Feature Extraction uses the boundary delineation approach. The approach consists of three steps namely, image segmentation is a step that delivers closed contours capturing the outlies of visible objects in the image (Crommelinck, 2019). For this study image segmentation used a Red Green Blue (RGB) orthoimage of the study area. Boundary classification which is the second step refers to training a machine learning algorithm to predict boundary probabilities for lines obtained through image segmentation (Crommelinck, 2019).The final step is using the interactive delineation plugin in QGIS as shown in figure 7 below.

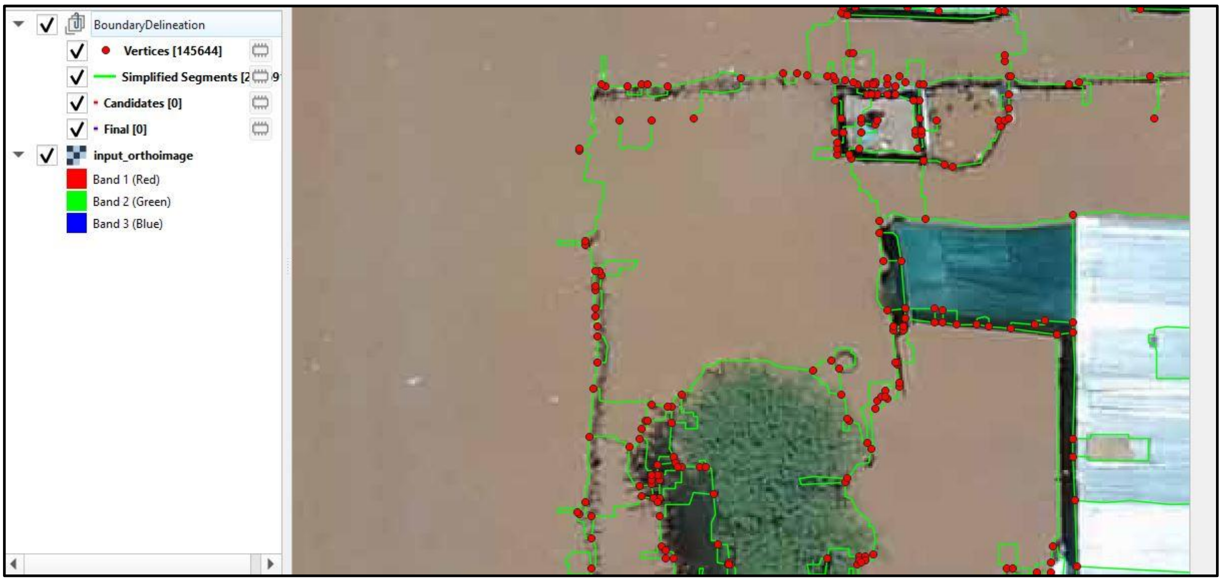


Figure 7: Boundary delineation in QGIS

4.2. Characteristics of conventional and innovative spatial data collection methods

The next sub-section presents the characteristics of the conventional and innovative spatial data collection methods which are currently used in Namibia for cadastral surveying and specifically those that were used for Freedom Square.

4.2.1. Characteristics of the conventional data collection methods used in Namibia

The following were used as characteristics to assess the conventional and innovative methods which were used for Freedom Square; name of the methods, period of existence, aim of using the methods, software for processing data, data storage, accuracy, and costs. These characteristics were identified during the interviews with the respondents and from literature. Table 2 presents the characteristics of the methods.

Conventional Methods				
Characteristics	**Method**	**Method**	**Method**	**Method**
Name of the method	Handheld GPS	DGPS (RTK)	Total station	UAV
Aim of using the methods	Geolocation	Cadastral surveying	Cadastral surveying	Capturing aerial images
Software	QGIS & ArcMap	Leica Geo Office & surpac	Leica Geo Office & surpac	QGIS
Data storage	Computer & hard drives	Computer & cloud	Computer & cloud	Computer
Accuracy	1-3cm	+-3cm	Accuracy class A, B & C (According to Land Survey Act)	5cm
Costs	1 Handheld GPS = 2805 Namibian Dollars (175 euro)	Ranging from 32 000 Namibian dollars (2000 euro)	Ranging from 12 800 Namibian dollars (800 euro)	15 000-20 000 Namibian dollars (937.50 euro)
Time	1 month	+-1month excluding processing	+-3month excluding processing	1.5 week including processing
Spatial reference system	WGS84	Schwarzeck	Schwarzeck	Schwarzeck
Data updating	n/a	No updating	No updating	No updating

Table 2: Characteristics of conventional methods

The conventional methods, GPS, DGPS and total stations are regulated by the Land Survey Act and aerial images, or photogrammetry regulations are not clearly stated in the Land Survey Act. An interpretation of the results. Table 2 is described row by row using the characteristics of the methods. UAV technologies are used for capturing aerial images as well and these are regulated by the UAV regulations.

4.2.1.1. Aim of using the methods and period of use

According to the respondents, these methods are used for cadastral surveying. Further, a respondent stated that, "*when a survey is done with a GPS, the purpose, is to collect the locations of the parcels according to what the town planner planned*". GNSS methods were used for surveying the outer boundaries by a professional land surveyor and by a land measurer to survey the inner boundaries. The land measurer stated that "*the total station was used to place one point out of 1000 points so it can be regarded as if it was not used*" and in addition, UAV images were captured to use as a base map and for monitoring the situation on the ground.

4.2.1.2. Software

The responses revealed that open-source software such as QGIS are used for data obtained from handheld GPS and UAVs. In addition, 2 respondents stated that, "*ArcGIS is occasionally used by some organisations, but due to the cost of the license we sometimes tend to use opensource software or ArcGIS which is unlicensed*". For DGPS Leica Geo Office and surpac are used. A respondent from the Gobabis Municipality indicated that they do not have access to any GIS software and another respondent from City of Windhoek stated that "*due to budget constraints, we cannot always afford software that are needed*".

4.2.1.3. Data storage

It was stated by the respondents that the data is mostly stored on computers and backed up on hard drives and for some methods like DGPS, data is also stored on a cloud.

4.2.1.4. Accuracy

In Namibia accuracy is deemed to be very important, and this is because of the legal framework which emphasizes on very high accuracy. When using GPS, accuracy of 2-4cm is required and for photogrammetry, accuracy of 10cm is acceptable although 3-5cm is preferred by the Surveyors because of the common standards and the usage of methods such as the UAVs which produce higher accuracy. The Namibian Land Survey Act of 1993 that regulates cadastral surveying are done according to the law, it is mandatory to ensure that plots are surveyed by a Professional Land Surveyor to legally register the land rights and the same principles applies to informal settlement as well. There are specific regulations for the usage of GPS receivers and photogrammetry defined in the Land Survey Act. GNSS measurements are summarized as satellite-based positioning (SBP) in Namibian legislation (Government of Namibia, 2002b). Absolute positioning error of GNSS measurements should not exceed 0.06 m. Photogrammetric methods are very vaguely defined in the Act, it only states that the SG must accept the respective method, and that the land surveyor is responsible for demarcating the position in field (Government of Namibia, 2002b).

4.2.1.5. Cost

According to local authority officials, cost is an important aspect because of current problems faced to getting access to latest software's and tools which could assist in mapping informal settlements. It was stated that, "a need to investigate cheaper alternative methods has risen and an example of alternative methods are UAVs instead of using expensive airplane flights". The last couple of years UAV mapping has been used especially in communal areas and it is based on structure form motion photogrammetry which is different from the old metric photogrammetry method used previously. It is much cheaper and the last 5 years surveyors started buying drones for 15 000-20 000 Namibian dollars, so most surveyors do mapping with those which are cheap and are cost effective and produce excellent results.

4.2.1.6. Time

Time is taken into consideration and for the case of Freedom Square, the land measurer stated that, "*surveying the internal boundaries took about 1 month and a total of 1164 plots, including public open spaces & streets in 9 block erven* *were mapped*". Another Surveyor respondent that surveying "*1000 parcels with a GPS including processing and creating general plan would take me 2 months but with a total station the same work will take me 5 months*".

4.2.1.7. Spatial reference system

Currently, all measurements must be taken in the national reference framework Schwarzeck Lo22. It is a cartesian 2D coordinate system with axes in direction west and south (Y, X), based on Bessel Namibia ellipsoid using German legal meter This system is only valid for Namibia and would require any method based on GPS positioning to transform all measurements from the WGS84 reference frame to Lo22 (Government of Namibia, 2002b).

4.2.1.8. Data updating

The Freedom Square settlement mapping initially started with using high aerial images and each structure was given a number that was later linked to the attribute data on the households. New structures which were not appearing on the aerial image were then drawn with a handheld GPS by students and NHAG officials. In 2014 there were only 700 households who resided in Freedom Square; this number increased in 2015 to 1100 households. This required an update on the initial enumerations and mapped data (Chigbu, Bendzko, Mabakeng, Kuusaana, & Tutu, 2021). In contrast to this, respondents indicated that there are no upgrading plans once the settlement is formalized because it is preferred to plan an area completely, including surveying works once off with good accuracy. However, according to a Municipal respondent, a register is kept where land tenure data is updated based on what is happening on the ground.

4.2.2. Characteristics of the innovative data collection methods used in Namibia

The innovative methods are not backed up by the law as it is with the conventional methods. The methods identified are STDM, Kobo collect and photogrammetry using UAV technology and they are not backed up by the state as it is with the conventional methods, including the photogrammetry methods which are used. Some characteristics are not applicable to all methods because of the intended nature and use of the tool. Table 3 presents a summary of the innovative methods and they are further elaborated below the table.

Innovative methods		
Characteristics	**Method**	**Method**
Name of the method	STDM	Kobo Collect
Period of use	2014	n/a
Aim of using the methods	Data management & certificate generation	Cadastral surveying
Software	QGIS and gvSIG	Kobo Collect
Data storage	STDM database	Kobo cloud
Accuracy	n/a	n/a
Costs	n/a	40350 Namibian Dollars (2521.88 euro)
Time	n/a	10 days
Boundary	n/a	Only geolocation
Spatial reference system	n/a	GNSS (WGS84) Schwarzeck
Data updating	n/a	n/a

Table 3: Innovative methods

4.2.2.1. Aim of using the methods & Period of use

Kobo Collect was used for the enumeration of the Freedom Square settlement, in preparation for the registration of Land Hold Titles, under the FLTS. The enumeration period was from the 28 June 2019 to 8

July 2019. The STDM's purpose was to improve the data management and provision of certificates of recognition to residents, while awaiting the implementation of the FLTS. STDM was tested in Freedom Square in 2015 although the study area was selected in 2014 (Mabakeng, 2019).

4.2.2.2. Software

As indicated in the table Kobo Collect is a free and open-source suite which consists of tools for field data collection suitable for challenging environments, the location points collected from Kobo Collect can be accessed via any GIS platform or Google Earth. For STDM, all field maps were digitized using open-source GIS software such as gvSIG software and QGIS.

4.2.2.3. Data storage

Data for Kobo Collect is stored on the Kobo cloud as well as on the local computers because the software allows for data to be downloaded. STDM data is stored on the STDM database.

4.2.2.4. Costs

Due to cost being an important factor during data collection in Freedom Square, Kobo Collect which is a free data collection platform has been used for enumeration purposes in preparation for the registration of Land Hold Titles. Additional materials were purchased for the software to be used on it. The tablets which were purchased were Android driven because that is the only operation system supported by the software suite which includes a good GNSS which is vital for determining the location faster, and not only by using GPS but also other systems such as Glonass. Furthermore, 4G pocket Wi-Fi routers were purchased, and it was of an advantage because it made tasks easier and quicker especially uploading data (Hamuteta, 2019). The table below shows the costs that were incurred during the data collection process of Gobabis. In addition, no costs were incurred for using STDM. The costs presented below are those incurred by Kobo Collect.

Procurements:

Quantity	Item	Cost
5	Tablets	36000
1	4G Pocket Wi-Fi	800
	Extension cables	500
	Total: (Namibian Dollar)	**37 300**

Table 4: Procurement items (Hamuteta, 2019)

Consumables:

Quantity	Item	Cost
1	4G Credit 15 GB	2150
9	MTC Credit for Field Workers	900
	Total: (Namibian Dollar)	**3050**

Table 5: Consumable items (Hamuteta, 2019)

4.2.2.5. Time

It took approximately 10 days to complete collection of personal data which was used for registering the land hold titles. The number of households enumerated were 1000 and the team consisted of 10 enumerators that were grouped in pairs of five, two data verifiers, a field supervisor, and a field coordinator.

4.2.2.6. Spatial reference system

It was stated that the reference system which was used for the Kobo Collect was WGS8, which was later converted to the local reference system.

4.2.3. Characteristics of the SmartSkeMa and Automatic Feature Extraction innovative methods

The characteristics of the its4land innovative tools are described in the section. Some of the characteristics such as costs, data updating is not applicable for these tools.

Characteristics	Method	Method
Name of the method	SmartSkeMa	Automatic Feature Extraction
Period of existence	Since 2020	Since 2020
Aim of using the methods	Land tenure documentation	Automatic boundary delineation
Software	SmartSkeMa system on a browser, preferably Firefox QGIS or any GIS platform	QGIS & ArcGIS MATLAB Python
Data storage	On the personal computer	On the personal computer
Accuracy	n/a	n/a
Costs	Printing = 16 Namibian Dollar Transparent paper & marker = 25 Namibian Dollar Scanning = 10 Namibian Dollar	n/a
Time	50 parcels= 2 hours	50 parcels= 6 hours
Boundary	Visible/Sketch boundaries	Visible boundaries
Spatial reference system	Schwarzeck	Schwarzeck and WGS84
Data updating	n/a	n/a

Table 6: SmartSkeMa & Automatic Feature Extraction

4.2.3.1. Aim of using the methods

The aim of using the SmartSkeMa and the Automatic Feature Extraction is for land tenure documentation. The SmartSkeMa uses the sketching approach whereby the Automatic Feature Extraction uses boundary delineation approach. Both these methods have been in existence since 2020.

4.2.3.2. Software

The SmartSkeMa system is operated on a browser and the output can be used in any GIS platform such as QGIS. For processing the data obtained from the field, SmartSkeMa was setup using the instruction manual provided. In addition to this, jpg tiles were created using GDAL in QGIS. The input image from the field was inserted as the “orthophoto drawing”, a URL link to the jpg tiles was added, and the base map data which included the GCP data should also be loaded in the SmartSkeMa system. Apart from the spatial data, non-spatial data such as the local domain model and parties should be added. Once all the required information is met, the image can be vectorized automatically, and once that is achieved successfully geometries can be aligned and edited. Example of the SmartSkeMa platform is shown in figure 8 below with the vectorized image on the left and the base map on the right.

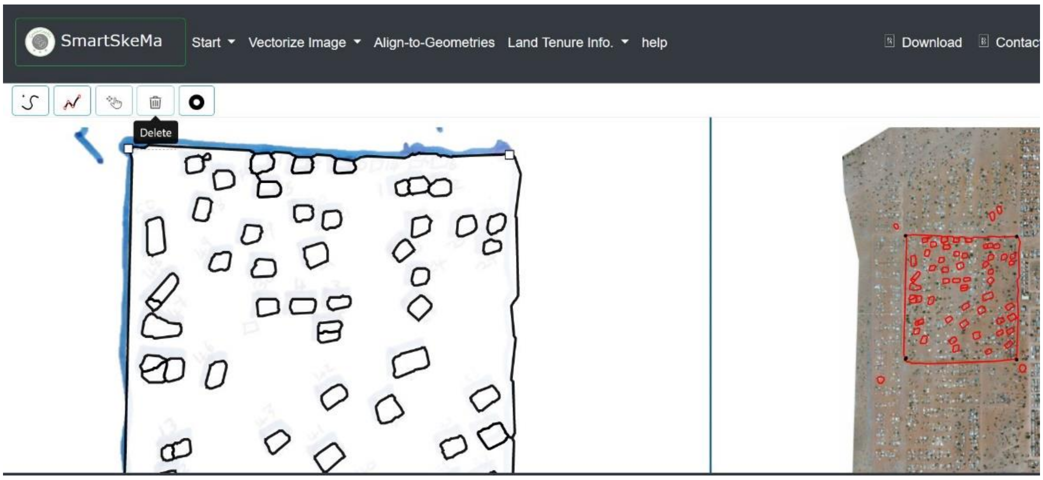


Figure 8: SmartSkeMa platform

Automatic Feature Extraction requires both QGIS and ArcGIS, additional software's required are MATLAB and Python. For this study both QGIS and ArcGIS were used. In addition, MATLAB is required to run the Multiresolution Combinatorial Grouping (MCG) code. The output of this was shapefile of image segmented lines without attributes. Figure 9 below MCG image segmentation results and MCG lines derived from raster to vector conversion.

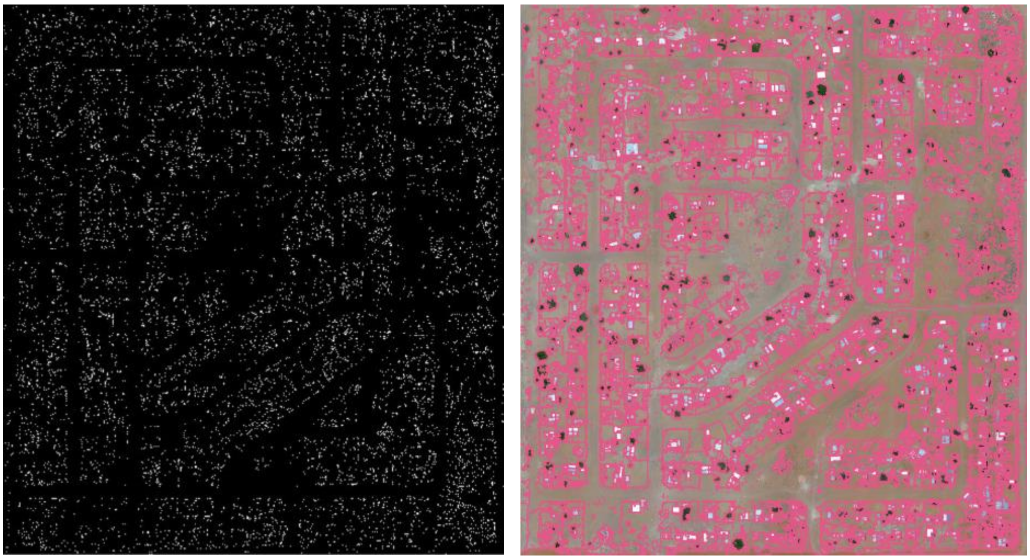


Figure 9: Image segmentation

Python and its various packages are required for boundary classification, the source code which needs to be modified with the study areas data is provided on GitHub. This step requires lines to be labelled into "boundary getting a value of 1" and "not boundary getting a value of 0" which can either be done manually or semi-automatically and for this study lines were labelled manually.

4.2.3.3. Data storage

Both these methods data are stored on the user's personal computer as they do not have any databases yet.

4.2.4. Accuracy

The accuracy of SmartSkeMa and Automatic Feature Extraction have not yet been comprehensively established. In order to estimate how accurate these methods can be, a field study was conducted where land parcels were collected and a desktop study was also done.

4.2.4.1. Cost

For Automatic Feature Extraction, no costs are involved, but for SmartSkeMa costs related to the acquisition of fieldwork material are involved. A map needs to be printed on either an A3 or A0 paper and the cost per page is 16 Namibian Dollar (1 euro), acquisition of transparent paper and marker are 25 Namibian Dollar (1.50 euro) and scanning 10 Namibian Dollar (0.60 euro).

4.2.4.2. Time

Based on the study, mapping 50 parcels in the field with the community members took the research assistant 2 hours, this is excluding the prior informative session which was held. Digitizing the same 50 parcels in the Automatic Feature Extraction took 6 hours, this was because of having to scroll around searching for the parcels.

4.2.4.3. Spatial reference system

Both these methods use the local reference system which in Namibia's case is the Schwarzeck EPSG: 4293. But a combination with WGS84/Pseudo Mercator was done because the boundary delineation plugin was not working with Schwarzeck.

4.3. Actors involved in implementing these methods

The following section presents the actors involved in implementing these methods in Namibia. Section 4.3.1 discusses the actors in data collection in Namibia, secondly section 4.3.2 describes actors involved in SmartSkeMa. Finally, section 4.3.3 describes actors involved in Automatic Feature Extraction.

4.3.1. Actors in data collection in Namibia

The FLTS consists of many different actors, and they are categorized in three categories: key actors, primary actors, and secondary actors. Some of these actors have a direct role and others have an indirect role to play in providing land tenure. The actors discussed below are the key actors only as identified during interviews with respondents from Ministry of Agriculture, Water and Land Reform, NHAG and town planners and through literature. Table 7 depicts the actors involved in data collection in Namibia.

Field team
Professional land surveyors
Town planners
Enumerators
Land measurers
Community members
Government Actors
Ministry of Agriculture, Water & Land Reform
Land Rights Office
Local Authorities
Ministry of Urban and Rural Development

Table 7: Actors involved in data collection in Namibia

The first set of actors are the field team, consisting of professional land surveyors who are required to survey the outer boundaries of the settlement and ensure that the layout plan meets the accuracy standards. The town planners work together with the community members to plan the settlement and design the layout plan, they are also responsible for obtaining approval for township establishment. The enumerators are from GIZ, and they are responsible for collecting data that is used for land hold title registration. Finally, the land measurer who is a survey technician is responsible for surveying the inner boundaries according to the land survey act.

The second set of actors consists of Government ministries. Firstly, the Ministry of Agriculture, Water & Land Reform negotiates with Local Authorities to find out whether they are interested in taking part in the FLTS project or not. Once the Local Authorities are interested, the Ministry then contracts a town planner to develop a layout plan because it will be a complete township establishment. Moreover, they oversee and monitor the implementation of the FLTS, facilitate the surveying of the block erven, undertake awareness campaigns on the FLTA and conducts training of stakeholders. In addition, the Ministry is also responsible for guiding the evaluation of the piloting phase and working with all stakeholders to ensure that the titles issued. The Directorate of Survey and Mapping and the Deeds Registry are part of this Ministry, and that is why the Ministry facilitates the surveying process and ensures that titles are issued. The Minister after consultation with the Ministry of Urban and Rural Development establishes a Land Rights Office.

The Land Rights Office is responsible for taking care of the starter and land hold title registers and there may be several Land Rights Offices set up across the country. The Land Rights Office works under the supervision of a Land Rights Registrar who is assisted by registration officers and land measurers (Ministry of Land Reform, 2016). Some of the key functions of the Land Rights Office is to notify the Registrar of Deeds of each scheme establishment and conducting the necessary internal planning (measurements by the land measurer). Further, respondents stated that the land measurers measure the plots intended for the scheme, they indicate the physical boundaries on the block and prepare a description of the plots which gives boundaries and allocates plot numbers, this description is called a land hold plan. They are also responsible for filing documentary records of all schemes and for transferring rights in cases of inheritance, sale, etc. In addition, the Deeds Registry establishes and supervises the starter and land hold title registries and endorses the title deeds of the external boundaries known as blockerven.

The Local Authorities receives the applications from the land occupants for entering the FLTS. They are responsible for investigating the feasibility and desirability of creating a starter or a land hold title scheme and they initiate the establishment of schemes on their own initiative or upon request from the individual land occupants. Feasibility studies are conducted to determine issues which might affect the success of the scheme, for example to determine whether it would be possible the desired number of houses on the terrain in question or look at the costs of providing basic services on the land in question (Ministry of Land Reform, 2016).

In addition, the Local Authorities then conducts a social economic survey to identify the number of informal settlements and allocate them numbers etc. A respondent from the Local Authority stated that they often conduct these surveys even if it is not for the FLTS because it helps guide them when they are providing services such as water, sewer etc. By the time they join the FLTS this information is in most cases already available. Further, the communities are responsible for initiating and deciding together with the Local Authorities whether a Starter Title or Land Hold Title Scheme can be established. They participate in the planning and designing of the relevant area and manage the blockerfs through the Scheme Associations. They resolve disputes within blockerfs through the Management Committees of the Scheme Associations.

The Ministry of Urban and Rural Development supervises the town planning activities of the Local Authorities and coordinates the infrastructure development on each block erf. This Ministry is also responsible for township approvals which are submitted by the Town Planners. In addition, the town planners are responsible for creating the layout plan which is then verified by the surveyors to ensure that it abides to the legal requirements. They are also responsible for obtaining approval from the Minister of Urban and Rural Development for the establishment of the township.

4.3.2. Actors in SmartSkeMa

The actors involved in the SmartSkeMa are described in accordance with the workflow which consists of four steps.

1. Preparation
GIS expert
2. Mapping and tenure documentation
Community members/landowners
Community leader
3. Data processing in SmartSkeMa
GIS expert
4. Data query and export
GIS expert

Table 8: Actors involved in SmartSkeMa

The first step involves preparation of the system land tenure mapping or for a community to use on an ongoing basis (M. C. Chipofya, Jan, & Schwering, 2021). The GIS expert is required to obtain either aerial image or vector maps and to set up the system. In the case of this study, aerial image was obtained and georeferenced. Further, the GIS expert is also required to process the data obtained from the field in the SmartSkeMa platform as well as using the output from the SmartSkeMa in a GIS software. The community members map the parcels and assist in identifying the boundaries and the community leader organizes the community.

4.3.3. Actors in Automatic Feature Extraction

The actors involved in the Automatic Feature Extraction are described in accordance with the workflow which consists of four steps.

1. Image segmentation
GIS expert
2. Boundary Classification
GIS expert
3. Boundary delineation
GIS expert
4. Field verification
Community members

Table 9: Actors involved in Automatic Feature Extraction

The Automatic Feature Extraction consists of two main actors only. The GIS expert prepares the data, processes the data, and defines the algorithm. The community members verify the delineated parcel boundaries after they have been processed in the office

4.4. Indicators for comparing performance of data collection methods

In the next sub-sections, indicators which will be used for comparing the performance of data collection methods are presented. The definitions of the criterion in sub-section 5.2.2 are based on the fit-for purpose principles and they are adopted from the study by Rahmatizadeh et al (2018).

4.4.1. Indicators for measuring the performance of these data collection methods

Respondents indicated that Namibia has no performance measurement framework and that are in accordance with the law. Methods are chosen and used based on experience, current methods trending and professional knowledge. This judgement is made based on the knowledge of the strength and weaknesses of the different methods available, and factors such as cost and time. A surveyor stated that what Namibia is lacking is quality standards for all mapping methods and it is a big issue especially when it comes to cadastral mapping. A surveyor from the Municipality specifically indicated that, "*I don't think we have even attempted to measure performance*, *we just use methods that are currently available in the market and that are in accordance with the law*". A town planner further iterated that; from previous experience they face challenges in terms of statutory requirements. This is caused by the fact that people in informal settlements settle in such a manner that makes it difficult for planners to plan according to what the state requires. There is currently a policy that requires a minimum parcel size to be 300 square meters, but to produce 300 square meters for each household in informal settlements is almost impossible. The respondent therefore stated that, "*what we try to do is squeeze settlers to erf sizes of 150 square meters or sometimes even less, so I would say that this is an area where performance measurements and evaluation of the current guiding tools need to be done to meet the needs of specific communities*".

4.4.2. Criteria for selecting spatial data collection methods

Surveyors, Municipality employees, academics, and NHAG indicated the indicators they would consider when choosing spatial data collection methods through a ranking questionnaire. The respondents were required to rank indicators according to importance, i.e., one being very important and five being less important. The identified indicators are used to compare the innovative methods against conventional methods to address sub-objective 3.

4.4.2.1. Data indicators

Data parameters, also known as data quality, consists of accuracy, reliability, and completeness. The accuracy should relate to the purpose instead of technical standards; this enables upgrading and updating to be done overtime when required. For this study, accuracy will not be measured according to the conventional legal standard. Accuracy will be measured according to purpose, which is to provide security for all, and positional accuracy will be considered. Reliability refers to having information that is authoritative and up-to-date and completeness referring to having a cadastre that is based on complete coverage of the country.

	Ranked importance of data parameters (1st=highest, 3rd=lowest)		
Indicators	1st	2nd	3rd
Accuracy	5	2	3
Reliability	5	2	3
Completeness	0	6	4

Table 10: Data parameters ranks

Results are presented in table 10 above. Firstly, an analysis has been made that both accuracy and reliability have been ranked equally in all three places (1st, 2nd, and 3rd) and 50% of the respondents opted for these methods as their first choice. The result indicates that the responses for considering accuracy and reliability are ranked as equally important and this could have been influenced by the Namibian legal framework and by the surveying community. A surveyor stated that, "the aim is to get the job done once with the highest possible accuracy." Whereby on the other hand town planners stated that accuracy is not that important to them, that is why they sometimes opt to use images from Google Earth which by surveyors are not considered to be accurate and reliable enough. Respondents from the interviews stated that, "*the level of accuracy is a big issue when it comes to incorporating the current data from informal settlements into a formal register. I mean, that has been a big issue for a few years now and that's why I think components of the registrations of flexible land tenure rights have been an issue*". Further, 60% of the respondents ranked completeness as their second choice of importance, whereby completeness received no ranking for being the first choice. Completeness to some respondents is an important factor, because to professions such as town planners, academics and NHAG, the focus is not on accuracy, but it is more on providing base data that can be used for informal settlement upgrading. Respondent from NUST indicated that, "*we proposed the complete mapping of all the informal structures and formal structures in Namibia using open street map that gives us the building footprint for most of the informal settlement*" and further " the *proposal would be to either focus on using a continuum of accuracy where you initially don't have the highest level of accuracy when you are collecting your boundaries and then you can increase your accuracy as you go. Secondly, we can just start looking at how do we improve accuracy at the beginning of the project."*

4.4.2.2. Data collection indicators

Data parameters collection parameters consists of open & transparency, verifiability, implementation, affordability, time, and repeatability. It refers to the actual process of data collection, therefore when making a choice to select a spatial data collection method the process should be open & transparent to all parties involved, the data should be able to be verified, according to the FFP implementation should be easy, it should take be fast and the process should be able to be repeated.

Ranked importance of data collection parameters (1st=highest, 6th =lowest)						
Indicators	1st	2nd	3rd	4th	5th	6th
Open & transparent	0	2	4	3	1	0
Verifiability	4	0	2	1	1	2
Implementation	5	1	0	2	1	1
Affordability	0	1	0	2	6	1
Time	1	3	3	2	0	1
Repeatability	0	3	1	0	1	5

Table 11: Data collection parameters

Results are presented in table 11 above. Based on the results, implementation is ranked the highest by 50% of the respondents therefore making it be the most important factor respondents would consider when selecting methods within the data collection parameters. On the other hand, 40% of the respondents ranked verifiability as being important to them as well. The second important indicator is time and repeatability, each got ranked by 30% of the respondents as their preferred choice which totals to 60% of the respondents. The third indicator is open & transparency with 40% of the respondents and open & transparency as the 4th indicator. Affordability got ranked the second lowest, with a total of 60% opting for it and the least important indicator in this category is repeatability.

4.4.2.3. Post-data collection indicators

Post-data collection refers to the manner data is handled after data collection. These parameters consist of common standards, update mechanisms, upgradability, metadata services and data sharing. Compliance with common standards in this study refers to the way the methods would fit into the current system and according to the laws. Update mechanisms relate to manners in which data can be upgraded after collections and upgradability refers to methods which can be upgraded over time. Data sharing refers to the strategy how the data will be shared.

Ranked importance of post-data collection parameters (1st=highest, 5th =lowest)					
Indicators	1st	2nd	3rd	4th	5th
Common standards	7	0	0	1	2
Update mechanisms	0	2	2	4	2
Upgradability	3	1	1	2	3
Metadata services	0	5	2	1	2
Data sharing	0	2	5	2	1

Table 12: post-data collection parameters

Table 12 above shows the results for post-data collection parameters which were selected as being important when selecting spatial data collection methods. According to these results, common standards were ranked the most important with 70% of the respondents ranking it first and upgradability being the least important by 30% of the respondents. Compliance with common standards for this study considers how the methods comply with the current legal framework because that influences the type of spatial data collection methods applied and chosen in Namibia.

4.4.3. Summary

From the findings above, Namibia most terrestrial surveying methods such as the tapes and pentagon prisms are not being used anymore, but total stations are used occasionally n combination with GNSS methods. GNSS (RTK) are the most used methods, and these are all used for cadastral surveying. The aerial survey method used frequently are the UAV because of its convenience although the regulations hinder the usage in urban areas. It was also found that the STDM was piloted but never implemented and an open-source free software, Kobo Collect was used to collect information in preparation for land hold title registration. Further, the actors with key role to play in informal settlement upgrading under the FLTS were identified and their specific roles were described. The key actors were identified to consist of actors who have a direct role in data collection such as surveyors and those that are involved in decision making and facilitation such as the Governmental institutions. The Automatic Feature Extraction and SmartSkeMa main actors are GIS experts and community members who are involved in data collection and verification. The findings also found out that Namibia does not have any performance measurement framework in place and the indicators for selecting spatial data collection methods were acquired from the ranking questionnaires, and they are accuracy, reliability, ease of implementation and compliance with common standards. These indicators will be used in the next chapter for the comparison.

5. ANALYSIS AND DISCUSSION

This chapter evaluates and compares the conventional surveying methods against the Automatic Feature Extraction and SmartSkeMa. The chapter is based on the results obtained from chapter 4 and the indicators which are used to compare the different methods are implementation, compliance with common standards, and accuracy and reliability. The comparison is done in section 5.1 and section 5.2 discusses the results obtained from the comparison.

5.1. Comparison of conventional surveying and innovative methods

5.1.1. Implementation

This data collection parameter refers to the availability of required tools and professionals and includes the ease of access to the method (Rahmatizadeh et al., 2018). Implementation of the different methods is assessed according to the **number of activities** involved in processing**, input data, time** required, **system requirements**, and the **expected level of expertise** to use the tool.

5.1.1.1. Conventional surveying

The number of activities involved in the conventional surveying for informal settlements upgrading under the FLTS are categorized in two. Firstly, before any formal land right adjudication and formalization can be done for informal settlement upgrading under the FLTS, the land should be subdivided or consolidated. This is done to ensure that the scheme is situated on one registered portion of land (Government of Namibia, 2018). The registration of starter titles is based on a point cadastre approach and once the approval for establishing a starter title scheme has been granted, a professional land surveyor is hired. The professional land surveyor determines the location of the block and the land measurer specifies the reference points for each starter title (Government of Namibia, 2018). Further, a land measurer is appointed by the Ministry of Agriculture, Water and Land Reform and is required to survey the internal boundaries of all the plots, streets and other public open spaces as shown on the layout plan. Internal and outer boundary surveying were made to re-block the settlement through participatory planning and upgrading. The internal boundaries in the settlement were measured by a land measurer and maintained the accuracy requirements according to the Land Survey Act of the country. Initial boundary recordation for Freedom Square was implemented using aerial images, and accuracy was improved upon relocation and installation of services. Data enumeration in preparation for land hold title registration is finally carried out.

For inner boundary surveying, ground reference points are required to be used to compare with the data received from the DGPS. In addition, during the enumeration process orthophotos are required for orientation purposes during fieldwork and keeping track of the household which are already enumerated. The data obtained during the enumeration with Kobo Collect is stored as a Microsoft excel and this is needed to produce the land hold titles.

The total time period for participatory data collection, planning, and flexible surveying methods were done over a period of eight years from 2013 to 2020 to deliver secure land rights under the FLTS(Chigbu et al., 2021). According to the land measurer, the time taken to survey the inner boundaries was approximately 1 month. The data for Land Hold Titles registration was collected over a period of 2.5 weeks (Hamuteta, 2019). A total of 1080 land hold titles were handed over to the residents in March 2021.

The hardware needed for surveying the internal boundaries was that the DGPS RTK and the external boundaries of the settlement were surveyed by a professional land surveyor according to the high accuracy requirements under Land Survey Act 33 of 1993 of Namibia. The aerial images were captured using an

Unmanned Aerial Vehicle (UAV), which ensured the acquisition was fast and reflected the state of the settlement. The new settlement layout was overlaid on the images to identify households that need to be relocated, further these images were used for orientation purposes during data enumeration. In addition to the hardware mentioned, computers are required as well for processing, storing, recording the data. The software required to process the data obtained from surveying inner and outer boundary was Leica Geo Office, Surpac as well as QGIS. For collecting enumeration data that was needed for Land Hold title registration, Kobo Collect was used, and it required android tablets.

The expertise required are a professional land surveyor to survey the outer boundaries and a survey technician to survey the inner boundaries. Enumeration is done by administrators together with the community.

5.1.1.2. Automatic Feature Extraction

The first step for the Automatic Feature Extraction is preparing the orthoimage by clipping it into tiles that do not exceed 10 000x 10 000 pixel and for this study the image was tiled into tiles of 5000 x 5000 resulting in 4 tiled images. The output of this was a shapefile of image segmented lines without attributes which were required to be used for boundary classification. Secondly, boundary classification was done which refers to training a machine learning algorithm to predict boundary probabilities for lines obtained through image segmentation (Crommelinck, n.d.). This step requires lines to be labelled into "boundary getting a value of 1" and "not boundary getting a value of 0" which can either be done manually or semi-automatically and for this study lines were digitized and labelled manually.

The final step allows the users to start the actual delineation. This step requires the its4land QGIS boundary delineation plugin which supports the creation of final cadastral boundaries. After the final cadastral boundaries are done, field verification to ensure that the boundaries are delineated correctly can be done with the help of the community members and improvements can be done accordingly.

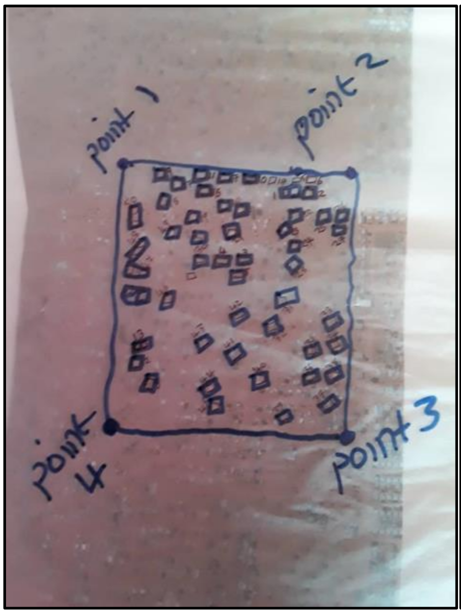
Input data for this method is an orthoimage (RGB orthoimage image raster) of the study area in .tiff format and a world file (.tfw). Further, the time it took to manually digitize 50 parcels was 6 hours, this was caused by having to allocate the parcels which were distributed randomly. This was done under the Random Forest Classification step, where lines were manually selected and given either value 1 if it is a boundary and 0 if it is not a boundary.

The hardware required is a computer. In addition, the software required are ArcGIS which was used to convert raster to polylines although this can also be done in QGIS. MATLAB was required to run a Multiscale Combinatorial Grouping (MCG) code and apply MCG to all orthoimages stored in that directory; the end goal was to produce image segmented lines. Python and its various packages are required for the boundary classification step, the source code which needs to be modified with the study areas data is provided on GitHub. The final step allows the users to start the actual delineation This step requires the its4land QGIS boundary delineation plugin which supports the creation of final cadastral boundaries.

The use of Automatic Feature Extraction requires basic GIS skills and basic programming knowledge. There are two distinct steps here. The setup requires some programming, while the usage on data requires only basic GIS skills. The community members help with verification at the end of the project.

5.1.1.3. SmartSkeMa

SmartSkeMa activities as described in appendix C, involve preparing the orthoimage by georeferencing the map before fieldwork. The GCP's had to be marked clearly on the image and the map was printed on an A3 paper although the preferable size to be printed on is A0. The data preparation is followed by setting up and testing SmartSkeMa and for this study, this was done simultaneously while the boundary mapping and tenure information in the field were being collected. Before the fieldwork started for this study, an informative meeting with the community was held to get their permission to partake in this exercise. Once the mapping was done, the sketch map was scanned and loaded in SmartSkeMa. The input requirements for SmartSkeMa are, an orthoimage of the study area and the GCP must be indicated clearly on the orthoimage. Further, land tenure information from the field is required together with the parcels which were mapped as illustrated in figure 10 below. In addition, transparent paper and markers were required in preparation for fieldwork.



House No	Parcel nr.	Name	Surname	Type of ownership
1	517	Isack	Hashoongo	Land hold Title
2	516	Nina	Goagoses	Land hold Title
3	552	Robson	Musiwa	Land hold Title
4	551	Gift	Mazambani	Land hold Title
5	553	Saima	Johannes	Land hold Title
6	510	Letisia	Mushala	Land hold Title
7	399	Anna	Narises	Land hold Title
8	469	Petrus Tus	Immanuel	Land hold Title
9	394	Maria	Hogobes	Land hold Title
10	398	Johannes	Marungu	Land hold Title
11	401	Sirenga	Garises	Land hold Title
12	443	Aletha	Isaacks	Land hold Title
13	442	Johannes	Araeb	Land hold Title
14	403	David Hip	Dumeni	Land hold Title
15	404	Veronia K	Kgobetsi	Land hold Title
16	402	Alfred	Ganeb	Land hold Title
17	406	Regina	Oaes	Land hold Title
18	507	Susanna	Goeieman	Land hold Title
19	473	Isabella	Garises	Land hold Title

Land Tenure Information

Figure 10: Scanned map & land tenure information

The time it took for the community to map the boundaries of 50 parcels was 2 hours and within those 2 hours they completed the land tenure information. The hardware required are computer and a scanner or camera. The software required are QGIS or any GIS software which are needed for displaying the output as indicated in figure 11 below. Docker is used for storing the image, transparent paper and marker are both required for fieldwork.

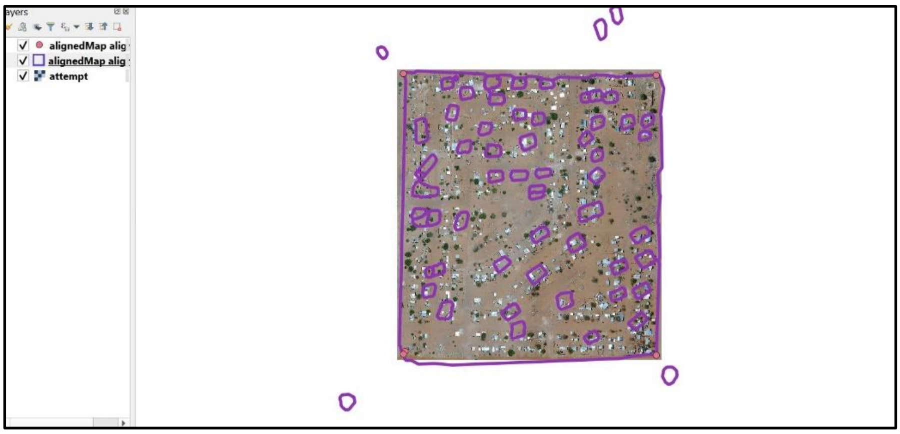


Figure 11: Output data from SmartSkeMa

This tool does not require much specific specialized skills besides familiarity with GIS platform. The community members collect the input data by mapping their parcels, this therefore means that mapping can be done by a paraprofessional. Below is table 13 summarizing implementation involved for all the methods.

	Conventional surveying	**Automatic Feature Extraction**	**SmartSkeMa**
Number of activities	*Subdivision or Consolidation *Registration of starter title *Survey outer boundary *Survey of inner boundaries *Enumeration	*Community Verification *Image segmentation *Boundary classification *Interactive delineation	*Community involvement *Preparation *Data processing *Data querying and export
Input data	*Ground reference points	*Orthophoto *World file	*Orthophoto * Land tenure information *GCP * Scanned Sketch map
Time	1 month 2.5 weeks Total: +- 48 days	50 parcels= 6 hours	50 parcels= 2 hours
System requirements	**Hardware** *Computer *GPS *DGPS (RTK) **Software** *Leica Geo Office *Surpac *QGIS/ArcGIS **Additional** *Kobo Collect *STDM	**Hardware** *Computer **Software** *ArcGIS *QGIS *Python *MATLAB	**Hardware** *Computer *Scanner/camera **Software** *QGIS *Docker *SmartSkeMa software **Additional** *Transparent paper *Marker
Level of expertise	*Surveying technician *Administrators	*GIS expert *Community member	*GIS expert *Community member

Table 13: Implementation comparison

Summary

The implementation for the above-described methods consists of similarities and differences. The similarities are that community members are involved in all the methods; parcels are captured but in different ways because conventional method uses beacon-based cadastre to capture the inner boundaries and Automatic Feature Extraction and SmartSkeMa boundaries are captured by vectorization. Referencing points are required for all the methods and computers are used for processing data. The differences are that the conventional method takes up more time compared to the Automatic Feature Extraction and SmartSkeMa. Further, surveyors are required for the conventional methods but for Automatic Feature Extraction and SmartSkeMa GIS experts are required. Further discussion of implementation is done in sub-section 5.2.2.

5.1.2. Compliance with common standards

Compliance with common standards is assessed according to the Namibian legal framework because that influences the type of spatial data collection methods used. Further, it investigates compliance with the common standards relating to data standards of the methods. Data standards will be assessed based on the format data from the method is stored, whether the method is integrated within a database, whether the method/output can be used with a common GIS system.

5.1.2.1. Legal compliance

In Namibia, the legal framework related to land tenure mapping consists of the Namibian Constitution, National Land Policy, Flexible Land Tenure Act, UAV regulations and the Land Survey Act. The Namibian Constitution is the supreme law of the country and according to Article 16 of the constitution every Namibian has the right to acquire, dispose and own land in the country.

To understand how decisions are made for selecting spatial data collection methods, an understanding of the legal framework was of importance. The following legal documents were reviewed. The National Land Policy of 1998 is based on the principles mentioned in the Constitution and it focuses on redressing the social and economic injustices which were inherited from the colonial past. A special commitment is to ensure equity in access to land and in security of tenure. The Flexible Land Tenure Act 4 of 2012 came into play to create alternative forms of land title that are simpler and cheaper to administer than the formal ones. Secondly, it is to provide security of title for people living in informal settlements and to empower these people economically by means of these rights. Finally, the Land Survey Act 33 of 1993 regulates the surveying of land in Namibia and plays a big role in the decision making of methods. Most crucial for this thesis is analysing legal parameters which are stated by the laws and regulations related to spatial data collection.

There is a lack of reasonable UAV usage regulations in the current legal framework. Currently, all UAV measurements being taken including approaches by professional surveyors and City of Windhoek are para- or illegal, since there is no single use case for cadastral purposes defined by Civil Aviation Authority yet and the regulation prohibits the use of UAVs over residential area.

According to the Land Survey Act, points which are coordinated by photogrammetric methods shall fall wholly within the perimeter of the ground control points. They should be measured in at least two stereoscopic models where the base over height ratio shall not be greater than 0.80 or be measured in at least four photographs for bundle intersections. Every beacon, the coordinates of which have been determined photogrammetrically, shall be adequately checked by the land surveyor. Unless otherwise adequately checked by the land surveyor, in a township, the relative positions of adjacent beacons near one another which have been determined independently of one another or from distances greater than 300 metres shall be verified by the measurement of at least two distances terminating at such beacons if the difference in the directions of the two check distances is not less than 30 degrees and not more than 150 degrees.

Any survey of land shall be based on the national control survey system but, the Surveyor-General may, in exceptional circumstances and subject to necessary conditions which he or she may impose, exempt any survey from the operation of this sub-regulation. A land surveyor may use the co-ordinate value of any survey station or beacon whose position on the trigonometrical survey system has been determined in the manner and with a degree of accuracy acceptable to the Surveyor-General and whose physical position has been verified by the land surveyor concerned. Unit of measure on any diagram the sides, and when required the coordinates, shall be expressed in metres.

Further, according to the FLTA regulations, a computer system may be used to keep registers which are prescribed in terms of the Act and these computers must be maintained in a transparent manner so that it reflects the information in the register (Government of Namibia, 2018). The land measurer surveys the internal boundaries of all plots, streets and other public places shown on the layout plan in accordance with the regulations made in terms of the Land Survey Act, 1993 (Act No. 33 of 1993) which survey must be done to an accuracy required by at least Class C in terms of such Regulations; and prepare the land hold plan.

5.1.2.2. Data standards

The output data format from data captured with DGPS are but not limited to these are csv, ascii and shapefiles. For Automatic Feature Extraction data format are shapefiles for the final output and for SmartSkeMa it is geojson. These data formats can be used in its original format or converted to different formats in any GIS software. The boundaries for the conventional method are beacon based, and points are captured which are processed later, and for Automatic Feature Extraction and SmartSkeMa, visible boundaries are needed for processing.

The conventional surveying of the internal boundaries was done using the DGPS RTK in the local reference system, Schwarzeck 4293. The World Geodetic Systems 1984 (WGS84) measurements must be transformed into the national control survey system, the Schwarzeck, EPSG 4293 (Government of the Republic of Namibia, 2002). It is a cartesian 2D coordinate system with axes in direction west and south (Y, X), based on Bessel Namibia ellipsoid using German legal meter (GLM). For enumeration using kobo collect, (WGS84) measurements was used. Automatic Feature Extraction initially started off with Schwarzeck 4293 but had to be changed to WGS 84 to be able to use the boundary delineation plugin and the SmartSkeMa used Schwarzeck 4293.

5.1.3. Accuracy & Reliability

This section compares how accurate were the parcels mapped in the field and how accurate it ends up being when it is finally transferred into georeferenced data. It further also presents the accuracy requirements for the conventional surveying methods. The conventional methods are applied with high accuracy and Automatic Feature Extraction and SmartSkema are limited in the level of precision and accuracy that can be achieved with them. The boundaries produced by the conventional methods are different from those produced by Automatic Feature Extraction and SmartSkeMa. The conventional method boundaries are beacon based because of the method that is used, whereby Automatic Feature Extraction and SmartSkeMa are line based. For this reason, a direct comparison of the accuracy measures of these methods is not meaningful. However, comparison by way of buffer 1m is done and the Automatic Feature Extraction and SmartSkeMa are overlayed over the layout plan.

5.1.3.1. Conventional surveying

For the technical implementation of these surveys, the accuracy requirements for DGPS (RTK) is +-3cm. For photogrammetry accuracy of 10cm is required. The legal framework requires all surveying activities are required to maintain the high accuracy standards. For this study, the final layout plan of Freedom Square was used as a map reference to overlay the output data from Automatic Feature Extraction and SmartSkeMa over the layout plan. This was done to get an estimate of how precise the output from the innovative methods is. The town planners assisted the communities to design the layout plan and upon completion the land measurer surveyed the area according to the legal standards.

5.1.3.2. Automatic Feature Extraction

During boundary delineation with the plugin in QGIS, the result for the test data during the processing is shown below in figure 12. This process relies heavily on visible boundaries or familiarity with the area, for this study manual delineation was done because of poor visible boundaries and the blue line in the figure below indicates that.

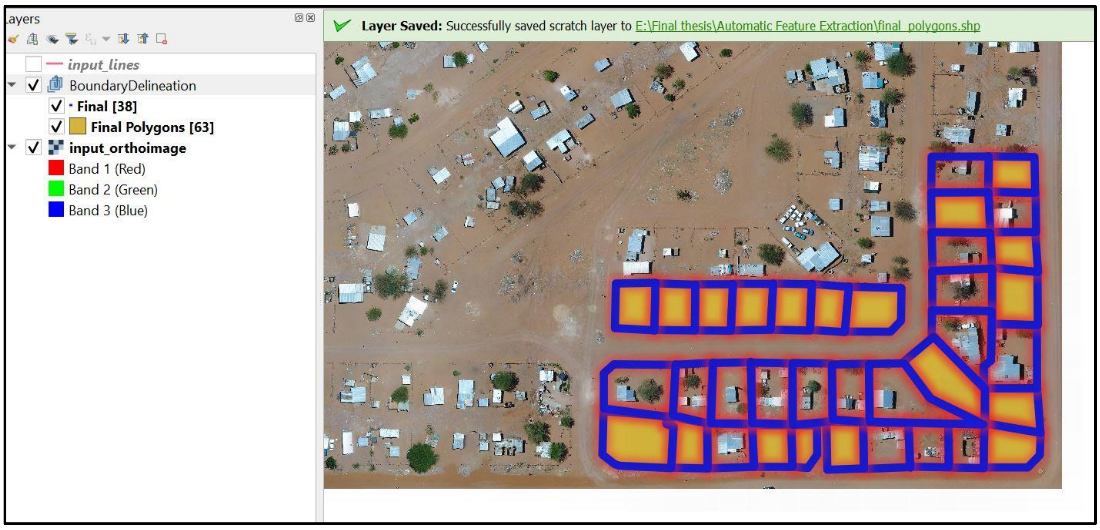


Figure 12: Boundary delineation

Further, figure 13 depicts the final polygons which were processed by the boundary delineation plugin. From this result, certain boundaries were not completely delineated and this could be due to the software not recognizing the boundaries well.

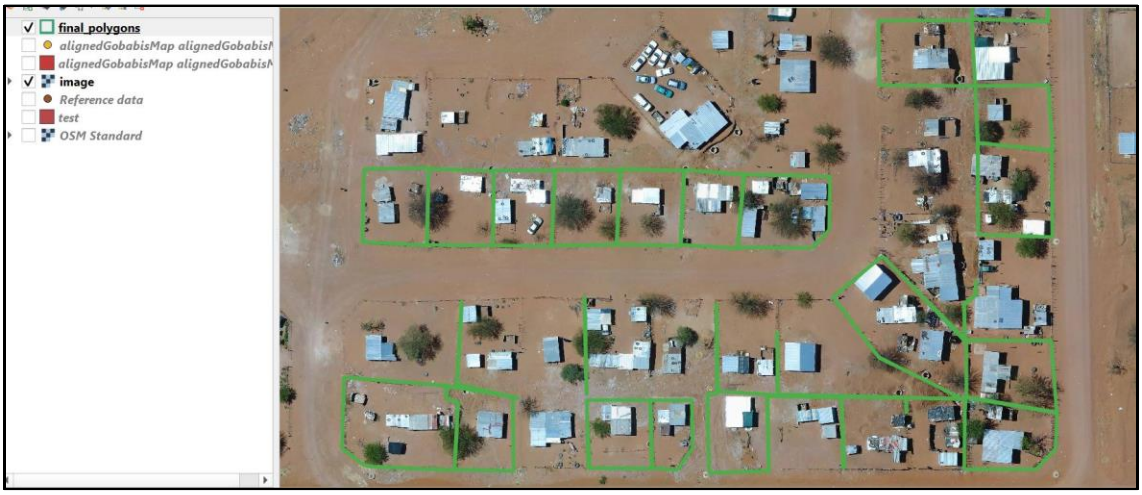


Figure 13: Final parcels delineated

Based on visually inspecting figure 13, the boundaries which were captured align well with the boundaries in the image and this was because of using general boundaries.

5.1.3.3. SmartSkeMa

The accuracy and reliability for the SmartSkeMa depends greatly on the quality of the output from the fieldwork because if the field data is poor, the output becomes very bad. Further, the GCPs play a vital role to play in the accuracy and reliability of the output and to obtain optimal results, it would be better to use a marker instead of a pen. For this study GCP were poorly distributed before the field mapping which contributed to distortions in the output data. With SmartSkeMa an option to either scan or capture the image with a camera is provided, but according to the results of this study a scanner is the best solution. Pictures captured with a camera are prone to lighting distortions and the colour effects the detectability of the image.

The output file was overlayed over an orthoimage in QGIS as demonstrated in the figure 14 below and precision problems were detected as the output from the field did not align with the original image. This was caused by image being printed on an A3 paper during fieldwork as it compromised the result of the image. To address this precision problem, a desktop exercise to reproduce the process of the same area has been done by printing out smaller sections of the map on A3 for higher precision.

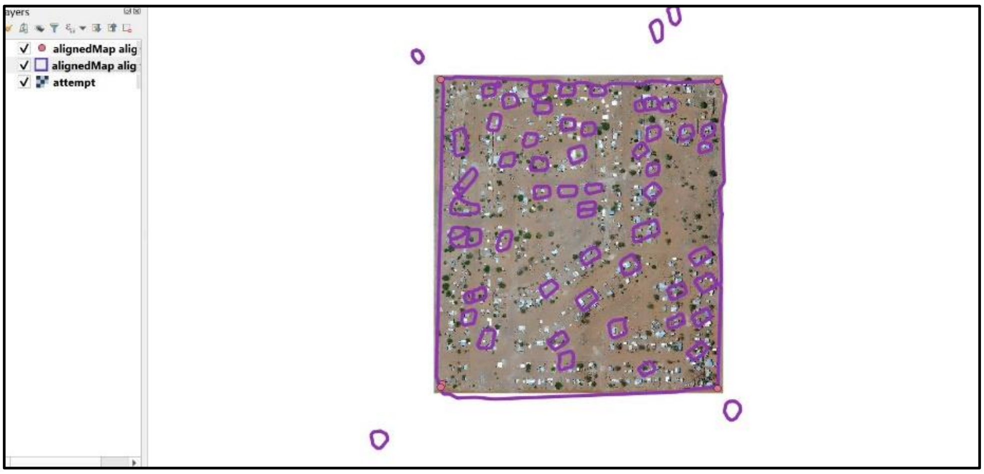


Figure 14: Downloaded SmartSkeMa data in QGIS

To improve the accuracy and precision of the results from the SmartSkeMa, a desktop exercise was conducted. More GCP points were distributed, and the image was printed on tiles of A3. The output was more accurate and reliable as shown in figure 15 below. This output was the one used for further analysis.

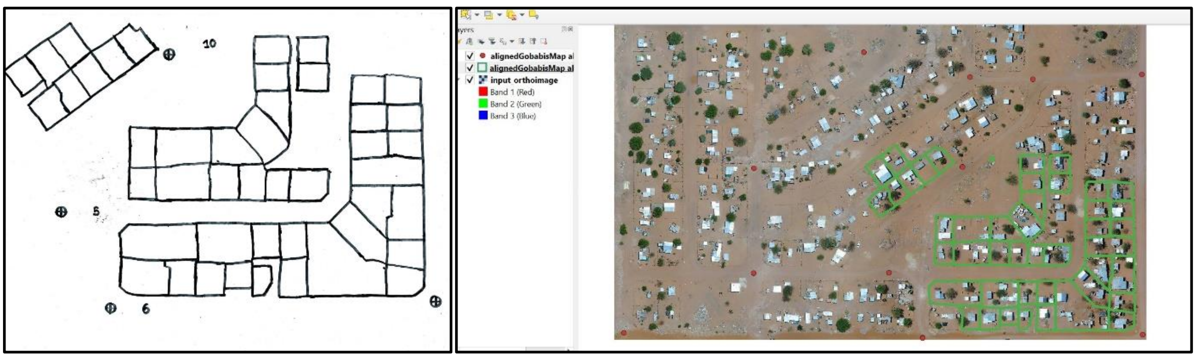


Figure 15: Rectified SmartSkeMa

To improve the accuracy, it is very important to select and distribute ground control points very well as indicated with the red dots in figure 15 above. The better the points are distributed, the more accurate the result will be.

5.1.3.4. Accuracy of Automatic Feature Extraction and SmartSkeMa relative to the official plan

In addition, accuracy between the 3 methods were further compared by overlaying the output from Automatic Feature Extraction and Smart Skema over the reference data which is a layout plan obtained using the conventional methods as shown in figure 16.

Figure 16: Positional accuracy

From the figure below, orange line represents data from SmartSkeMa, the blue lines represent data from Automatic Feature Extraction and the black lines are the reference data. It is evident that are some geometric errors such as edge error because the extracted boundaries do not match the boundaries of the reference data. For SmartSkeMa shape error can also be detected because the orange line deviates from the original reference data shape. There are some over segmentation scenarios detected especially with the Automatic Feature Extraction because some areas are omitted from the reference data. After this a buffer of 1m was made around the reference data as shown in figure 17. Since SmartSkeMa relies on general boundaries, the accuracy of these boundaries are about 3m (Spatial Collective, 2018).

Figure 17: Buffered

A buffer was created as per figure 17, and it is evident that most of the parcels fall within the 1m and although some over segmentation is still evident. The errors were mostly caused by a lack of clear visible boundaries around the parcels.

5.2. Discussion of the comparison

This chapter discusses the results presented in section 5.1 above and an overall comparison of the conventional and innovative spatial data collection methods are made.

5.2.1. Comparison of innovative methods against conventional methods

The analysis to compare the methods which were used in Freedom Square against the Automatic Feature Extraction and SmartSkeMa comprised of 3 components:

1. Implementation, which consists of the number of activities involved, the input data required, the time each method requires, the reference system required, and the level of expertise required,
2. Compliance with common standards, and this includes the legal framework and data standards, and
3. Accuracy and reliability

5.2.2. Implementation

Based on the results from the table 13 above, all the methods involve community members. Although the difference is that for conventional methods, the community members are not involved in mapping of the parcels as that is done by either a professional surveyor or a land measurer. The community involvement is during the subdivision or consolidation stage and during enumeration with guidance from a town planner to create a layout plan. For Automatic Feature Extraction, the community is not involved in creating the data, they are only involved in verifying, with SmartSkeMa the data for processing is derived from the community.

All the methods require orthophotos and the conventional method and SmartSkeMa require ground control/reference points as input data. The difference with the usage of the orthophotos is that for SmartSkeMa it is used for data collection and processing. For Automatic Feature Extraction they are used for processing only. For conventional methods it is used for orientation purposed during fieldwork. Regarding time, it took longer with the conventional method, but it is worth highlighting that, the time for the conventional method was for surveying 1100 parcels within the settlement and the time for Automatic Feature Extraction and SmartSkeMa was for 50 parcels only.

The conventional method requires more sophisticated tools compared to Automatic Feature Extraction and SmartSkeMa. This aligns with the statements made by Lengoiboni et al. (2018); Salifu (2018) and, Abubakari (2018) that conventional approaches use more sophisticated tools whereas the innovative approaches use simple tools. A hardware similarity they all have is the computer, and for the software it is that they can all use QGIS or ArcGIS. However, the Automatic Feature Extraction requires different software such as MATLAB and python, thus requiring some additional programming knowledge compared to SmartSkeMa. The conventional method is different from Automatic Feature Extraction and SmartSkeMa because surveyors are needed and for the latter only GIS experts and community members are required. The difference is mainly caused by the legal requirements of Namibia.

5.2.3. Compliance with common standards

Law compliance is chosen as one indicator to assess the suitability of Automatic Feature Extraction and SmartSkeMa. Land adjudication is a comprehensive process which combines administrative, technical, and legal perspectives. From the legal perspective, the legal framework stipulates the responsibilities and obligations of land surveyors. The specific laws and regulations related to cadastral surveying are, the Land Survey Act, the Flexible Land Tenure Act, and their regulations, respectively. This aligns with van Asperen (2014), the process of formalized system follows categorized top-down procedures regarding the state laws.

According to the findings in chapter 4, the innovative methods do not comply with the current legal framework as it does not make provision for data obtained using photogrammetry methods such as the SmartSkeMa and the Automatic Feature Extraction. In addition, the legal framework is very strict on the usage of UAVs for cadastral purposes as they prohibit UAV usage over residential areas, this then results in photogrammetry images to be obtained with airplane flights which are too expensive. Images can also be obtained from Google Earth, but the quality of the images are usually poor thus making it not suitable. Further, the legal framework expects surveying to be done by a surveyor if it is to be formally registered and the innovative methods do not make use of surveyors but rather involve GIS experts and community members. The legal framework also expects certain documents to be submitted, but do not specify which documents should be submitted when using photogrammetry methods which therefore contributes the methods not to be compatible with the legal framework.

Attempts of incorporating alternative methods such as the SDTM have been made although the legal framework is still a huge hindrance and needs revision. This is in alignment with Van Aspen (2014) and Bennett et al (2013) that conventional methods may be turned into innovative tools by applying pro-poor principles on them and that innovative approaches may be used to support conventional approaches or operate in parallel with them. Currently, informal settlement land tenure mapping is regulated by the legal framework and it is done by professional land surveyors for outer boundaries (Republic of Namibia, 1993) and by land measurers for inner blocks (Government of Namibia, 2018). Further, planning of the settlement is done professionally by a town planner and obtaining approval for these layout plans goes through long procedures and this is in agreement with Tuladarh (2004) and Hanstad (1998) that such approach are considered slow, complex, bureaucratic and expensive.

In addition to the legal framework, there are data standards that need to be complied with. A requirement of the Land Administration Domain Model (LADM) is that the existing ISO and OGC standards must be followed, particularly the ISO 1915:2012 geographic information standards (Lemmen, van Oosterom, & Bennett, 2015). Namibia, uses a local reference system Schwarzeck for its surveying activities only, which contradicts the LADM which indicates that provisions must be made to accommodate future changes to reference systems that may occur due to technological changes (Lemmen et al., 2015). Automatic Feature Extraction is therefore not compatible with the standards. Schwarzeck units are degrees and during the line labelling process under the boundary classification step in the workflow, a buffer in meters is supposed to be made (Crommelinck, n.d.). This therefore results in reference systems to be changed, to enable the buffer to be created so that the plugin can be used, this however could also be noted as a limitation of the Automatic Feature Extraction tool. This is a limitation because it is not compatible with all reference systems. The advantage and similarity of the data produced from all these methods is that it is compatible with all GIS platforms.

5.2.4. Accuracy and reliability

The accuracy and reliability of Automatic Feature Extraction and SmartSkeMa based on visual inspection are more suitable for data collection for informal settlements who do not have any data. This is because the legal framework requires specific high accuracy. Special attention should be given when collecting data in the field for SmartSkeMa because lack of GCPs or uneven distribution of them could result in poor results. Another area which requires special attention is printing and scanning of the orthophotos in the field and this is in alignment with a statement by Mumbone (2015) that the printing and scanning of these orthophotos causes them to lose accuracy. Further, the type of spatial boundaries influences the accuracy and reliability of the data because the conventional methods use point-based beacon boundaries, and the Automatic Feature Extraction and SmartSkeMa rely heavily on clear visible boundaries. With reference to section 5.1.3.4, a few errors occur when the parcels from the Automatic Feature Extraction are overlayed on the reference parcels (Nyandwi, Koeva, Kohli, & Bennett, 2019). The Automatic Feature Extraction and SmartSkeMa made use of general boundaries rather than fixed boundaries like with the conventional method. SmartSkeMa aligns better with the reference map compared to Automatic Feature Extraction and relating to the 1m buffer, SmartSkeMa lies well within the 1m buffer except some shape error that occur.

5.2.5. Summary

The research found that the main similarity regarding the spatial framework for the 3 methods was the use of field surveys and involvement of community members. For the conventional method and SmartSkeMa, the field survey was used as the primary method for data collection, whereas Automatic Feature Extraction used the field survey for verification of captured data. The field survey is usually done for fixed and accurate boundaries using sophisticated technologies like DGPS under the conventional approach. Yet, innovative approaches use mainly aerial images and simple methods like sketching. The community involvement for conventional methods is for planning and subdivision, whereby for Automatic Feature Extraction it is for verification and for SmartSkeMa it is for data collection. Further, based on the comparison, the innovative methods do not comply with the legal common standards especially regarding accuracy and the manner of data collection, but it complies with the data standards. This however results in challenges in harmonising the data collected by innovative methods with the data from the conventional methods.

In addition, the use of the innovative methods would be suitable in Namibia but under certain circumstances. The methods will have to be used in conjunction with the conventional methods, because the legal requirements are firm. GIS experts could use the innovative methods as a starting point for collecting spatial data at the different local authority levels, and when it is time for formalization under the FTS the surveyors could do the surveying according to the legal standards and data could just be upgraded. The innovative methods cannot reach the accuracy requirements for demarcating fixed boundaries, because these boundaries require about 3cm accuracy. Lower accuracy and precision were observed with the Automatic Feature Extraction and the SmartSkeMa compared to the reference data. However, a buffer of 1m was created and these innovative methods fall within the 1m distance. This therefore means that the innovative methods have potential of being integrated in the informal settlement upgrading process. Informal settlement upgrading has 5 processes, which are subdivision/consolidation, registration of starter, survey of outer boundary, survey of inner boundaries and enumeration. The SmartSkeMa would be able to be integrated in the process when the layout plan is being prepared and subdivision is taking place. The sketch map approach can be used and town planners and community can plan the settlements together. In instances where town planners are not hired, the community together with the local authority officials can use the tool and upgrade the data based on the town planners' requirements later. Another advantage of the SmartSkeMa is that land tenure data can be collected at the same time which would reduce field work time. The Automatic Feature Extraction can best used at local authorities who need base data for informal settlements, however based on the process involved and the technical processing required, this method might not be suitable to all local authorities.

6. CONCLUSION AND RECOMMENDATIONS

The previous chapter discussed the results of the comparison, and this chapter presents the conclusion that summarises the findings of the study. It also presents recommendations for possible further research.

6.1. Conclusion

New tools to support the conventional land administration system are needed. Many methods have been developed to support mapping activities in developing countries. These methods could either be used in combination with the existing methods, or the innovative methods could be used separately. A framework for selecting FFP data collection method was developed. This study builds upon the framework by using the parameters identified to compare the performance of Automatic Feature Extraction and SmartSkeMa against the conventional GNSS methods. Further, the comparison identifies a set of indicators from the parameters of the framework to determine the suitability of the innovative methods in Namibia.

The main objective of this study is to compare the different spatial data collection methods for informal settlement land tenure mapping in Gobabis, Namibia. To achieve the objective of the research, 3 sub-objectives were identified by answering the related research questions as captured below.

6.1.1. To identify the characteristics of spatial data collection methods to understand why some spatial data collection methods are preferred over others by the actors

What are the conventional and innovative spatial data collection methods currently used in Namibia?

The study revealed that for cadastral surveying, Namibia uses GNSS methods such as the GPS, DGPS RTK, total stations, aerial images obtained from either airflights or UAV and Lidar is seldomly used. For Freedom Square specifically, DGPS RTK was used, and aerial image was captured using UAV. As for the innovative methods, STDM was piloted but never implemented and Kobo Collect was used for data collection in preparation for land hold title registration.

What are the main characteristics of the conventional and the innovative spatial data collection methods?

The characteristics which were highlighted were: name of the methods, aim of using the methods, software for processing data, data storage, accuracy, and costs. Some of these characteristics were later used in sub-objective 3 for the comparison.

Who are the actors involved in implementing these methods?

The actors who the study revealed were the key actors who are categorized in the field team and government actors. The field team consists of the professional land surveyors, town planners, enumerators, land measurers and the community members. The government actors are Ministry of Agriculture, Water & Land Reform, Land Rights Office, Local Authorities and Ministry of Urban and Rural Development.

6.1.2. To identify indicators for comparing the of data collection methods

What are the indicators for measuring the performance of these data collection methods?

Namibia does not have any quality assessment framework which is a disadvantage to the country's land administration system because there is a need to evaluate and improve the quality of land administration systems so that maximum benefits can be achieved through better management of land.

What are the criteria for selecting spatial data collection methods?

The criteria which were chosen were implementation, compliance with common standards, accuracy, and reliability. These criteria were used in combination with the characteristics identified in sub-objective 1 for the comparison of the methods.

6.1.3. To compare the innovative methods against the conventional methods

What are the gaps between the conventional and innovative spatial data collection methods?

The research observed gaps within the legal framework which implicates the incorporation of innovative methods. The greatest being related to the method and requirement for fieldwork, spatial boundaries, level of expertise required, and the time. This was mainly due to the major differences between the conventional methods and the innovative methods.

To what degree do the innovative data collection methods enhance the current conventional methods used?

The innovative methods enhance the conventional method by enhancing the time required for data collection and processing. Furthermore, the innovative methods have potential of being used for spatial planning especially the SmartSkeMa tool. An advantage of this tool is that it collects land tenure information during the mapping process therefore enumerators would not be required to go back to the field to collect data required for registration. Both the innovative tools could also be useful as the first step to data collection for local authorities who do not have any spatial data on the informal settlements.

How can the innovative spatial data collection methods be incorporated with the conventional spatial data collection methods?

These methods can be used by local authorities as the starting point to collect data and creating informal settlement registers. Once it is time for the FLTS project to start, the collected data can be verified by a surveyor in the field according to the required standards and be easily incorporated. However, to achieve the effective integration of the innovative methods approaches establishing standards and policies will be required that will be adopted by all the organisations to ease the integration process.

6.2. Recommendations

The study has contributed to existing literature on spatial data collection methods, cadastral surveying, selection of data collection methods based on a comparing innovative method against conventional methods. From this study, characteristics of each method are revealed, and selection criteria have been established based on the Namibian country context. This may be useful for researchers, NGO, governmental organisations, and municipalities as the results can be a guiding tool to selecting methods which are suitable for the specific context.

The result of the study serves as a basis for selecting spatial data collection methods for informal settlement land tenure mapping. It provides information on the characteristics of the methods, the selection criteria and suitability of the Automatic Feature Extraction and SmartSkeMa in Namibia, based on the Freedom Square study. Based on this information the research highlights the following recommendations:

- The research indicated that methods are chosen based on familiarity and experience and that there is no performance measurement framework. Therefore, there is a need to establish a performance measurement framework to evaluate the effectiveness of the methods currently used.
- The research identified that integration of previously obtained data on informal settlement are not integrated in the FLTS. However, there should be policies for integrating data collected by innovative methods Therefore, to fully benefit from the innovative methods incorporation is required.

- The legal framework should be amended, or regulations should be drafted to support the innovative tools. This would be of great advantage to the country as it is busy with scaling up registration of informal settlements. These innovative methods could provide base data which could later be upgraded according to the legal standards.

6.3. Further research

This research focused on comparing the innovative methods against the conventional methods. The scope was limited to identifying the characteristics of the methods, identifying indicators which would be used for comparison. Further study is required and these are the suggestions:

- A quality assessment framework could be designed and tested for measuring the performance of the data collection methods used in Namibia.
- Further research on the institutional framework should be done to determine the impact it has on incorporating innovative methods within the conventional system for informal settlement registrations. This would also be useful to determine the receptiveness of the innovative methods by the actors involved.
- Automatic Feature Extraction and SmartSkeMa could be tested in informal settlements that have not been formally planned to determine the suitability for mapping informal settlements which might not have clear visible boundaries.
- Further research could be done on how data obtained from innovative methods can be incorporated with the conventional methods from an institutional and legal perspective, because there are not enough studies done on analyzing the institutional framework.

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APPENDIX A: EXAMPLE OF CERTIFCATE FROM STDM

EX ORIENTE LUX

GOBABIS MUNICIPALITY
CERTICIFICATE OF RECOGNITION

Certificate no: 101728

It hereby certify that it recognised its land occupation

Land Occupant: Aluis Ganeb

National ID: 61050510011

Residential address: Freedom Square

Description of portion of land in respect of which right of recognition has been granted:

Erf No: 2060 Location: Freedom Square

Area (m²): 309 Block Number: B8

Description of land which municipality granted recognition rights:

Approved land use: Residential

Issued date: 24/08/2017

Gobabis Municipality, CEO **Honorable Worship Mayor**

....

Source: NHAG

APPENDIX B: FREEDOM SQUARE LAYOUT PLAN

APPENDIX C: LANDHOLD TITLE CERTIFICATE

CERTIFICATE OF LAND HOLD TITLE RIGHT

Issued in terms of section 13(12) and regulation 22(1)(b) of
the Flexible Land Tenure Act, 2012 (Act No. 4 of 2012)

Certificate No. LH0114/2020

I, the Land Rights Registrar at Windhoek, hereby certify that

PETRUS KANTJIME

Identity Number 53011500347

Unmarried

his/her heirs, executors, administrators, or assigned, is the registered the holder of

(a) **CERTAIN:** Plot No: 114, Portion 153 of the Fram Townlands of Gobabis No. 114

SITUATED: Sunshine Scheme
Gobabis Municipality Council
Registration Division L
Omaheke Region

Measuring: 300 (Three Zero Zero) Square Meters, as shown and more fully described in the Land Hold Plan No. L-FLTS 1;

and

(b) an undivided share in the common property on the said land in the said scheme, as shown and more fully described in the said Land Hold Plan, and that the said holder's title to the said plot and undivided share in the said common property are subject to, or shall benefit by: the servitudes, other real rights and conditions if any, endorsed in the said Land Hold Plan; and the servitudes referred to in section 10(5) of the Flexible Land Tenure Act, 2012.

Subject to the conditions imposed by the Gobabis Municipality Council in terms of section 13(6) of the Flexible Land Tenure Act, 2012.

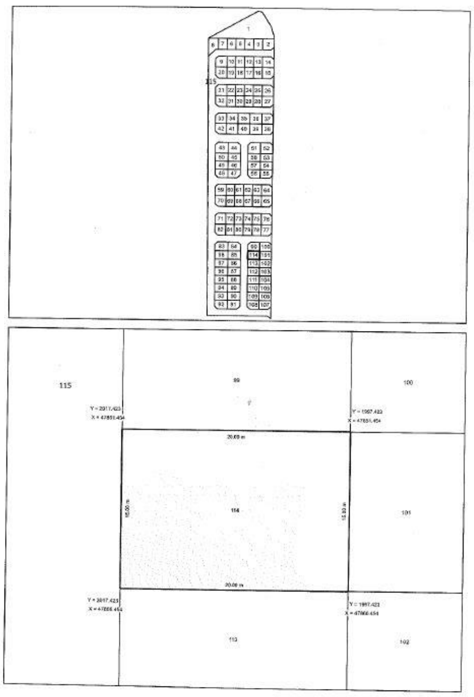
Registered in the Land Rights Office – Reference No. FK.0001 / 2020 S

Signed on this ......19...... day of ..November.. 20.20. and confirmed with my seal of office.

....
Land Rights Registrar

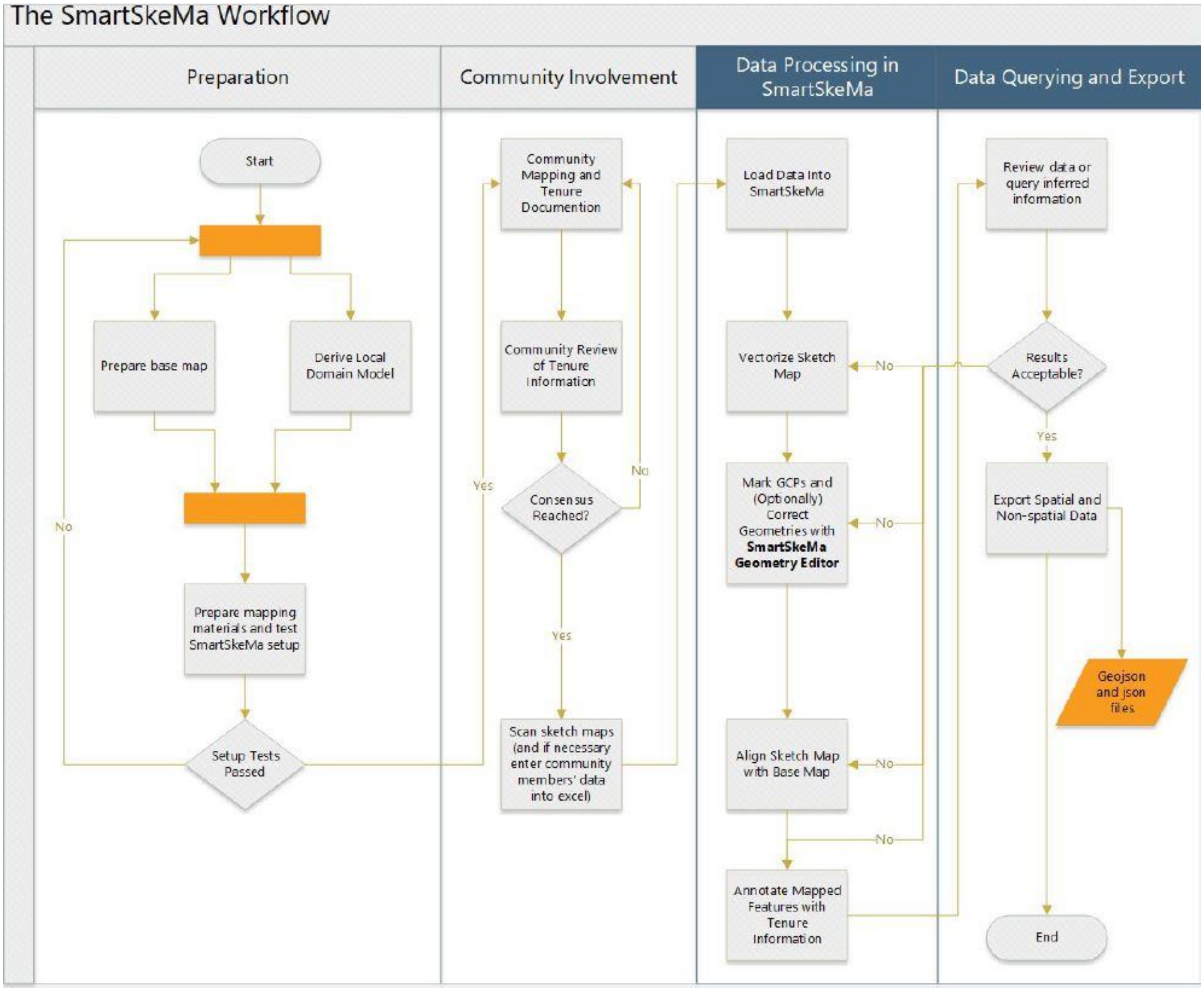
REGISTRAR OF LAND RIGHTS OFFICE
MINISTRY OF LAND REFORM

LAND HOLD PLAN
No. L-FLTS 1
Plot No: 114, Sunshine Scheme, Lo22/19°



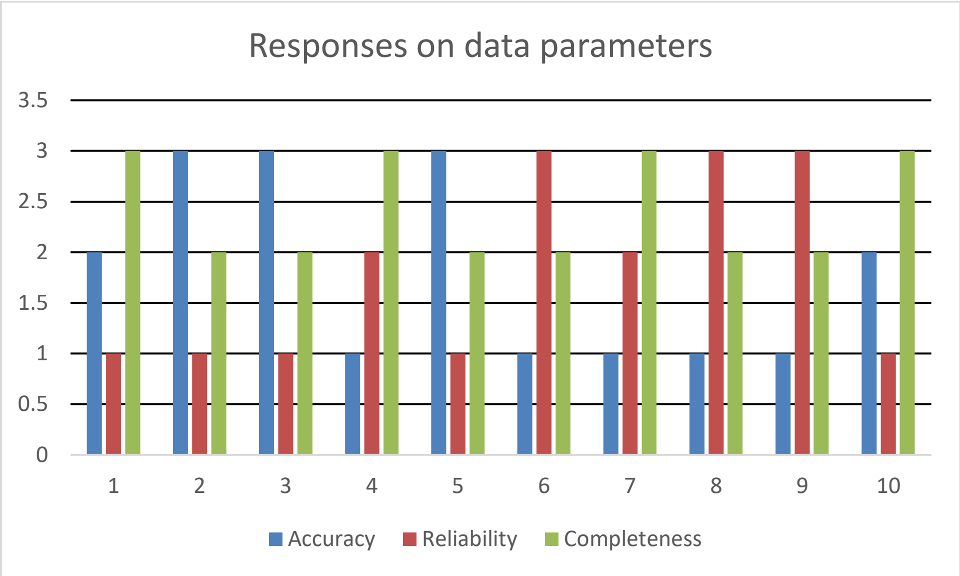
Source: Research Assistant

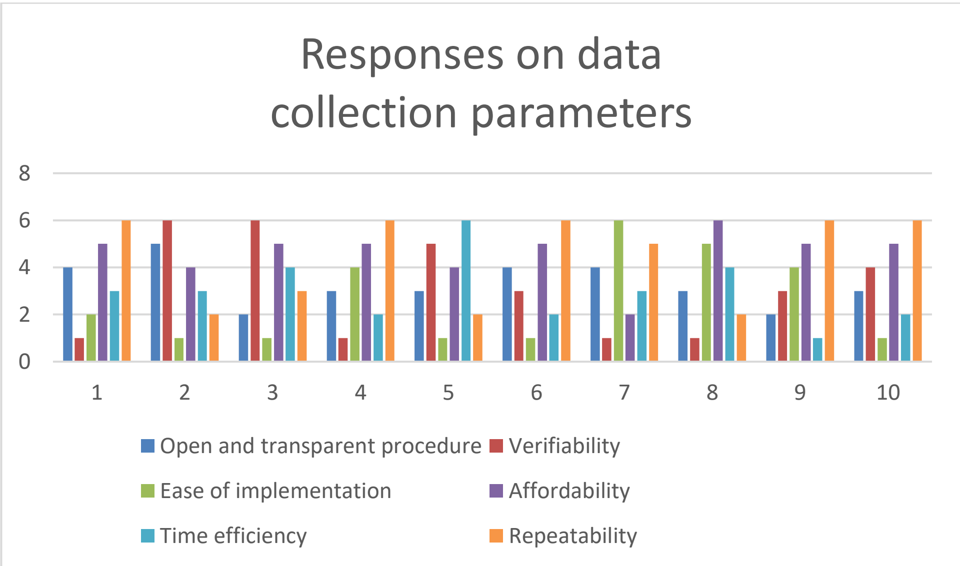
APPENDIX D: SMARTSKEMA WORKFLOW

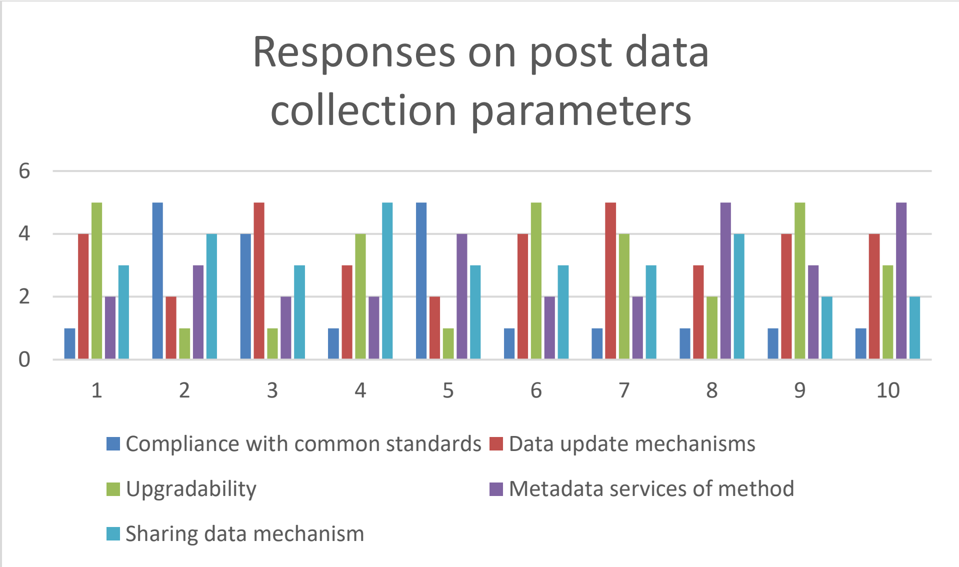


(Source: (M. C. Chipofya et al., 2021))

APPENDIX E: RANKING QUESTIONNAIRE






Responses on post data collection parameters
6
4
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9
10
Compliance with common standards
Data update mechanisms
Upgradability
Metadata services of method
Sharing data mechanism